

Commonwealth of Kentucky

Before the Public Service Commission

In the Matter of:

APPLICATION OF BIG RIVERS ELECTRIC)
CORPORATION FOR APPROVAL OF ITS)
2012 ENVIRONMENTAL COMPLIANCE)
PLAN, FOR APPROVAL OF ITS)
AMENDED ENVIRONMENTAL COST)
RECOVERY SURCHARGE TARIFF, FOR)
CERTIFICATES OF PUBLIC)
CONVIENENCE AND NECESSITY, AND)
FOR AUTHORITY TO ESTABLISH A)
REGULATORY ACCOUNT.)

Case No. 2012-00063

**Direct Testimony of
Rachel S. Wilson**

**On Behalf of
Sierra Club**

Public Version

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July 23, 2012

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1 **1. INTRODUCTION AND QUALIFICATIONS**

2 **Q Please state your name, business address, and position.**

3 **A**My name is Rachel S. Wilson and I am an associate with Synapse Energy
4 Economics, Inc. (Synapse). My business address is 485 Massachusetts Avenue,
5 Suite 2, Cambridge, Massachusetts 02139.

6 **Q Please describe Synapse Energy Economics.**

7 **A**Synapse Energy Economics is a research and consulting firm specializing in
8 energy and environmental issues, including electric generation, transmission and
9 distribution system reliability, ratemaking and rate design, electric industry
10 restructuring and market power, electricity market prices, stranded costs,
11 efficiency, renewable energy, environmental quality, and nuclear power.

12 Synapse’s clients include state consumer advocates, public utilities commission
13 staff, attorneys general, environmental organizations, federal government, and
14 utilities.

15 **Q Please summarize your work experience and educational background.**

16 **A**At Synapse, I conduct research and write testimony and publications that focus on
17 a variety of issues relating to electric utilities, including: integrated resource
18 planning; federal and state clean air policies; emissions from electricity
19 generation; environmental compliance technologies, strategies, and costs;
20 electrical system dispatch; and valuation of environmental externalities from
21 power plants.

22 I also perform modeling analyses of electric power systems. I am proficient in the
23 use of spreadsheet analysis tools, as well as optimization and electricity dispatch
24 models to conduct analyses of utility service territories and regional energy
25 markets. I have direct experience running the Strategist, Promod, Prosym/Market
26 Analytics, and Plexos models, and have reviewed input and output data for a
27 number of other industry models.

1 Prior to joining Synapse in 2008, I worked for the Analysis Group, Inc., an
2 economic and business consulting firm, where I provided litigation support in the
3 form of research and quantitative analyses on a variety of issues relating to the
4 electric industry.

5 I hold a Master of Environmental Management from Yale University and a
6 Bachelor of Arts in Environment, Economics, and Politics from Claremont
7 McKenna College in Claremont, California.

8 A copy of my current resume is attached as Exhibit RSW-1.

9 **Q On whose behalf are you testifying in this case?**

10 **A** I am testifying on behalf of Sierra Club.

11 **Q Have you testified previously before the Kentucky Public Service**
12 **Commission?**

13 **A** Yes. On September 16, 2011, I filed direct testimony in the joint application of
14 Kentucky Utilities Company/Louisville Gas & Electric for Certificates of Public
15 Convenience and Necessity (CPCN) in Case Numbers 2011-00161 and 2011-
16 00162. I also filed direct testimony on March 12, 2012 in the application of
17 Kentucky Power for CPCN in Case Number 2011-00401.

18 **Q What is the purpose of your testimony?**

19 **A** My testimony reviews the regulatory requirements and economic justifications of
20 specific environmental retrofits made by Big Rivers Electric Corporation
21 (“BREC” or the “Company”), for which capital recovery is requested in this case.
22 I review the current and expected running costs of the Company’s coal-fired units,
23 and compare these costs to different alternatives. I conclude that the Company’s
24 economic justification for these environmental retrofits, in the form of its
25 financial modeling analysis, did not consider a full range of alternative
26 compliance options and contained several flaws that bias its analysis in favor of
27 installation of emission control retrofit projects.

1 **Q Please identify the documents and filings on which you base your opinion**
2 **regarding the Company’s analysis of the environmental compliance costs**
3 **affecting its fleet of coal plants.**

4 **A** In addition to the application, Company witness testimonies, and discovery
5 responses in this case, I have reviewed the Sargent & Lundy input assumptions
6 and calculations relating to environmental retrofit options, the PACE Global input
7 and assumptions and resulting market prices, the ACES Planning and Risk model
8 inputs and outputs, and the BREC financial modeling calculations.

9 **2. CONCLUSIONS AND OVERVIEW OF TESTIMONY**

10 **Q In your opinion, do the facts and evidence presented in this case support the**
11 **Company’s request for CPCN?**

12 **A** No, they do not. There are a number of assumptions in the modeling presented by
13 the Company in this docket that are incorrect, which bias the Company’s results
14 in favor of the installation of pollution control retrofits and the continued
15 operation of the BREC coal fleet. These include, but are not limited to: 1)
16 modeling of only some of the controls expected for future regulatory compliance
17 rather than the entire suite of anticipated controls; 2) a natural gas price forecast
18 that is out-of-date and higher than current forecasts; 3) use of a carbon dioxide
19 (CO₂) emissions price in the determination of market energy prices, but not in unit
20 running costs; 4) exclusion of ongoing capital expenditures and operating and
21 maintenance (O&M) costs at each of the coal units; 5) failure to examine the
22 forward going costs of each of the BREC units on an individual basis; and 6)
23 failure to model any alternative options (e.g. natural gas combined-cycle (NGCC),
24 energy market purchases, etc.) for comparison to the retrofit case.

25 Synapse created a cash flow model that calculates the forward going costs of each
26 of the BREC units on a stand-alone basis, and discounts those costs to determine
27 the total net present value revenue requirement (NPVRR) of the retrofits selected
28 by the Company for each unit individually. The “Retrofit” option is then
29 compared to a natural gas combined-cycle replacement option.

1 The scenario used in our cash flow model represents what I believe is most likely
 2 to occur and includes the entire suite of pollution controls that are expected to
 3 bring the BREC coal units into compliance with both existing and expected U.S.
 4 Environmental Protection Agency (EPA) regulations. Second, it updates the
 5 Company’s natural gas price forecast and instead uses the U.S. Energy
 6 Information Administration’s (EIA) natural gas forecast from the *2012 Annual*
 7 *Energy Outlook*. Third, the CO₂ emissions price used by BREC’s consultant
 8 PACE Global in modeling market energy prices is added in to the analysis of the
 9 future cost of operating BREC’s generating units, as are the ongoing capital
 10 expenditures and O&M costs at each of the units. NPVRR at each of the units is
 11 then calculated under these revised assumptions for the “Retrofit” option. We then
 12 compare these results to the NPVRR associated with a natural gas combined-
 13 cycle replacement option.

14 The results of this case – the “Synapse Recommended Case” – are shown in Table
 15 1 (also in Exhibit RSW-2), below. These results indicate that all of the BREC coal
 16 units are uneconomic when compared to a natural gas replacement option and
 17 should be considered for retirement.

18 **Table 1. Comparison of Natural Gas Combined Cycle (NGCC) Replacement to BREC Unit**
 19 **Retrofits. Includes all pollution control retrofits, the AEO 2012 natural gas price forecast,**
 20 **and the PACE CO₂ price forecast (millions 2012\$).**

	NGCC Replacement 2015 minus Retrofit	% Difference from Retrofit
Wilson	(\$259)	-13.88%
Green 1	(\$204)	-18.53%
Green 2	(\$213)	-19.83%
HMPL 1	(\$82)	-12.47%
HMPL 2	(\$107)	-15.56%
Coleman 1	(\$108)	-15.84%
Coleman 2	(\$90)	-13.74%
Coleman 3	(\$103)	-14.92%
Total	(\$1,165)	-15.73%

21

1 The next sections of my testimony describe in more detail the errors that I believe
2 were made by BREC in its modeling analysis and the scenarios modeled by
3 Synapse in our cash flow analysis.

4 **3. CHARACTERISTICS OF UNITS THAT AFFECT THEIR RUNNING COSTS**

5 **Q Please describe the characteristics of electric generating units that affect**
6 **their running costs.**

7 **A**Running costs of electric generating units are made up of two components – fixed
8 and variable costs. Fixed costs include investment capital, property taxes, and
9 fixed O&M expenses. Variable costs include fuel costs, emissions costs, and
10 variable O&M expenses.

11 Characteristics unique to individual generating units affect their running costs, in
12 particular generating unit size, age, heat rate, and installed pollution controls. Unit
13 heat rate is a measure of the efficiency of the plant, with lower heat rates
14 indicating that a generating unit is converting heat input (in the form of fuel) to
15 energy output at a more efficient rate. Heat rate is related to age, and tends to
16 degrade over time as units get older. It is also related to size, as smaller units tend
17 to operate less efficiently than larger units. Higher heat rates, indicating a lower
18 efficiency, lead to increased fuel and emissions costs, and increase the running
19 costs of a generating unit.

20 As units get older, component parts degrade and require replacement. These
21 replacements represent ongoing capital expenditures, which may increase as units
22 age.

23 Pollution control technologies affect the running cost of a unit in various ways.
24 First, they require investment capital and increase the fixed costs at a unit in a
25 given year. Size of the unit matters when installing pollution controls due to
26 economies of scale; smaller units are more expensive to retrofit on a \$/kW
27 (dollar/kilowatt) basis. Emission control equipment requires electricity to run,
28 lowering the net output of a generating unit, which is called “parasitic load,”
29 meaning that the same fuel and emissions costs are incurred but result in less

1 electricity output. Many emission controls also require the use of a reagent, the
2 cost of which increases variable O&M.

3 **4. ENVIRONMENTAL REQUIREMENTS FACING THE BREC COAL FLEET**

4 **Q What are the recent and emerging EPA requirements with which the**
5 **Company's coal fleet will have to comply?**

6 **A** The EPA has recently proposed a number of rules to protect human health and the
7 environment. These rules are in various states of promulgation and, taken
8 together, may have a significant economic implications for coal-fired generation.
9 There are six rules that will have an effect on the coal-fired units in the United
10 States, and the units in the BREC fleet:

- 11 A. Cross-States Air Pollution Rule (CSAPR)
- 12 B. Mercury and Air Toxics Standards (MATS)
- 13 C. National Ambient Air Quality Standards (NAAQS)
- 14 D. Coal Combustion Residuals (CCR)
- 15 E. Cooling Water Intake Rule (316(b))
- 16 F. Effluent limitation guidelines

17 In addition, regulation of CO₂ through federal legislation or EPA rulemaking will
18 have a significant impact on the economics of coal-fired units.

19 **Q Were all of these rules described sufficiently in Company witness testimony?**

20 **A** No. Company witness Thomas Shaw describes CSAPR, MATS, CCR, and 316(b)
21 rules. He does not discuss the NAAQS or the Effluent Limitation Guidelines, nor
22 does he discuss the possibility of a CO₂ emissions allowance price.

23 **Q Please briefly describe the purpose and impact of NAAQS.**

24 **A** NAAQS set maximum air quality limitations that must be met at all locations
25 across the nation. Compliance with the NAAQS can be determined through air
26 quality monitoring stations, which are located in various cities throughout the

1 U.S., or through air quality dispersion modeling. If, upon evaluation, states have
2 areas found to be in “nonattainment” of a particular NAAQS, states are required
3 to set enforceable requirements to reduce emissions from sources contributing to
4 nonattainment such that the NAAQS are attained and maintained. EPA has
5 established NAAQS for six pollutants: sulfur dioxide (SO₂), nitrogen oxides
6 (NO_x), carbon monoxide, ozone, particulate matter, and lead. EPA is required to
7 periodically review and evaluate the need to strengthen the NAAQS if necessary
8 to protect public health and welfare. For example, EPA is currently evaluating the
9 NAAQS for ozone and particulate matter. Utilities are expecting new compliance
10 requirements stemming from these anticipated NAAQS revisions as early as
11 2016, but no later than 2018. Sargent & Lundy confirms this in Table ES-3 of
12 Exhibit DePriest-2, which lists a NAAQS compliance window of 2016-2018.

13 **Q Please briefly describe the purpose and impact of the expected Effluent**
14 **Limitation Guidelines.**

15 **A** Following a multi-year study of steam-generating units across the country, EPA
16 found that coal-fired power plants are currently discharging a higher-than-
17 expected level of toxic-weighted pollutants. Current effluent regulations were last
18 updated in 1982 and do not reflect the changes that have occurred in the electric
19 power industry over the last thirty years, and do not adequately manage the
20 pollutants being discharged from coal-fired generating units. Coal ash ponds and
21 flue gas desulfurization (FGD) systems used by such power plants are the source
22 of a large portion of these pollutants, and are likely to increase in the future as
23 environmental regulations are promulgated and pollution controls are installed.
24 No new rule has yet been proposed, but EPA intends to issue the proposed
25 regulation in November 2012 and a final rule in April 2014.¹ New requirements

¹ See U.S. Environmental Protection Agency website. Accessed July 20, 2012. Available at:
http://water.epa.gov/scitech/wastetech/guide/steam_index.cfm

1 will be implemented in 2014-2019 through the 5-year National Pollutant
2 Discharge Elimination System (NPDES) permit cycle.²

3 **Q Please describe the purpose and impact of regulation of emissions of CO₂.**

4 While there is not currently a federal law or proposed rulemaking requiring a
5 control technology, cap-and-trade program, or tax on emissions of CO₂,
6 discussions at the EPA and at the Congressional level are ongoing. The most
7 recent legislative proposal to reduce emissions of CO₂ has taken the form of a
8 Clean Energy Standard (CES), as introduced by Senator Bingaman on March 1,
9 2012. A CES encourages the use of low-carbon power through the allocation of
10 clean energy credits to those generation technologies that emit less CO₂, which
11 generation owners would consider in their dispatch decisions. In Senator
12 Bingaman's bill, credits are determined based on individual power plant
13 emissions and generating sources are given a certain number of credits based on
14 their carbon profile, with lower emitting sources rewarded with a larger number
15 of clean energy credits. In any given year, electric utilities would be required to
16 hold a certain number of clean energy credits for a specific percentage of their
17 sales.

18 **Q Have there been any third-party analyses that evaluate the economic effect of**
19 **the rules listed above on the U.S. coal fleet?**

20 Yes, there have been several. The studies evaluate different combinations of the
21 rules listed above. Study authors include the following organizations:

- 22 A. Investment and research firms (Credit Suisse and Bernstein Research)
- 23 B. Consulting firms (MJ Bradley, Charles River Associates, Brattle Group,
24 and NERA Economic Consulting)

² See U.S. Environmental Protection Agency. *Steam Electric ELG Rulemaking*. UMRA and Federalism Implications: Consultation Meeting. October 11, 2011. <http://water.epa.gov/scitech/wastetech/guide/upload/Steam-Electric-ELG-Rulemaking-UMRA-and-Federalism-Implications-Consultation-Meeting-Presentation.pdf>

1 C. Government and industry groups (North American Electric Reliability
2 Corporation (NERC)), Edison Electric Institute (EEI), Electric Power
3 Research Institute (EPRI), U.S. Department of Energy, and Bipartisan
4 Policy Center)

5 **Q Can you draw any conclusions about the effect of the EPA rules on coal**
6 **economics based on the results of these studies?**

7 Yes. There are two very important conclusions that one can draw when looking at
8 the results of these studies. The first is that the forward-going economics of the
9 coal fleet changes based on the number of rules that are taken into consideration
10 when doing the analysis. A coal unit might still be economic to run when retrofit
11 with controls that would allow it to comply with CSAPR and MATS, but if costs
12 for compliance with the CCR rule are added, the forward-going costs of that same
13 unit may at that point be higher than a natural gas or market alternative. In a 2010
14 study presented by ICF Consulting for the Edison Electric Institute (EEI) entitled
15 *EEI Preliminary Reference Case and Scenario Results*, three scenarios are
16 examined. The first looks at the effects of MATS, the second looks at the
17 combined effect of MATS, CCR and 316(b), and the third scenario looks at the
18 effects of those three rules with the addition of a CO₂ emissions price. A copy of
19 this study is provided as Exhibit RSW-3.

20 Table 2, below, shows the number of expected gigawatts (GW) retired under the
21 draft EPA rules as reported by ICF under the three scenarios.

22 **Table 2. Coal Retirements in the ICF/EEI Analysis.**

Scenario	Coal Retired (GW)	
	Low Estimate	High Estimate
MATS	25	50
MATS, CCR, 316(b)	30	60
MATS, CCR, 316(b), CO ₂	70	120

23
24 As seen in Table 2, when regulations are examined in combination rather than
25 independently, the effect on coal unit retirements is greater. The high estimate

1 goes up by 10 GW when CCR and 316(b) are considered along with MATS. That
2 estimate doubles with the addition of CO₂ regulation. As costs of emission control
3 retrofits are compounded to comply with the EPA rules, the forward-going costs
4 of running previously cost-effective coal units increase to the point at which they
5 are uneconomic when compared to replacement options.

6 The second conclusion that one can draw when reviewing these studies is that
7 lower natural gas prices lead to more coal retirements. As natural gas prices fall,
8 the costs of operating natural gas-fired replacement generation decline, causing
9 natural gas replacement capacity to look more favorable when compared to coal
10 units with installed emission controls. EPRI's 2012 study, entitled *Analysis of*
11 *Current and Pending EPA Regulations on the U.S. Electric Sector* evaluates the
12 number of coal retirements/repowerings resulting from the combination of the
13 CSAPR, MATS, ozone and haze, SO₂ NAAQS, CCR, and 316(b) rules at five
14 different forecasts of natural gas prices. A copy of this study is provided as
15 Exhibit RSW-4.

16 Table 3, below, shows the number of coal retirements/repowerings that might be
17 expected at each natural gas forecast. EPRI's Reference case natural gas price
18 forecast begins at approximately \$5.90/mmBtu in 2010 and rises to approximately
19 \$7.30/mmBtu in 2035 (2009\$).

20 **Table 3. Coal Retirements/Repowerings in EPRI's 2012 Analysis.**

Scenario	Coal Retired/Refueled (GW)
Gas Plus \$2	30
Gas Plus \$1	50
Reference	57
Gas Minus \$1	75
Gas Minus \$2	120

21

22 As shown in Table 3, a lowering of the natural gas forecast has a more dramatic
23 effect on the number of coal retirements/repowerings than does an increase in the
24 natural gas price forecast. The Gas Plus \$2 scenario causes the number of

1 retirements/repowerings to drop by 27 GW from the Reference case, while the
2 Gas Minus \$2 scenario increase coal retirements/repowerings by 63 GW.
3 Similarly, the Gas Plus \$1 scenario causes the number of retirements/repowerings
4 to drop by 7 GW from the Reference case, while the Gas Minus \$1 scenario
5 increase coal retirements/repowerings by 18 GW. Natural gas price is therefore a
6 significant determinant of the number of coal plant retirements that will occur as a
7 result of EPA rules.

8 5. EFFECT OF EPA REGULATIONS ON BREC UNITS

9 **Q Which of the EPA regulations were considered by BREC when the Company**
10 **determined which environmental retrofits were necessary to install on its**
11 **units?**

12 **A** In the 2012 Environmental Compliance Plan submitted in this docket, BREC
13 plans to install environmental retrofits that would bring its coal-fired units into
14 compliance with CSAPR and MATS only. Sargent & Lundy made
15 recommendations for technologies intended to also bring the units into
16 compliance with the NAAQS revisions, the CCR, 316(b), and Effluent rules, but
17 these recommendations were ignored by BREC in its analysis.

18 **Q Do you agree with the Company's assessment of CSAPR and the control**
19 **technologies needed to bring its units into compliance with the rule?**

20 **A** Yes, generally. I do have some issues of concern, however. First, according to
21 page 9 of Mr. Berry's direct testimony, BREC is assuming that the new FGD
22 system that it intends to install at the Wilson unit will have 99% SO₂ removal
23 efficiency, but in Response to Data Request Sierra Club 2-23a, the Company
24 states that it's the overall control efficiency included in its permit application is
25 98%. The Wilson plant is able to meet its CSAPR SO₂ limits, but the Company
26 may be assuming that the extra 1% in control efficiency may result in additional
27 allowances that could be used at another one of its units, and if control efficiency
28 of 98% occurs, these bonus allowances may not materialize.

1 Additionally, Sargent & Lundy recommended advanced low NO_x burners at the
2 Coleman units, as shown on page 15 of the direct testimony of Mr. DePriest, in
3 order to provide BREC with a degree of margin in its NO_x compliance strategy
4 and to reduce the NO_x burden until the selective catalytic reduction technology
5 (SCR) at Green comes online in 2015. Advanced low NO_x burners could be
6 installed at a capital cost of \$5.94 million per unit, according the Sargent & Lundy
7 workbook entitled “Capital and O&M.xls,” provided by the Company on June 14
8 as part of the folder entitled “Sargent and Lundy Production to Big Rivers.”
9 BREC elected not to install the advanced low NO_x burners, and instead plans to
10 rely on the allowance market. There is some degree of risk involved in reliance on
11 the allowance market, as the availability of allowances depends on whether or not
12 other utilities install control technologies that gives them the ability to sell excess
13 allowances into the market. It also assumes that these allowances will be available
14 at a reasonable price. Historically, allowances of SO₂ and NO_x have been subject
15 to some price volatility³ and it is possible that future prices may rise above what
16 BREC has estimated for future compliance.

17 **Q Do you agree with the Company’s assessment of MATS and the control**
18 **technologies needed to bring its units into compliance with the standards?**

19 **A**No. The Company provided “limited available stack test data”⁴ to Sargent &
20 Lundy, and this data was used by S&L to develop the MATS compliance
21 recommendations. In the Company’s Response to Sierra Club Data Request 1-36,
22 BREC states that the stack test was performed at operational loads with pollution
23 control equipment in service. A single stack test, however, represents nothing
24 more than a snapshot, often taken under optimal operating conditions, that tells
25 little about the emissions from that unit when the stack test is not occurring. This
26 is especially true during periods of startup and shutdown, when control equipment

³ See U.S. Environmental Protection Agency. *Allowance Market Assessment: A Closer Look at the Two Biggest Price Changes in Federal SO₂ and NO_x Allowance Markets*. White Paper. April 23, 2009. Available at: <http://www.epa.gov/airmarkt/resource/docs/marketassessmnt.pdf>

⁴ Exhibit DePriest-2. Page 2-4.

1 may not be fully operational. Emissions, therefore, are likely higher than indicated
2 by the stack test. Installation of Continuous Emissions Monitors (CEMs) would
3 determine whether or not the limited stack test data is truly representative of unit
4 emissions.

5 On page 28, lines 7-18 of Mr. DePriest's testimony and on page 4-12 of Exhibit
6 DePriest-2, it is stated that retrofitting the BREC units with ACI and/or DSI
7 technologies for MATS compliance will lead to additional loading of particulate
8 matter, and upgrades of existing electro static precipitators (ESPs) may be
9 required for units to remain in compliance with the rule. BREC has yet to conduct
10 the testing necessary to determine if ESP upgrades are necessary. As the
11 Company states in its Response to Sierra Club Data Request 2-10, if these
12 upgrades are required, BREC would return to the Commission in early 2013 to
13 seek CPCN and rate recovery for these controls. It is possible that installation of
14 the combination of ACI, DSI and ESP upgrades may still not bring some or all of
15 BREC's units into compliance with MATS. As the Company states in its
16 Response to Sierra Club Data Request 2-10, it would then evaluate polishing
17 baghouse (and full baghouse technologies, if necessary) retrofits, and would again
18 return to seek CPCN and rate recovery in early 2013.

19 In its workbook entitled "Capital and O&M.xls," provided by the Company on
20 June 14 as part of the folder entitled "Sargent and Lundy Production to Big
21 Rivers," Sargent & Lundy gives the capital and annual O&M costs for the ESP
22 upgrades that are shown in Table 4, below.

23

1 **Table 4. Estimated Capital and Annual O&M Costs for ESP Upgrades.**

	Capital Cost (\$M)	Annual O&M (\$M)
Coleman Unit 1	2.72	0.09
Coleman Unit 2	2.72	0.09
Coleman Unit 3	2.72	0.09
Wilson Unit 1	4.54	0.17
Green Unit 1	3.34	0.07
Green Unit 2	3.34	0.07
HMP&L Unit 1	2.5	0.08
HMP&L Unit 2	2.5	0.08

2

3 Sargent & Lundy also gave capital cost estimates for baghouse technologies,
 4 shown on page 5-5 of Exhibit DePriest-2, if they were to be required. Those
 5 estimates are shown in Table 5.

6 **Table 5. Estimated Capital Costs for Baghouse Technologies.**

	Per Unit Capital Cost (\$M)
Green 1/2	75
HMPL 1/2	51

7

8 **Q Do you agree with the Company’s assessment of the NAAQS revisions and**
 9 **the control technologies needed to bring its units into compliance with the**
 10 **expected standards?**

11 **A** No. In Table ES-2 of Exhibit DePriest-2, Sargent & Lundy presents a table of
 12 recommended NAAQS compliance retrofits, including an SCR at Unit 1 of the
 13 R.D. Green plant. BREC, however, chose to leave this SCR out of its 2012
 14 Environmental Compliance Plan. The Company states in its Response to Sierra
 15 Club Data Request 2-7 that it expects that the ozone NAAQS will be finalized in
 16 2013 and that states will be given three years from that date to comply with the
 17 revised limits. Thus, compliance with the revised NAAQS could occur as early as
 18 2016. On page 19, lines 18-21 of Mr. Berry’s direct testimony, he states that the
 19 expected in-service date of the SCR at Green 2 is July 1, 2015. Depending on
 20 when in 2013 the NAAQS revisions are finalized, the Company may return to this
 21 Commission as early as six months from now to seek CPCN and rate recovery for
 22 an SCR at Green 1 to comply with these rules. Given the recommendation from

1 Sargent & Lundy as well as the time frame for compliance, BREC should
2 certainly include this additional SCR at Green 1 in its Environmental Compliance
3 Plan and current financial analysis. In its workbook entitled “Capital and
4 O&M.xls,” provided by the Company on June 14 as part of the folder entitled
5 “Sargent and Lundy Production to Big Rivers,” Sargent & Lundy states that the
6 capital cost of the SCR is \$81 million and O&M costs are \$2.16 million annually.

7 **Q Do you agree with the Company’s assessment of the CCR rule and the**
8 **control technologies needed to bring its units into compliance with the**
9 **expected standards?**

10 **A** No, as BREC does not include the compliance options associated with the
11 expected rule in its financial analysis. Mr. Shaw states on page 19 of his direct
12 testimony that “the alternatives under consideration by the EPA are of such
13 substantially different form that Big Rivers believes an immediate response to the
14 proposal would not be appropriate.” However, BREC does have some expectation
15 of what compliance under the CCR rule might look like for its units. In the BREC
16 presentation of its 2012 Environmental Compliance Plan at the Kenergy Board
17 Meeting on May 8, 2012 (provided in Response to Sierra Club Data Request 1-
18 57), slide 17 states that BREC is “not expecting the worst case.”

19 BREC also has recommendations from Sargent & Lundy about the retrofits that
20 might be expected for compliance. The Company need not move forward with
21 plans to retrofit its units in order to comply with the CCR rule at this time, but it
22 should include some assumption about expected costs of the rule in its financial
23 analysis. In its workbook entitled “Capital and O&M.xls,” provided by the
24 Company on June 14 as part of the folder entitled “Sargent and Lundy Production
25 to Big Rivers,” Sargent & Lundy gives the capital costs for CCR compliance that
26 are shown in Table 6, below.

27

1

Table 6. Estimated Capital Costs for CCR Compliance Technologies.

	S&L Recommended Tech	Capital Cost (\$M)
Coleman Unit 1	Dry Bottom Conversion - Remote SSC & Fly Ash Conversion to Dry Pneumatic	38
Coleman Unit 2		
Coleman Unit 3		
Green Unit 1	Dry Bottom Conversion - Remote SSC	28
Green Unit 2		
HMP&L Unit 1	Dry Bottom Conversion - Remote SSC	28
HMP&L Unit 2		

2

3 **Q**

Do you agree with the Company’s assessment of the 316(b) rule and the control technologies needed to bring its units into compliance with the expected standards?

4

5

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No, as BREC does not include the compliance options associated with the expected rule in its financial analysis. Again, Mr. Shaw states on page 20 of his direct testimony that “the alternatives described in this proposal are of such substantially different form that Big Rivers believes an immediate response to the proposal would not be appropriate.” On slide 16 of that same May 8, 2012 presentation to the Kenergy Board, BREC states that the 316(b) rules could require a cooling tower at Coleman and modifications for intake structures at Reid/HMPL. Sargent & Lundy’s recommendations for compliance are less stringent than these. On page 6-8 of Exhibit DePriest-2, Sargent & Lundy states that the intake screens at Coleman and Sebree are inadequate and recommends rotating circular intake screens with fish pumps to meet the expected impingement mortality reductions. BREC should, at a minimum, include the costs associated with these recommendations in its financial modeling. In its workbook entitled “Capital and O&M.xls,” provided by the Company on June 14 as part of the folder entitled “Sargent and Lundy Production to Big Rivers,” Sargent & Lundy gives the capital and annual O&M costs for 316(b) compliance that are shown in Table 7, below.

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Table 7. Estimated Capital Costs for CCR Compliance Technologies.

316(b)	S&L Recommended Tech	Capital Cost (\$M)	Annual O&M (\$M)
Coleman Unit 1	Replacement Intake Screen	1.33	0.25
Coleman Unit 2	Replacement Intake Screen	1.33	0.25
Coleman Unit 3	Replacement Intake Screen	1.33	0.25
Green Unit 1	Replacement Intake Screen	2.05	0.37
Green Unit 2			
HMP&L Unit 1			
HMP&L Unit 2			
Reid Unit 1			
Reid Unit RT			

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3 **Q Do you agree with the Company’s assessment of the Effluent Limitations**
4 **Guidelines and the control technologies needed to bring its units into**
5 **compliance with the expected standards?**

6 **A** No, as BREC does not include the compliance options associated with the
7 expected rule in its financial analysis. On page 2-9 of Exhibit DePriest-2, Sargent
8 & Lundy states that for the Coleman, Wilson, and Sebree units, “it may become
9 necessary to install advanced wastewater treatment/removal systems for mercury
10 and other metals.” An estimate of potential costs of advanced wastewater
11 treatment and removal should have been provided, and BREC should have
12 included these costs in its financial modeling.

13 **Q Do you agree that an emissions price for CO₂ should have been omitted from**
14 **the BREC financial analysis?**

15 **A** No. At a minimum, the presence of a CO₂ emissions price in the PACE Global
16 output energy prices should have led the Company to also include a CO₂ price in
17 the dispatch of its units in the ACES Planning and Risk (PaR) modeling, and in its
18 financial modeling calculations.

19 While the future of CO₂ regulations is still somewhat unknown, an emissions
20 allowance price, when it begins, will have a significant effect on coal-fired
21 generation. Other utilities are planning for this by including a CO₂ allowance
22 price in their optimization and dispatch modeling. Synapse has collected 21
23 different utility IRP and CPCN docket documents from 2010-2012 from utilities

1 operating across the US. Nineteen of those utilities assume a price per ton for
2 CO₂, and all but three of those reference CO₂ price forecasts are higher than the
3 forecast used by PACE Global in its modeling. Figure 1 shows the range of utility
4 forecasts as compared to the PACE Global forecast. The utilities included in this
5 Figure are listed in Exhibit RSW-5.

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11 [CONFIDENTIAL FIGURE REMOVED]
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19 **6. DESCRIPTION OF COMPANY MODELING**

20 **Q Please describe the modeling methods used by BREC in this docket.**

21 **A** It is my understanding that three different modeling methodologies were used to
22 support the BREC analysis. First, PACE Global used the Aurora model to
23 determine hourly energy prices using input forecasts of coal prices, natural gas
24 prices, CO₂ emissions, load, and capital costs for CC, CT, and wind generation
25 technologies.

1 Those hourly energy prices were then given to ACES Power Marketing for use in
2 production cost modeling using the PaR model. ACES did not use an input CO₂
3 emissions price in its dispatch when running the PaR model. Outputs from ACES
4 production cost modeling included unit generation, capacity factor, fuel used and
5 cost, emissions and emissions cost, and variable O&M. The PaR model also
6 output wholesale market purchases and off-system sales.

7 BREC took the unit and system outputs from the ACES modeling and used them
8 as inputs in its own spreadsheet financial model. The financial model calculates
9 the NPVRR by first summing the production costs in a given year (start-up costs,
10 fuel costs, costs for reagents, allowance purchases, purchased power, and off-
11 system sales) with the fixed cost of capital in a given year (debt service, debt
12 issuance cost, property tax, property insurance, and labor) to arrive at the revenue
13 requirements in each of the years in the study period. The net present value of this
14 stream of revenue requirements was then calculated.

15 BREC used this financial modeling methodology to calculate an NPVRR for three
16 different scenarios: 1) a “Build” case, in which all of the emission control
17 technologies deemed necessary for compliance with CSAPR and MATS are
18 installed on the BREC units; 2) the “Partial Build” case, in which the same set of
19 emission controls are installed as in the “Build” case, with the exception of the
20 SCR on Green Unit 2; and 3) the “Buy” case, in which only MATS emission
21 controls are installed, unit generation is curtailed to meet the CSAPR emissions
22 limits, and power is purchased in the wholesale market to meet the remaining
23 electricity demand.

24 7. CONCERNS WITH THE BREC FINANCIAL MODELING INPUT ASSUMPTIONS

25 **Q Did you identify any problems with the Company’s financial modeling?**

26 **A** Yes, I have five major areas of concern with the BREC financial modeling. The
27 first area of concern is that several of the Company’s input assumptions are
28 flawed, which I will address in this section. The remaining four areas of concern
29 will be addressed in the next section.

1 **Q Which of the Company’s input assumptions do you believe are flawed?**

2 **A** I believe that several of the Company’s input assumptions are flawed, including:

- 3 A. The load forecast, which does not include the effects of DSM;
- 4 B. The input natural gas price forecast from the PACE Global modeling;
- 5 C. The use of a CO₂ emissions price to determine the energy market prices in
- 6 the PACE Global modeling, but leaving it out of the ACES production
- 7 cost modeling and the dispatch of generating units;
- 8 D. The resulting output energy prices from the PACE Global modeling/Use
- 9 of inflated market prices;
- 10 E. The assumption that capacity, heat rates, forced outages, and availability
- 11 factors stay constant over time;
- 12 F. The use of both real and nominal dollars in calculations of NPVRR in the
- 13 BREC financial modeling.

14 **A. LOAD FORECAST**

15 **Q Why do you believe the load forecast used in the BREC analysis is incorrect?**

16 **A** In its Response to Sierra Club Data Request 2-27, the Company essentially admits

17 that its load forecast is overstated because it fails to account for various demand

18 side management (DSM) efforts. In part c, subpart iv of the response, BREC

19 states that the savings from energy efficiency programs that are currently being

20 implemented in 2012 are not included in the load forecast used in its analysis.

21 While level of participation and actual impacts are currently unknown, the

22 Company should at the very least include a conservative estimate of the impacts

23 of energy efficiency, or include a “low load” sensitivity analysis that reflects these

24 impacts. The Company goes on to say in part c, subpart v, that the load forecast

25 also does not explicitly include projected impacts of federal efficiency standards

26 or programs, but only indirectly includes them to the extent they impact historical

27 load data and economic forecast data. Overstating the load would likely cause the

1 BREC units to run more often than they otherwise would in the production
2 simulation modeling, possibly improving the economics of those units as they are
3 subject to fewer starts and less unit cycling. It might also lead to an overestimate
4 of the size of any replacement energy needed if the coal units were to retire, either
5 in the form of a NGCC replacement options, or market energy replacement.

6 **B. NATURAL GAS PRICE FORECAST**

7 **Q Why do you believe the natural gas price forecast used by PACE Global is**
8 **incorrect?**

9 The natural gas price forecast used by PACE Global to develop market energy
10 prices appears to be higher than other natural gas prices developed in 2011 and
11 2012. Figure 2 shows the PACE forecast compared to the EIA's natural gas price
12 forecast from its *Annual Energy Outlook* for the years 2010, 2011, and 2012.

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[CONFIDENTIAL FIGURE REMOVED]

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1 While the EIA forecast from 2010 is higher than the forecast from PACE Global,
2 the forecasts from 2011 and 2012 are both lower than that used by PACE in its
3 modeling.

4 In the near term, even the AEO 2012 natural gas price forecast is too high. The
5 natural gas price at Henry Hub has been less than \$3/mmBtu for all of 2012 thus
6 far, as shown in Figure 3, below.

Natural gas spot prices (Henry Hub)



7

8 **Figure 3. Natural gas spot prices at Henry Hub (\$/mmBtu).⁵**

9 Sources indicate that the drop in forecasts for both short and long-term natural gas
10 prices represent a fundamental shift in the industry rather than a temporary
11 anomaly, and are a result of recent growth in natural gas production due to shale
12 gas and the related sale of natural gas liquids. In EPA's proposed New Source
13 Performance Standards rule, the agency states that "technological developments
14 and discoveries of abundant natural gas reserves have caused natural gas prices to

⁵ U.S. Energy Information Administration. *Natural Gas Weekly Update*. For week ending July 11, 2011. Accessed July 18, 2012. Available at: <http://205.254.135.7/naturalgas/weekly/>

1 decline precipitously in recent years and have secured those relatively low prices
2 for the near future.”⁶

3 **C. CO₂ EMISSIONS PRICE FORECAST**

4 **Q How was a CO₂ emissions price used in the modeling performed in this**
5 **docket?**

6 **A** In its determination of hourly market prices, one of the inputs used by PACE
7 Global was a CO₂ emissions price beginning in 2018. In the 200 Aurora iterations
8 run by PACE, that CO₂ price was applied at varying levels in any given year to
9 the emissions from all of the coal and natural gas generating units in MISO,
10 raising the variable costs of operation accordingly, and thus raising the hourly
11 bids of each generator into the MISO market. PACE’s hourly energy prices are in
12 fact the market clearing price in a given hour. All generator bid prices and
13 associated generation are stacked from lowest to highest cost, and the market
14 clearing price is the price of the last generator needed to meet the forecasted load
15 in a given hour.

16 Those output market energy prices were then given to ACES for use in the PaR
17 model, which dispatches each of the generating units on an hourly basis and
18 calculates the resulting production costs. A CO₂ price is one of the variables that
19 can be included as an operating cost of a generating unit, and if it is present, will
20 affect the dispatch of that unit. It is my understanding, confirmed in the
21 Company’s Response to Sierra Club Data Request 3-17, that in the production
22 cost runs produced by ACES and used by BREC in its financial modeling, a CO₂
23 emissions price was present in the market prices against which the generating
24 units were dispatched, but was not present in the costs of generation at each unit.

25 **Q Is this an appropriate way to account for likely future cost of CO₂ emissions?**

26 **A** No. Because a CO₂ price was included in the PACE output market prices, it also
27 should have been included in the ACES production cost modeling.

⁶ 77 Fed. Reg. 22,392, 22,394-22,395 (April 13, 2012)

1 **Q Why should a CO₂ emissions price be used in both the PACE modeling and**
2 **the ACES production cost modeling?**

3 **A** In the ACES production cost modeling, the CO₂ price has exerted an upward
4 effect on market prices, but because the CO₂ price is not incorporated in the
5 generating units' running costs, the units appear comparatively less expensive to
6 run and thus run more hours of the day than they would otherwise.

7 **D. MARKET ENERGY PRICES**

8 **Q Why are market energy prices important in this analysis?**

9 **A** Market energy prices are important for three reasons. First, because BREC bids its
10 generation into the MISO market, the market energy prices have an effect on the
11 units' dispatch. The higher the market prices, the more electricity output the
12 BREC units will produce. Secondly, the market energy prices affect the "Buy"
13 case that the Company modeled. BREC retrofits its units to comply with MATS,
14 runs the units only enough so that they remain in compliance with CSAPR
15 emissions limits, and buys the remainder of the energy necessary to meet load
16 from the market. The higher the market prices in the "Buy" case, the more
17 expensive the option. Third, market energy prices affect the calculation of a
18 market replacement option, where one or more coal units retire and the generation
19 from those units is replaced with market energy purchases.

20 **Q In other cases that have come before this Commission in the past year, both**
21 **utilities and intervenors have done a calculation of the costs of a market**
22 **replacement option. Why did you not present this calculation in your**
23 **analysis?**

24 **A** I attempted to present a calculation of the costs of a market replacement option
25 using the PACE energy prices, but in doing so, found that it always resulted in
26 higher costs than that of an NGCC replacement option. In my experience in the
27 past year, utility evaluations of a market replacement option have almost always
28 resulted in a lower NPVRR than the NGCC replacement. The fact that in this
29 case, the market option was coming out much higher indicated to me that the
30 market price forecast was inaccurate.

1 **Q Do you have any other reason to believe that the output market prices from**
2 **the PACE Global modeling are incorrect?**

3 **A** Yes. Coal and natural gas are typically the fuel types that are on the margin in any
4 given hour in MISO. Thus fuel price has an effect on the market price, as does a
5 CO₂ emissions price in later years. Using the Aurora output provided by PACE,
6 one is able to remove the effect of the natural gas price and CO₂ emissions price
7 on the hourly market price forecast. Removing these effects leaves you with the
8 marginal emissions rate for the generating unit that is on the margin in a given
9 hour. Coal-fired generators have a marginal emissions rate of about 1.0 – 1.1 tons
10 CO₂/MWh. Natural gas-fired generators have a marginal emissions rate of about
11 0.6 – 0.7 tons CO₂/MWh. When the effects of natural gas and CO₂ prices were
12 removed for the PACE forecast of market prices, the results suggested a marginal
13 emissions rate of 1.8 tons CO₂/MWh (megawatt hour) in later years, which is not
14 indicative of any type of generating unit that I know to be on the margin.

15 **E. CAPACITY, HEAT RATE, FORCED OUTAGES, AND AVAILABILITY**

16 **Q What does BREC assume in its modeling about the capacity of its units over**
17 **time?**

18 **A** BREC assumes that the capacity of its units stays constant. On page 24 of his
19 direct testimony, Mr. Berry states that “the S&L study did not include calculating
20 actual auxiliary power consumption for the recommended compliance strategies.

21 **Q Is it correct for BREC to assume a constant capacity rating over time?**

22 **A** No. Pollution control technologies require electricity to run. A portion of the
23 electricity generated at a unit thus will go toward providing that electricity to run
24 its emissions controls. This is known as parasitic load, and typically results in a
25 capacity derating of a particular unit. This derating is important because it means
26 that a smaller number of megawatts (MW) is then available to provide electricity
27 to serve load.

1 **Q What does BREC assume in its modeling about unit heat rates over time?**

2 **A** In its Response to Sierra Club Data Request 2-5 part e, the Company states that it
3 expects that unit heat rates will stay constant over time.

4 **Q Is it correct for BREC to assume a constant heat rate over time?**

5 **A** No. Heat rates often vary over time as generating unit component parts degrade
6 and are replaced. Heat rates might be expected to rise gradually (units become
7 less efficient) as components age, and then drop slightly when those aging parts
8 are replaced (unit efficiency increases). Heat rate is important because it reflects
9 the efficiency at which the generating unit converts fuel into electricity. A decline
10 in unit heat rate over time means that it is producing fewer megawatt hours
11 (MWh) of electricity over that period.

12 **Q What does BREC assume in its modeling about unit forced outages and**
13 **availability over time?**

14 **A** In its Response to Sierra Club Data Request 2-5 parts a-d, the Company states that
15 it expects that unit forced outages and availability will stay constant over time.

16 **Q Is it correct for BREC to assume constant forced outages and availability**
17 **over time?**

18 **A** No. In its Response to PSC 2-5, BREC gives the historic availability of its units
19 over the past five years. Availability varies from unit-to-unit and from year-to-
20 year due to the number of outages in any given year. Unit outages can be planned,
21 as when a unit undergoes routine maintenance or is taken offline for pollution
22 control installations, or unplanned, as when a component part fails unexpectedly.
23 Availability is the amount of time a generating unit is able to produce electricity
24 in a given period. Outages might increase as units age, or as they require
25 additional equipment replacement or retrofit, which would lead to a decrease in
26 availability. Outages and availability are important because if a plant is offline, it
27 is unable to generate electricity.

1 **F. REAL VERSUS NOMINAL DOLLARS**

2 **Q Does the BREC financial modeling use both real and nominal dollars?**

3 **A**Yes. The estimates of emission control capital and O&M costs developed by
4 Sargent & Lundy are presented in Exhibit DePriest-2 in 2011 dollars. The PaR
5 model used by ACES outputs the generation and operating costs for each of the
6 BREC units in nominal dollars. The BREC financial modeling uses each of these
7 values without converting them to the same base year dollars.

8 **Q Why is this incorrect?**

9 **A**BREC uses a discount rate of 7.93%, which I assume is a nominal discount rate
10 and implies that the analysis was done in nominal dollars. Unit operating costs
11 output by the PaR model are included in the BREC financial modeling in nominal
12 dollars, which account for the effects of inflation over time. Estimates from
13 Sargent & Lundy are in real 2011 dollars, and do not contain any effects of
14 inflation. BREC does not spend all of the capital required for the emissions
15 retrofits in 2011, but rather incurs it over time at some future start date. These
16 2011 dollar estimates should thus be multiplied by an inflation rate in order to
17 determine how much an investment incurred in a future year will cost in that
18 year's dollars. BREC does not convert these capital expenditures incurred in a
19 future year into that future year's dollars. These capital expenditures are thus
20 understated in the BREC financial modeling.

21 **8. ADDITIONAL CONCERNS WITH THE BREC FINANCIAL MODELING**

22 **Q Please describe your additional concerns with the BREC financial modeling.**

23 **A**My additional concerns with the financial modeling include the following: 1) that
24 BREC does not model the full set of controls that will be required under the EPA
25 rules; 2) that BREC does not model its units individually, but rather as a block,
26 choosing to retrofit all of the units together rather than examining the economics
27 of each unit on a standalone basis; 3) that the BREC financial modeling evaluates
28 a selection of future costs associated with the retrofits rather than the actual

1 forward going running costs of the units; and 4) that BREC does not model the
2 emission control retrofits against a reasonable set of alternative options, including
3 but not limited to: a natural gas-fired combustion turbine or combined cycle
4 replacement, a replacement with market purchases, or a replacement with some
5 combination of energy efficiency, renewables resources, natural gas units, and
6 market purchases. I will address each of these concerns in turn.

7 **Q Please explain what you mean when you say that BREC does not model the**
8 **full set of controls required under the EPA rules.**

9 **A** BREC models only the emission control retrofits that will be required under
10 CSAPR and MATS, and includes only a subset of the controls recommended by
11 Sargent & Lundy to comply with these rules. In addition to those technologies
12 chosen by the Company, Mr. DePriest states on page 20, lines 9-16 that Sargent &
13 Lundy recommended low NO_x burners on Coleman units 1-3 for CSAPR
14 compliance. As I mention above, in section 5 of my testimony, it is possible, and
15 even likely, that one or more of the BREC units will require additional retrofits to
16 comply with MATS, whether in the form of ESP upgrades, a polishing baghouse,
17 or a full baghouse.

18 In addition, Mr. Shaw and Mr. DePriest state in their direct testimonies that
19 BREC will also be subject to the NAAQS revisions, the CCR rule, the Water
20 Intake (316(b)) rule, and new limits on effluent. While the rules have yet to be
21 finalized, BREC expects that capital expenditures will be necessary to bring their
22 units into compliance. On page 19, lines 12-19 and page 20, lines 20-22 in the
23 direct testimony of Thomas Shaw, Mr. Shaw states that the alternatives under
24 consideration by the EPA for both the CCR and 316(b) rules are of such
25 substantially different form that “an immediate response to the proposal would
26 not be appropriate.” It is correct that the Company cannot be expected to seek
27 CPCN and begin construction of environmental projects before knowing what is
28 required by the final rules. However, Sargent & Lundy made recommendations
29 for those retrofits that it believes will bring the units into compliance with each of
30 the rules in their expected final form. BREC could have easily incorporated those

1 recommended capital expenditures associated with Sargent & Lundy's
2 recommendations into an economic analysis of its coal-fired units. BREC uses a
3 20 year planning horizon, and to assume that these upcoming rules will have no
4 effect on the capital expenditures or running costs at its coal units is unrealistic
5 and favors a retrofit scenario.

6 As I mention above, third-party analyses of the EPA rules predict more coal
7 retirements when all of the rules are considered together, as the cumulative capital
8 additions cause the running costs of additional generating units to be higher than
9 costs of a natural gas or market replacement option. Once BREC makes capital
10 investments for the emission controls necessary for compliance with CSAPR and
11 MATS, those costs are sunk and are no longer considered in the calculation of the
12 units' forward going running costs when additional emission control retrofits are
13 considered. By looking at the EPA regulations on a piecemeal basis as they
14 become final, BREC is not considering the real forward economics of its coal
15 units.

16 **Q Please explain what you mean when you say that BREC models its units as a**
17 **block and not individually.**

18 **A** Compliance with CSAPR allows for allowance trading, with units that are not
19 able to meet their emissions limits able to purchase SO₂ and NO_x allowances from
20 the market. BREC models emissions compliance based on total fleet emissions,
21 rather than installing retrofits such that each unit meets its individual emissions
22 limit. This is an acceptable modeling practice.

23 When considering actual running costs of coal unit, however, it is not acceptable
24 to model the BREC coal fleet as a whole instead of modeling each unit on a
25 standalone basis. Larger, more efficient units may be less expensive and thus
26 more economic to run, while smaller, less efficient units may be clearly
27 uneconomic to run. Modeling the units individually would reveal this difference
28 in running costs between the units. Modeling the units as a block would likely
29 mask this difference, as the efficiencies of the larger unit would compensate
30 somewhat for the poor economics of the smaller plant.

1 Certain units may also require additional capital expenditures to bring them into
2 compliance with environmental regulations, and older units may face the need for
3 more capital investments to continue operating. Taking all of the coal units as a
4 whole spreads these capital expenditures over the entire fleet, hiding the fact that
5 certain units require more investment capital and might be a candidate for
6 retirement rather than retrofit.

7 **Q Please explain what you mean when you say that BREC models a selection of**
8 **future costs associated with the retrofits rather than the actual forward going**
9 **running costs of the units. Why is this an error?**

10 **A** As I mentioned above, the BREC financial modeling calculates revenue
11 requirements based on the production costs in a given year (start-up costs, fuel
12 costs, costs for reagents, allowance purchases, purchased power, and off-system
13 sales) with the fixed cost of capital in a given year (debt service, debt issuance
14 cost, property tax, property insurance, and labor) to arrive at the revenue
15 requirements in each of the years in the study period.

16 The BREC financial modeling fails to take into account the ongoing capital costs
17 associated with routine maintenance at each of the units, which the Company
18 provided in its Confidential Response to Sierra Club Data Request 2-1a. [REDACTED]

19 [REDACTED]
20 [REDACTED] Costs have only been provided through 2015, but these costs will
21 continue through the study period, and may increase as the units age.

22 **Q Please explain what you mean when you say that BREC does not model unit**
23 **retrofits against alternative options.**

24 **A** BREC examines three options, but they are all variations on its “Build” case. In
25 evaluating the economics of coal units with emission control retrofits, other
26 utilities have evaluated the costs of the retrofits against replacement alternatives.
27 These alternatives might include a NGCC replacement unit, replacement with
28 market purchases, or a combination replacement option that looks at increased
29 levels of energy efficiency, renewable energy, and some gas and market
30 purchases. Without looking at such options for replacing any or all of BREC’s

1 coal units, there is simply no basis to conclude that retrofitting each such unit
2 represents the least-cost option.

3 The Commission has seen in previous cases that the retrofit of a coal unit is often
4 compared to the construction of a replacement natural gas-fired combined cycle
5 unit, to the purchase of an existing NGCC, or to the cost of entering into a
6 purchase power agreement (PPA) with the operator of an existing NGCC. BREC
7 did not explore any of these options, as stated by the Company in Response to
8 Data Request Sierra Club 1-50. Data from the EIA *2012 Annual Energy Outlook*
9 (attached as Exhibit RSW-6) suggests that capacity factors for oil and natural gas
10 generation are projected to be less than 20% through the BREC study period,
11 indicating that it is highly likely that BREC could have entered into a long-term
12 PPA for energy and capacity in MISO. A spreadsheet with this EIA data is
13 attached to my testimony as Exhibit RSW-7.

14 The Commission has also seen in previous cases that utilities typically examine
15 the cost of a coal unit retrofit against the cost of buying replacement power for
16 that unit on the market, and that this option typically results in a lower NPVRR
17 under current market conditions. The Company did not examine a market
18 replacement scenario, and the fact that its “Buy” case results in a much higher
19 NPVRR than its “Build” case suggests an error in its analysis.

20 Finally, the Company could have examined a combination replacement option.
21 Had BREC done an energy efficiency market potential study, it could be currently
22 achieving a high amount of savings. The Company then could have issued RFPs
23 for a lower amount of replacement energy, and examined renewable energy
24 sources as well natural gas and market energy purchases.

25 **9. DESCRIPTION AND RESULTS OF SYNAPSE ENERGY ECONOMICS FINANCIAL**
26 **MODELING**

27 **Q Did you perform any of your own financial modeling for this docket?**

28 **A** Yes. Synapse created a cash flow model that calculates the forward going costs of
29 each of the BREC units on an annual basis, and discounts this stream of costs to

1 determine the total NPVRR of the suite of retrofits included in the analysis for
2 each of the units on a standalone basis. The “Retrofit” option is then compared to
3 a natural gas combined-cycle replacement option. Certain input assumptions are
4 allowed to vary in the cash flow model and the user can create a number of
5 scenarios to examine.

6 **Q Please explain how you created your model and the inputs you used.**

7 **A** The cash flow model was designed to compare the revenue requirements
8 associated with the BREC 2012 Compliance Plan to a natural gas-fired combined
9 cycle replacement option that provides similar rated capacity and generation. The
10 model was created using as many of the inputs and assumptions found in
11 modeling performed by the Company, ACES Power Marketing, and PACE
12 Global as was possible. Any input that was not taken directly from BREC was
13 taken from a public source, and where possible was a source referenced by the
14 Company, e.g. the Energy Information Administration (EIA). The source for each
15 input assumption is documented in the model.

16 The cash flow analysis creates the nominal revenue requirements for each
17 environmental retrofit using the capital costs of the projects, AFUDC, book and
18 tax depreciation, income and deferred taxes, return on rate base, property taxes
19 and insurance costs. These capital revenue requirements are then combined with
20 generating unit-specific, on-going non-environmental capital expenditures,
21 generating unit-specific production costs (fuel costs, start costs, fixed and variable
22 O&M costs, emissions costs), and environmental retrofit project-specific O&M
23 costs, which sum to provide the nominal revenue requirements for each year, for
24 each generating unit. These nominal revenue requirements are then summed and
25 put in present value terms using the BREC nominal discount rate.

26 In calculating the NPVRR for the NGCC replacement option, we assumed
27 retirement of the BREC units at the end of 2015 and assumed installation of the
28 NGCC at the beginning of 2016. Similar to the calculation for the retrofit option,
29 the NPVRR calculation for the NGCC option includes capital costs with AFUDC

1 and unit production costs (fuel costs, fixed and variable O&M costs, emissions
2 costs). The NPVRR of the retrofit option was then compared to the NPVRR for
3 the NGCC replacement option on a unit-by-unit basis.

4 The cash flow spreadsheet model enables the creation of different scenarios
5 through the use of certain different input values, e.g. natural gas price, CO₂
6 emissions price, and selection of additional environmental compliance retrofit
7 technologies for each of the BREC units. The user can create different scenarios
8 by selecting variations on each of these inputs.

9 **Q What are the results of your financial modeling?**

10 **A** The difference in NPVRRs between the coal retrofit and NGCC replacement
11 option in the “Synapse Recommended Case” are shown in Table 4, below.
12 Negative values in the “NGCC Replacement” column indicate that building a
13 natural gas-fired unit is cheaper than installing pollution control retrofits on the
14 BREC coal units. The results in Table 8 (also in Exhibit RSW-2) indicate that all
15 of the BREC coal units are uneconomic when compared to a natural gas
16 replacement option and should be considered for retirement.

17 **Table 8. Synapse Recommended Case - Comparison of NGCC Replacement to BREC Unit**
18 **Retrofits (millions 2012\$).**

	NGCC Replacement 2015 minus Retrofit	% Difference from Retrofit
Wilson	(\$259)	-13.88%
Green 1	(\$204)	-18.53%
Green 2	(\$213)	-19.83%
HMPL 1	(\$82)	-12.47%
HMPL 2	(\$107)	-15.56%
Coleman 1	(\$108)	-15.84%
Coleman 2	(\$90)	-13.74%
Coleman 3	(\$103)	-14.92%
Total	(\$1,165)	-15.73%

19
20 The Synapse Recommended Case includes the controls in the BREC 2012
21 Environmental Compliance Plan, and also includes those controls recommended
22 by Sargent & Lundy for compliance with the revised NAAQS, the CCR rule, and

1 the 316(b) rule. Costs of compliance with the Effluent Limitations Guidelines
2 were also included, and were taken from the *2010 EPRI Cost Assessment of Coal*
3 *Combustion Residuals* and the *2011 EEI Potential Impacts of Environmental*
4 *Regulation*.

5 **Q How does your Recommended Case compare to the BREC analysis?**

6 **A** We put the input assumptions used by BREC (the BREC natural gas price
7 forecast, a CO₂ emissions price of \$0 in all years, and only those retrofits in the
8 Company's 2012 Environmental Compliance Plan) into our cash flow model and
9 got the results shown in Table 9 (also in Exhibit RSW-8) – the “Big Rivers Build
10 Case.”

11 **Table 9. Company Case - Comparison of NGCC Replacement to BREC Unit Retrofits**
12 **(millions 2012\$).**

	NGCC Replacement 2015 minus Retrofit	% Difference from Retrofit
Wilson	\$152	10.06%
Green 1	\$69	8.12%
Green 2	\$4	0.50%
HMPL 1	\$82	16.22%
HMPL 2	\$65	12.27%
Coleman 1	\$43	7.85%
Coleman 2	\$61	11.73%
Coleman 3	\$50	8.89%
Total	\$527	8.91%

13
14 The results from the BREC Build Case show that retrofitting the units with select
15 CSAPR and MATS compliance technologies only, under the Company's gas and
16 CO₂ input assumptions, result in positive benefits of varying amounts for each of
17 the units. Benefits of the Green 2 retrofits are smallest, at \$4 million NPVRR and
18 benefits of the Wilson retrofits are highest at \$152 million NPVRR.

19

1 **Q How do the results from your cash flow analysis go from a net benefit of \$527**
 2 **million under the BREC Build Case to a net cost of more than \$1 billion in**
 3 **the Synapse Recommended Case when compared to an NGCC alternative?**

4 **A** In order to help answer this question, I've prepared several tables that vary the
 5 input assumptions one at a time as I move between the BREC Build Case and the
 6 Synapse Recommended Case.

7 First, simply changing the CO₂ emissions price to be consistent throughout the
 8 BREC modeling⁷ causes Green Unit 2 to become uneconomic to run, as shown in
 9 Table 10. It also causes the total net benefit of retrofitting the coal fleet to drop by
 10 \$359 million. Table 10 is also attached as Exhibit RSW-9.

11 **Table 10. Comparison of Company Build Case with and without CO₂ (millions 2012\$).**

	Company Build Case	Company Build + CO2
	Zero CO2 Price, BREC NG price, ECP Retrofits	BREC CO2 Price, BREC NG price, ECP Retrofits
Wilson	\$151.56	\$55.89
Green 1	\$69.35	\$21.46
Green 2	\$4.44	(\$43.48)
HMPL 1	\$82.38	\$53.14
HMPL 2	\$65.29	\$31.36
Coleman 1	\$43.18	\$8.48
Coleman 2	\$60.88	\$26.58
Coleman 3	\$49.72	\$13.57
Total	\$526.81	\$167.00

12
 13 Changing the PACE/BREC natural gas price forecast to the most up-to-date EIA
 14 AEO 2012 forecast has an even more dramatic effect on the economics of the
 15 retire and replace scenario. Five of the eight BREC units are now uneconomic to
 16 run under an updated natural gas price forecast, and the net benefits of retrofitting
 17 the entire fleet are now negative. These results are shown in Table 11, and also in
 18 Exhibit RSW-10.

⁷ Of the 21 electric utilities we surveyed that have a public CO₂ price forecast, the PACE Global price forecast is the third lowest of the Reference cases.

1 **Table 11. Comparison of Company Build Case with PACE/BREC and EIA 2012 Natural**
 2 **Gas Price Forecasts (millions 2012\$).**

	Company Build Case	Company Build, AEO NG
	Zero CO2 Price, BREC NG price, ECP Retrofits	Zero CO2 Price, AEO NG price, ECP Retrofits
Wilson	\$151.56	(\$16.88)
Green 1	\$69.35	(\$25.73)
Green 2	\$4.44	(\$86.20)
HMPL 1	\$82.38	\$22.71
HMPL 2	\$65.29	\$3.80
Coleman 1	\$43.18	(\$15.52)
Coleman 2	\$60.88	\$2.70
Coleman 3	\$49.72	(\$12.22)
Total	\$526.81	(\$127.35)

3
 4 Changing the CO₂ and natural gas prices together yields even more dramatic
 5 results, shown in Table 12 (attached as Exhibit RSW-11) in the first and third
 6 columns, changing \$526 million in net benefits in the Company Build Case to
 7 \$487 million in net cost in the “Company Build + CO₂, AEO NG” scenario.

8 **Table 12. Comparison of Company Build Case with Changed Input Scenarios (millions**
 9 **2012\$).**

	Company Build Case	Company Build + CO2	Company Build + CO2, AEO NG	All Retrofits but Effluent + CO2, AEO NG	Synapse Recommended
	Zero CO2 Price, BREC NG price, ECP Retrofits	BREC CO2 Price, BREC NG price, ECP Retrofits	BREC CO2 Price, AEO NG price, ECP Retrofits	BREC CO2 Price, AEO NG price, All Retrofits but Effluent	BREC CO2 Price, AEO NG price, All Retrofits
Wilson	\$151.56	\$55.89	(\$112.55)	(\$116.10)	(\$259.04)
Green 1	\$69.35	\$21.46	(\$73.62)	(\$135.37)	(\$203.80)
Green 2	\$4.44	(\$43.48)	(\$134.12)	(\$144.63)	(\$213.05)
HMPL 1	\$82.38	\$53.14	(\$6.54)	(\$15.10)	(\$81.54)
HMPL 2	\$65.29	\$31.36	(\$30.13)	(\$38.69)	(\$106.72)
Coleman 1	\$43.18	\$8.48	(\$50.22)	(\$63.94)	(\$108.28)
Coleman 2	\$60.88	\$26.58	(\$31.60)	(\$45.33)	(\$89.67)
Coleman 3	\$49.72	\$13.57	(\$48.38)	(\$62.10)	(\$103.34)
Total	\$526.81	\$167.00	(\$487.16)	(\$621.25)	(\$1,165.44)

10
 11 Adding in the costs of compliance with expected EPA regulations causes the
 12 economics of the fleet retrofits to look even worse. Compliance with the revised
 13 NAAQS, CCR, and 316(b) rules in addition to CSAPR and MATS would have a

1 net total cost of \$621 million. Finally, adding in Effluent Limitation Guidelines
2 compliance costs leads to a net total cost of more than \$1 billion when compared
3 to a NGCC replacement option.

4 **10. CONCLUSIONS**

5 **Q Please summarize your conclusions.**

6 **A** Based on my review, I conclude that the errors present in the BREC modeling
7 causes the Company to understate the costs associated with the continued
8 operations of its coal fleet. Using corrected input assumptions and adding in the
9 costs of compliance with expected EPA regulations causes the costs of coal unit
10 retrofits to increase dramatically. When the complete retrofit scenario is compared
11 to a NGCC replacement scenario, we see that the NGCC scenario is more than \$1
12 billion cheaper than continued operation of the BREC coal fleet.

13 **Q Does this conclude your direct testimony?**

14 **A** Yes.

Rachel Wilson

Associate

Synapse Energy Economics

485 Massachusetts Ave., Suite 2, Cambridge, MA 02139

(617) 453-7044 • fax: (617) 661-0599

www.synapse-energy.com

rwilson@synapse-energy.com

PROFESSIONAL EXPERIENCE

Synapse Energy Economics Inc., Cambridge, MA. Associate, 2010 – present, Research Associate, 2008 – 2010.

- Performs consulting, conducts research, and assists in writing testimony and reports on a wide range of issues relating to electric utilities, including: federal and state clean air policies; emissions from electricity generation; environmental compliance technologies, strategies, and costs; integrated resource planning; valuation of environmental externalities from power plants; and the nexus between water and energy.
- Uses optimization and electricity dispatch models, including Strategist, PROMOD, PROSYM/Market Analytics, and PLEXOS to conduct analyses of utility service territories and regional energy markets.

Analysis Group, Inc., Boston, MA. Associate, Energy Practice, 2007 - 2008.

- Supported an expert witness asked to opine on various topics in the electric industry as they applied to merchant generators and provided incentives for their behavior in the late 1990s and early 2000s.
- Analyzed data related to coal production on Indian land and contractual royalties paid to the tribe over a 25 year period to determine if discrepancies exist between these values for the purposes of potential litigation.
- Examined Canadian policies relating to carbon dioxide, and assisted with research on linkage of international tradable permit systems.
- Managed analysts' work processes and evaluated work products.

Senior Analyst Intern, Energy Practice, 2006 - 2007.

- Supported an expert witness in litigation involving whether a defendant power company could financially absorb a greater investment in pollution control under its debt structure while still offering competitive rates. Analyzed impacts of federal and state clean air laws on energy generators and providers. Built a quantitative model showing the costs of these clean air policies to the defendant over a 30 year period. Built a financial model calculating impacts of various pollution control investment requirements.
- Researched the economics of art; assisted in damage calculations in arbitration between an artist and his publisher.

Yale Center for Environmental Law and Policy, New Haven, CT. Research Assistant, 2005 – 2007.

- Gathered and managed data for the Environmental Performance Index, presented at the 2006 World Economic Forum. Interpreted statistical output, wrote critical analyses of results, and edited report drafts.
- Part of the team that produced *Green to Gold*, an award-winning book on corporate environmental management and strategy. Managed data, conducted research, and implemented marketing strategy.

CERES, Boston, MA. Student Consultant, Spring 2006.

- As part of a four-person team, made strategic recommendations on all aspects of messaging and engagement to encourage corporate directors to act on the issue of climate change. First strategic recommendation was sustainable governance forums, which were profiled in New York Times article “Global Warming Subject for Directors at Big Companies” on September 21, 2006.

Marsh Risk and Insurance Services, Inc., Los Angeles, CA. Risk Analyst, Casualty Department, 2003 – 2005.

- Evaluated Fortune 500 clients’ risk management programs/requirements and formulated strategic plans and recommendations for customized risk solutions.
- Supported the placement of \$2 million in insurance premiums in the first year and \$3 million in the second year.
- Utilized quantitative models to create loss forecasts, cash flow analyses and benchmarking reports.
- Completed a year-long Graduate Training Program in risk management; ranked #1 in the western region of the US and shared #1 national ranking in a class of 200 young professionals.

EDUCATION

Yale School of Forestry & Environmental Studies, Master of Environmental Management, New Haven, Connecticut, 2007.

Concentration in Law, Economics, and Policy with a focus on energy issues and markets.

Claremont McKenna College, Bachelor of Arts in Environment, Economics, Politics (EEP) Claremont, California, 2003.

cum laude and EEP departmental honors.

School for International Training Quito, Ecuador. Spring 2002.

Semester abroad studying Comparative Ecology. Microfinance Intern – Viviendas del Hogar de Cristo in Guayaquil, Ecuador.

SKILLS AND ACCOMPLISHMENTS

Microsoft Office Suite, Lexis-Nexis, Platts Energy Database, Strategist, PROMOD, PROSYM/Market Analytics, and PLEXOS, some SAS and STATA.

Competent in oral and written Spanish.

Hold the Associate in Risk Management (ARM) professional designation.

PUBLICATIONS AND PRESENTATIONS

Fagan, R., M. Chang, P. Knight, M. Schultz, T. Comings, E. Hausman, and R. Wilson. *The Potential Rate Effects of Wind Energy and Transmission in the Midwest ISO Region*. Prepared for the Energy Future Coalition. May 22, 2012.

Wilson, R. *Comments Regarding MidAmerican Energy Company Filing on Coal-Fired Generation in Iowa*. Prepared for the Iowa Office of the Consumer Advocate. December 15, 2011.

Johnston, L., and R. Wilson. *Global Best Practices: Strategies for Decarbonizing Electric Power Supply*. Prepared for Regulatory Assistance Project (RAP). December 14, 2011.

Hausman, E., T. Comings, R. Wilson, and D. White. *Electricity Scenario Analysis for the Vermont Comprehensive Energy Plan 2011*. Prepared for the Vermont Department of Public Service. September 2011.

Hornby, R., P. Chernick, C. Swanson, D. White, J. Gifford, M. Chang, N. Hughes, M. Wittenstein, R. Wilson, and B. Biewald. *Avoided Energy Supply Costs in New England: 2011 Report*. Prepared for the Avoided-Energy-Supply-Component (AESC) Study Group. July 21, 2011.

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Johnston, L., E. Hausman., B. Biewald, R. Wilson, and D. White. *2011 Carbon Dioxide Price Forecast*. February 11, 2011.

Fisher, J., R. Wilson, N. Hughes, M. Wittenstein, and B. Biewald. *Benefits of Beyond BAU: Human, Social, and Environmental Damages Avoided Through the Retirement of the US Coal Fleet*. Prepared for the Civil Society Institute. January 25, 2011.

Peterson, P., V. Sabodash, R. Wilson, and D. Hurley. *Public Policy Impacts on Transmission Planning*. Prepared for Earthjustice, December 21, 2010.

Fisher, J., S. Levy, Y. Nishioka, P. Kirshen, R. Wilson, M. Chang, J. Kallay, and C. James. *Co-Benefits of Energy Efficiency and Renewable Energy in Utah*. Prepared for the State Energy Office of Utah, March 2010.

Wilson, R. "The Energy-Water Nexus: Interactions, Challenges, and Policy Solutions." Presented at the National Drinking Water Symposium 2009, October 2009.

Fisher, J., C. James, L. Johnston, D. Schlissel, R. Wilson, *Energy Future: A Green Alternative for Michigan*. Prepared for Natural Resources Defense Council and Energy Foundation, August 2009.

Schlissel, D., R. Wilson, L. Johnston, D. White, *An Assessment of Santee Cooper's 2008 Resource Planning*. April 2009.

Schlissel, D., A. Smith, R. Wilson, *Coal-Fired Power Plant Construction Costs*. July 2008.

TESTIMONY

Kentucky Public Service Commission. Direct testimony before the Commission on behalf of the Sierra Club. Testimony included discussion of STRATEGIST modeling relating to the application of Kentucky Power Company for a Certificate of Public Convenience and Necessity, and for approval of its 2011 environmental compliance plan and amended environmental cost recovery surcharge.

Kentucky Public Service Commission. Direct testimony before the Commission on behalf of Sierra Club and Natural Resources Defense Council. Testimony included discussion of STRATEGIST modeling relating to the applications of Kentucky Utilities Company, and Louisville Gas and Electric Company for Certificates of Public Convenience and Necessity, and approval of its 2011 compliance plan for recovery by environmental surcharge. September 16, 2011.

Minnesota Public Utilities Commission. Rebuttal testimony before the Commission on behalf of Izaak Walton League of America, Fresh Energy, Sierra Club, and Minnesota Center for Environmental Advocacy. Testimony described STRATEGIST modeling performed in the docket considering Otter Tail Power's application for an Advanced Determination of Prudence for BART retrofits at its Big Stone plant. September 7, 2011.

Resume dated June 2012.

	NGCC Replacement 2015 minus Retrofit	% Difference from Retrofit
Wilson	(\$259)	-13.88%
Green 1	(\$204)	-18.53%
Green 2	(\$213)	-19.83%
HMPL 1	(\$82)	-12.47%
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Coleman 1	(\$108)	-15.84%
Coleman 2	(\$90)	-13.74%
Coleman 3	(\$103)	-14.92%
Total	(\$1,165)	-15.73%



EEI Preliminary Reference Case and Scenario Results

May 21st, 2010

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Updated Reference Case



- Nuclear build limits – from NEI
 - Hard-wired units (5,500 MW)
 - Candidate units (4,300 MW) – allowed to be built on or after specified date, but only if deemed economic
 - Economic units – including 8 units above, up to 45 units by 2030 on national basis, regional limits based on existing brownfield sites
- Run year mapping
- Capacity credit update (10%) for wind
- Calibrated coal prices to AEO 2010
 - Minemouth prices calibrated to AEO 2010
 - Transportation prices based on EPA

MODELING ASSUMPTIONS

EEI Master Assumptions Matrix – Reference Case



	EPA ARRA Analysis	EEI Base Case
Electric Demand – National Annual Average	EPA/AEO2009	EPA/AEO2009
Electric Demand -Regional	EPA/AEO2009	EPA/AEO2009
Electric Demand Elasticity	na	na
Natural Gas Supply Curves (Henry Hub)	EPA	EPA
Natural Gas Basis Differentials	EPA	EPA
Coal Price Supply Curves and Coal Transportation Costs	EPA	AEO2010/EPA
Biomass Supply Curves	EPA/AEO2009	EPA/AEO2009
New Build Capital Costs	EPA	EIA AEO/2010
Retrofit Capital Costs	EPA	EVA/NERC
Mercury and HAP Retrofit Structure	EPA	EVA/NERC
Technology Limits	EPA	EPA/NEI
Financing Assumptions – New Builds	EPA	EPA
Financing Assumptions – Retrofits	EPA	EPA for regulated EIA for merchant
3P Policy	CAIR w/ 1.6 million ton bank carryover into 2012	CAIR plus state mercury limits
Carbon	None	None

MODELING ASSUMPTIONS

EEI Reference Case Regulations



	SO ₂ Program	NO _x Program		Mercury Program	CO ₂ Program
	25 States + DC	Annual	Ozone Season		
CAIR Phase I (2010 -2014)	2010 retirement ratio: 2:1 Existing Title IV for unaffected states	25 States + DC 1.522 million tons	25 States + DC 0.568 million tons	State Level Regulations CT, CO, DE, GA, IL, MA, MD, ME, MI, MN, MT, NC, NH, NJ, NM, NY, OR, WA, WI	None
CAIR Phase II (2015+)	25 States + DC Retirement ratio: 2.86:1 Existing Title IV for unaffected states	25 States + DC 1.268 million tons	25 States + DC 0.485 million tons		

- BART is included for all BART effected units not included in CAIR for SO₂ and NO_x and WRAP for SO₂.
- WRAP SO₂ is included.
- All existing state regulations for NO_x, SO₂, Hg and CO₂ are included.

MODELING ASSUMPTIONS

EEI Scenario Descriptions



Scenario	Description
HAPS (Scenario 1)	<p>All coal units required to have SCR, scrubber, ACI and fabric filter by 2015</p> <p>Ash (2015): All units with wet fly ash disposal and/or wet bottom ash disposal are required to convert to dry handling and install a landfill and wastewater treatment facility. Cost components are as follows:</p> <ul style="list-style-type: none"> • Conversion to dry fly ash handling - \$15 million per unit • Conversion to dry bottom ash handling - \$20 million per unit • New Landfill - \$30 million per facility • New wastewater treatment facility - \$120 million per facility
HAPS+Ash+Water (Scenario 2)	<p>Costs applied to units with ponds for fly ash and/or bottom ash based on EIA-923 Schedule 8A, 2008.¹</p> <p>Water (2015): All fossil and nuclear facilities that have at least one once-through cooling unit and would have been classified as a Phase II Facility under the remanded Phase II rule are required to install cooling towers. This does not apply to facilities that are completely closed-cycle cooling even if they use more than 50 million gallons per day. However, it does include some facilities that use helper towers to cool the thermal discharge during portions of the year. The costs are as follows:</p> <ul style="list-style-type: none"> • Nuclear - \$454/gpm (avg. \$220/kW) • Fossil - \$330/gpm (avg. \$215/kW) <p>Costs are applied to units described above based on EPRI's database of electric generating facilities.²</p>
HAPS+Ash+Water+CO2 (Scenario 3)	<p>CO₂ price consistent with EIA's August 2009 analysis of HR 2454 (Waxman-Markey). Prices start in 2012 at \$17/ton and increase to \$60/ton in 2030 (2008\$).</p>

¹ "20100507_Fly Ash and Bottom Ash Summary_Roewer.xls" received on May 7th, 2010

² "Master List 4-29-10 Working Draft to EEI_calcv1.xls" received on May 5th 2010.

MODELING ASSUMPTIONS

Run Year Structure

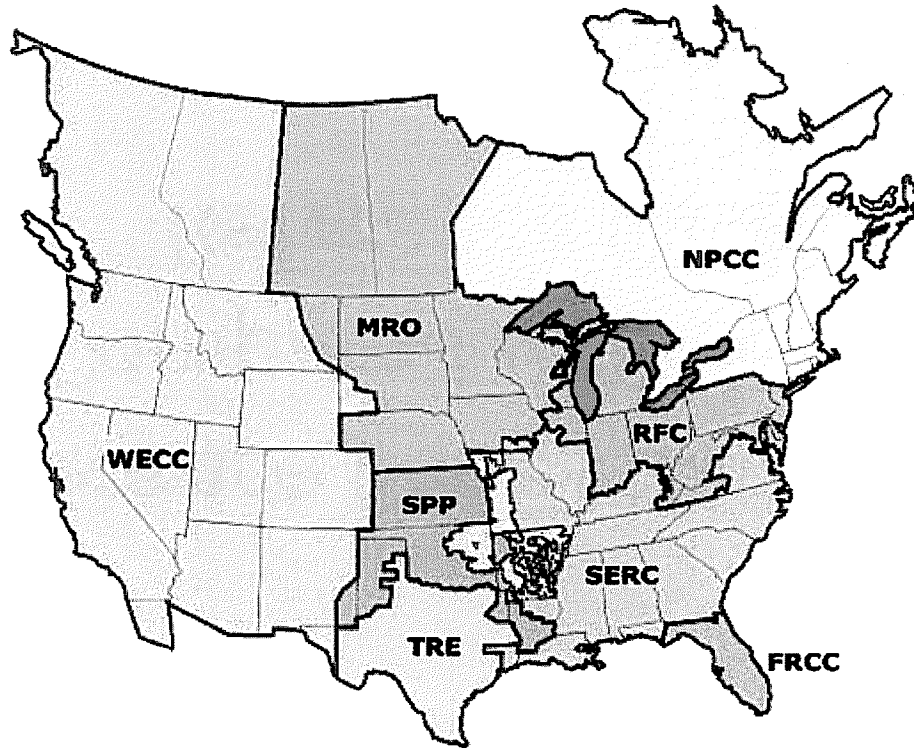


EPA Run Year	EPA Mapped Years
2012	2012-2013
2015	2014-2017
2020	2018-2022
2025	2023-2027
2032	2028-2035

EEI Run Year	EEI Mapped Years
2010	2010
2011	2011
2012	2012
2013	2013
2014	2014
2015	2015
2016	2016
2017	2017
2018	2018
2019	2019
2020	2020-2022
2025	2023-2027
2032	2028-2035

MODELING ASSUMPTIONS

NERC Region Map



FRCC – Florida Reliability Coordinating Council	SERC –SERC Reliability Corporation
MRO – Midwest Reliability Organization	SPP – Southwest Power Pool, RE
NPCC – Northeast Power Coordinating Council	TRE – Texas Regional Entity
RFC – Reliability First Corporation	WECC – Western Electricity Coordinating Council
Note: NERC regional results shown in this presentation include the US only	

Source: <http://www.nerc.com>



EEI Reference Case - National Level Results Compared to EPA ARRA 2009 Reference Case

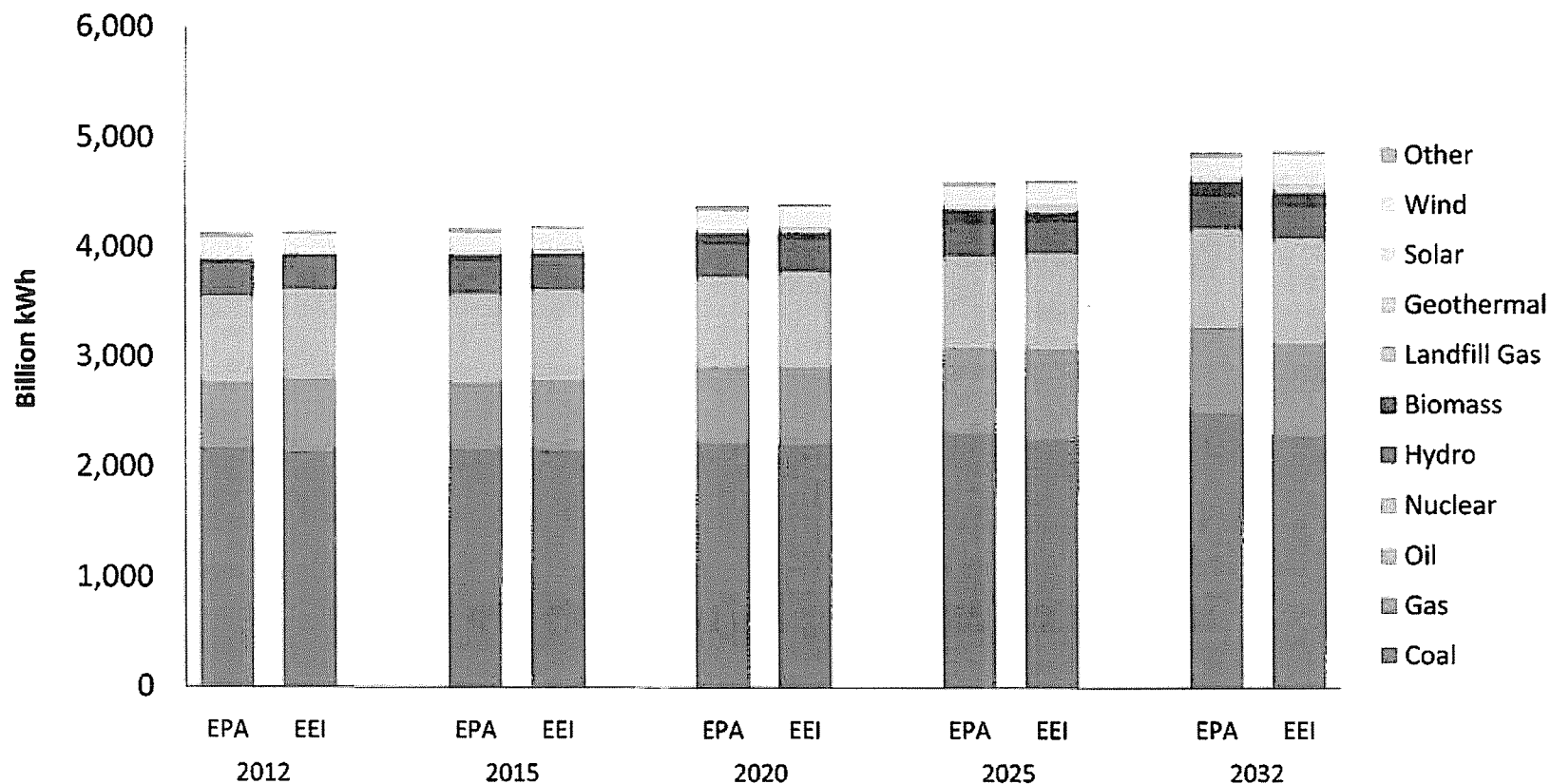
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NATIONAL RESULTS COMPARISON

National Generation By Type



National Generation



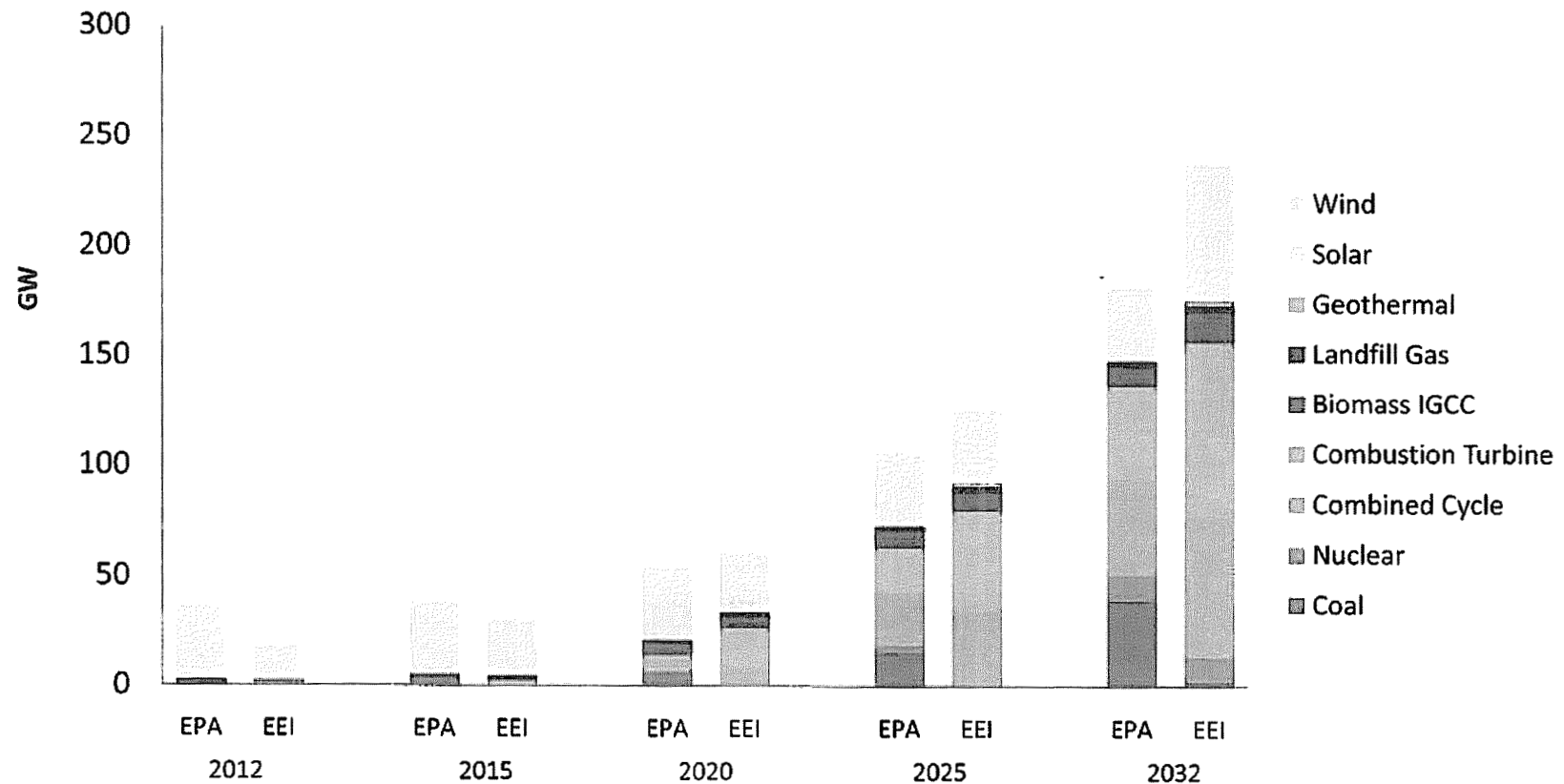
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NATIONAL RESULTS COMPARISON

National Cumulative Capacity Additions



National Cumulative Capacity Additions



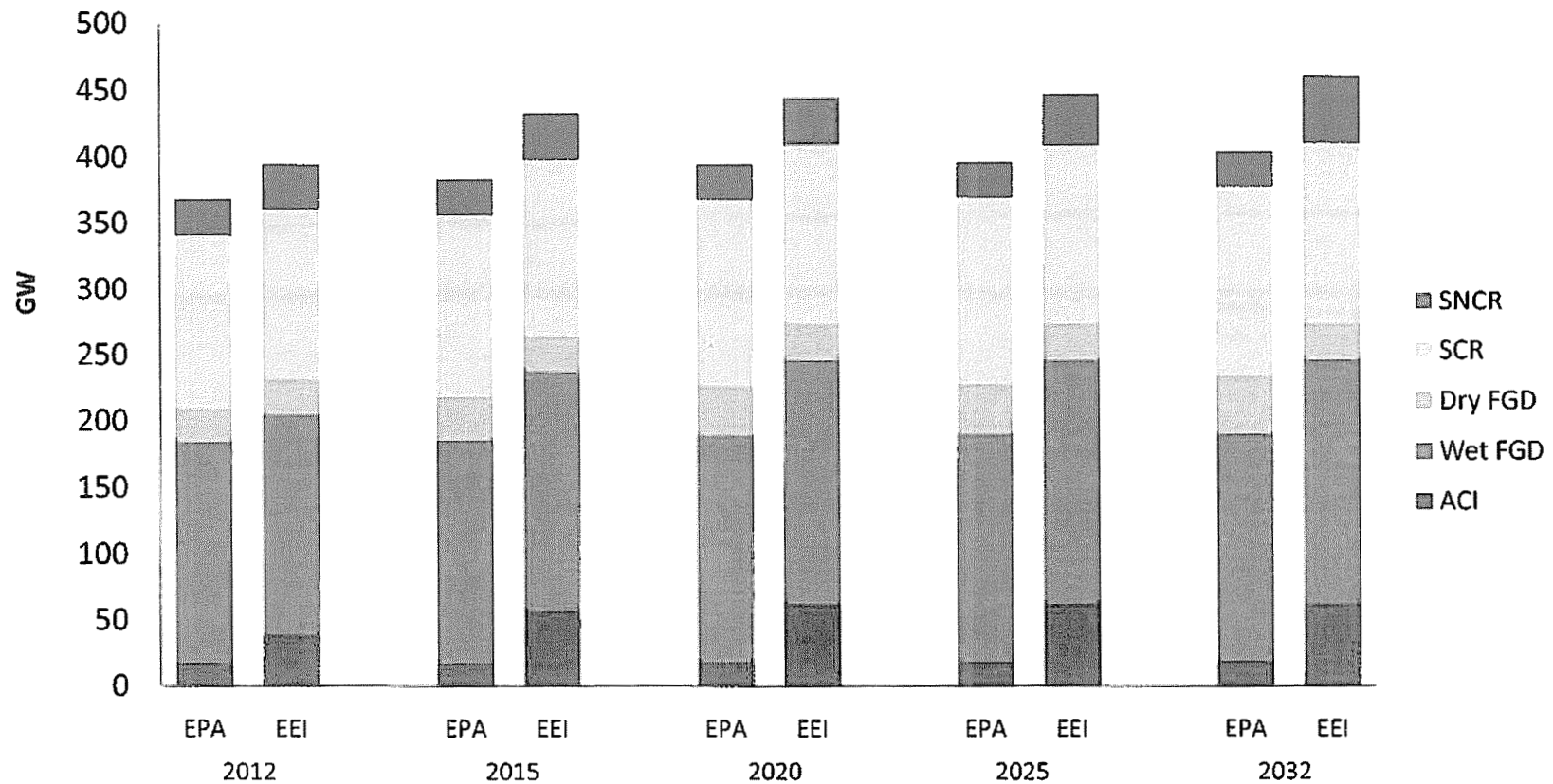
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NATIONAL RESULTS COMPARISON

National Cumulative Pollution Control Installations (Existing + Firm + Economic)



National Cumulative Pollution Control Retrofit Installations

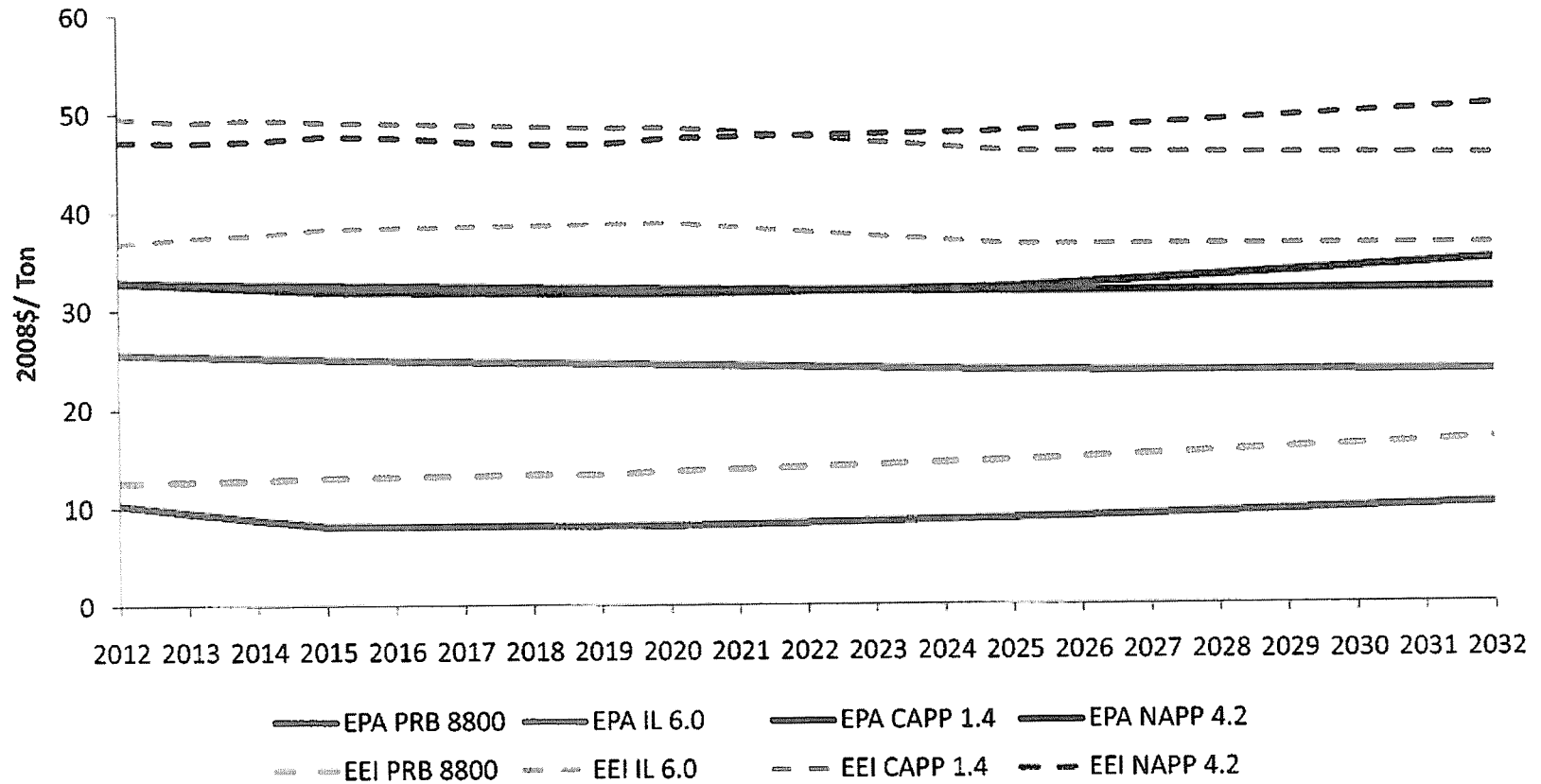


NATIONAL RESULTS COMPARISON

Minemouth Coal Prices



Minemouth Coal Prices

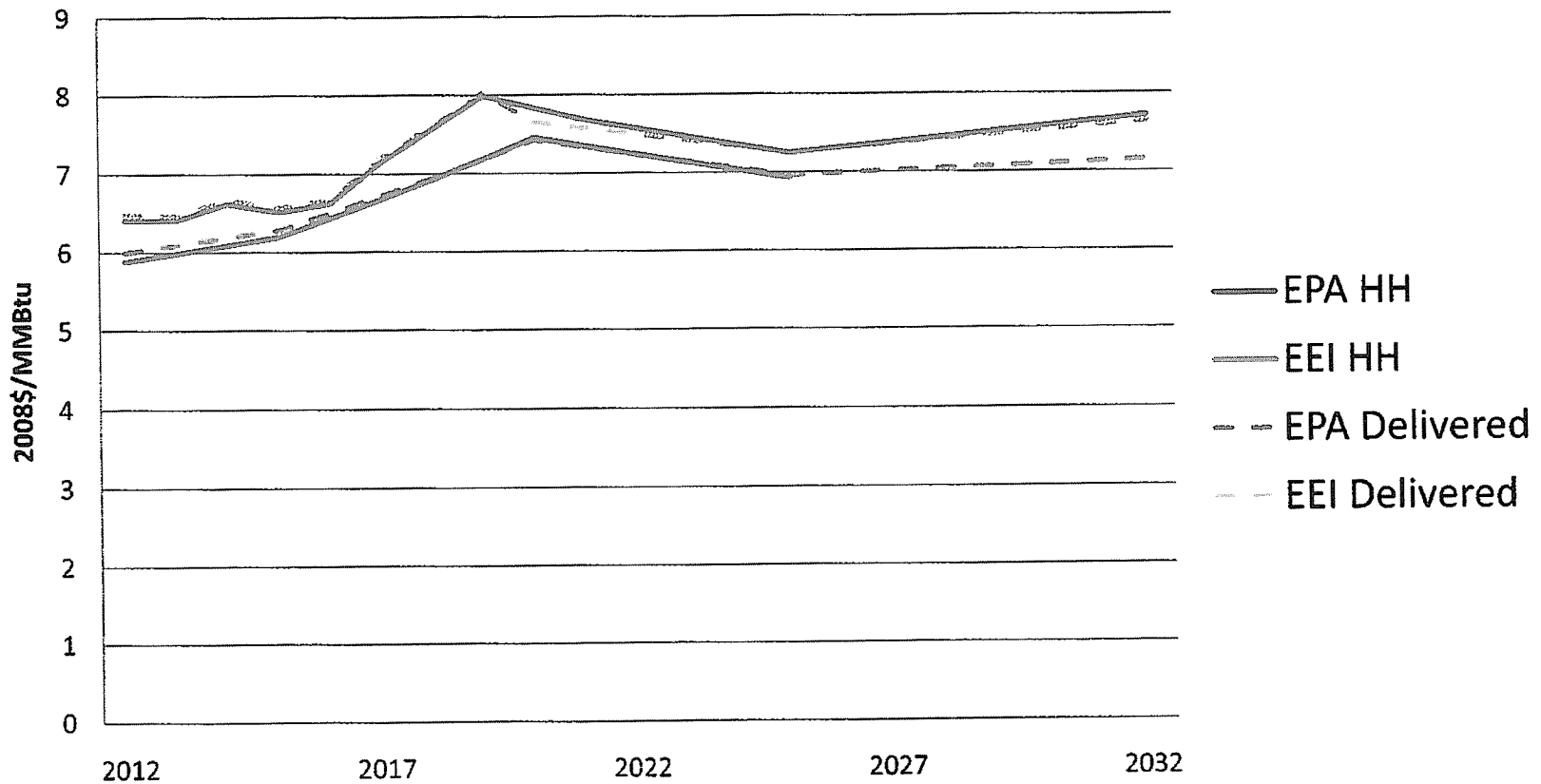


NATIONAL RESULTS COMPARISON

Henry Hub and Delivered Natural Gas Prices



Henry Hub and Delivered Natural Gas Prices

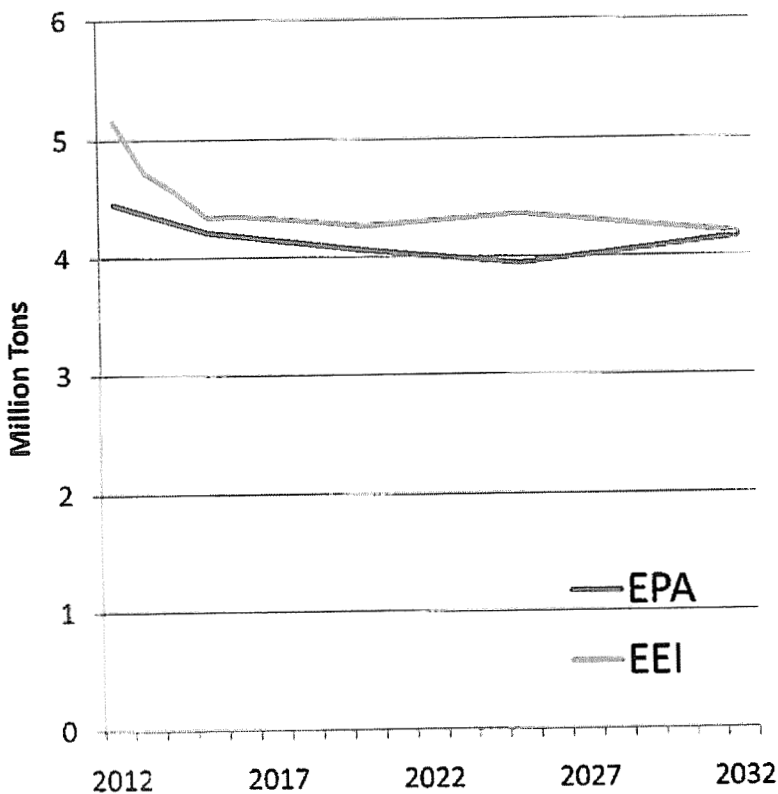


NATIONAL RESULTS COMPARISON

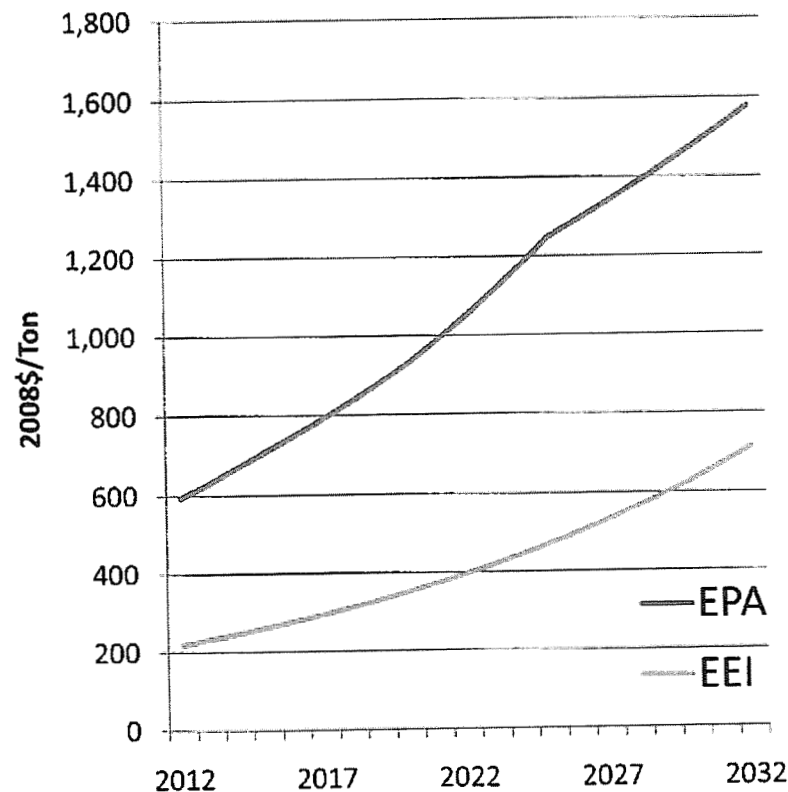
SO₂ Allowance Prices and Emissions



SO₂ Emissions



SO₂ Allowance Price



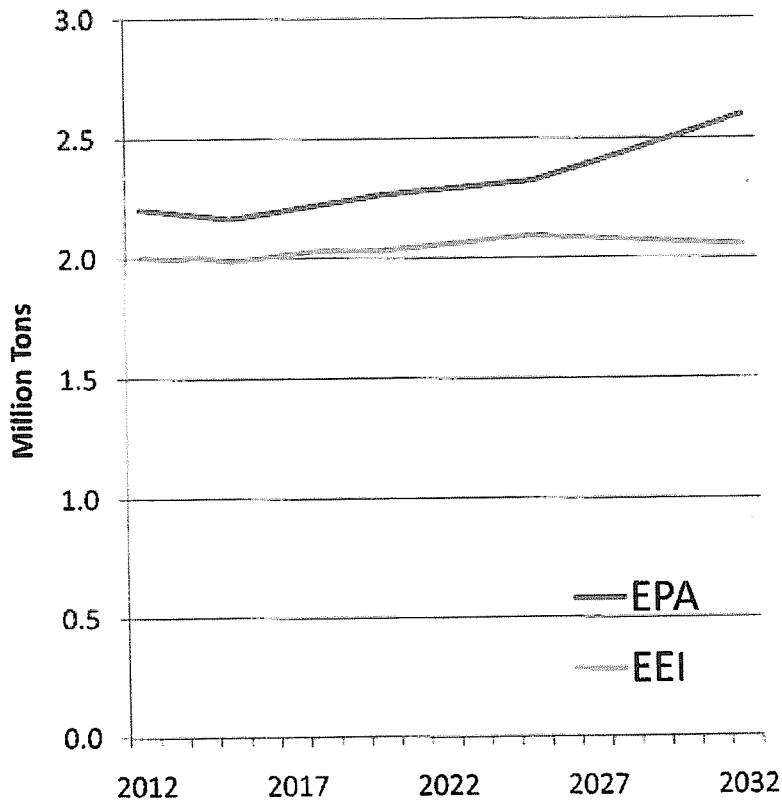
Note: The SO₂ price is the \$/ton price for units in a CAIR affected state. The \$/allowance prices can be derived by dividing by 2 in 2010-2014 and 2.86 in 2015 and beyond.

NATIONAL RESULTS COMPARISON

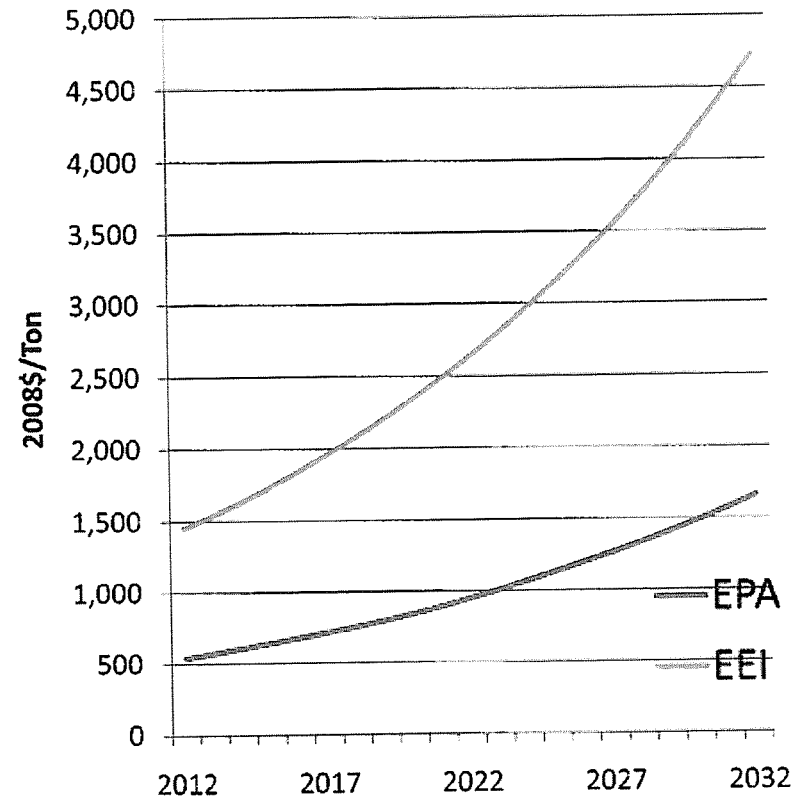
NO_x Allowance Prices and Emissions



National NO_x Emissions



CAIR Annual NO_x Allowance Price

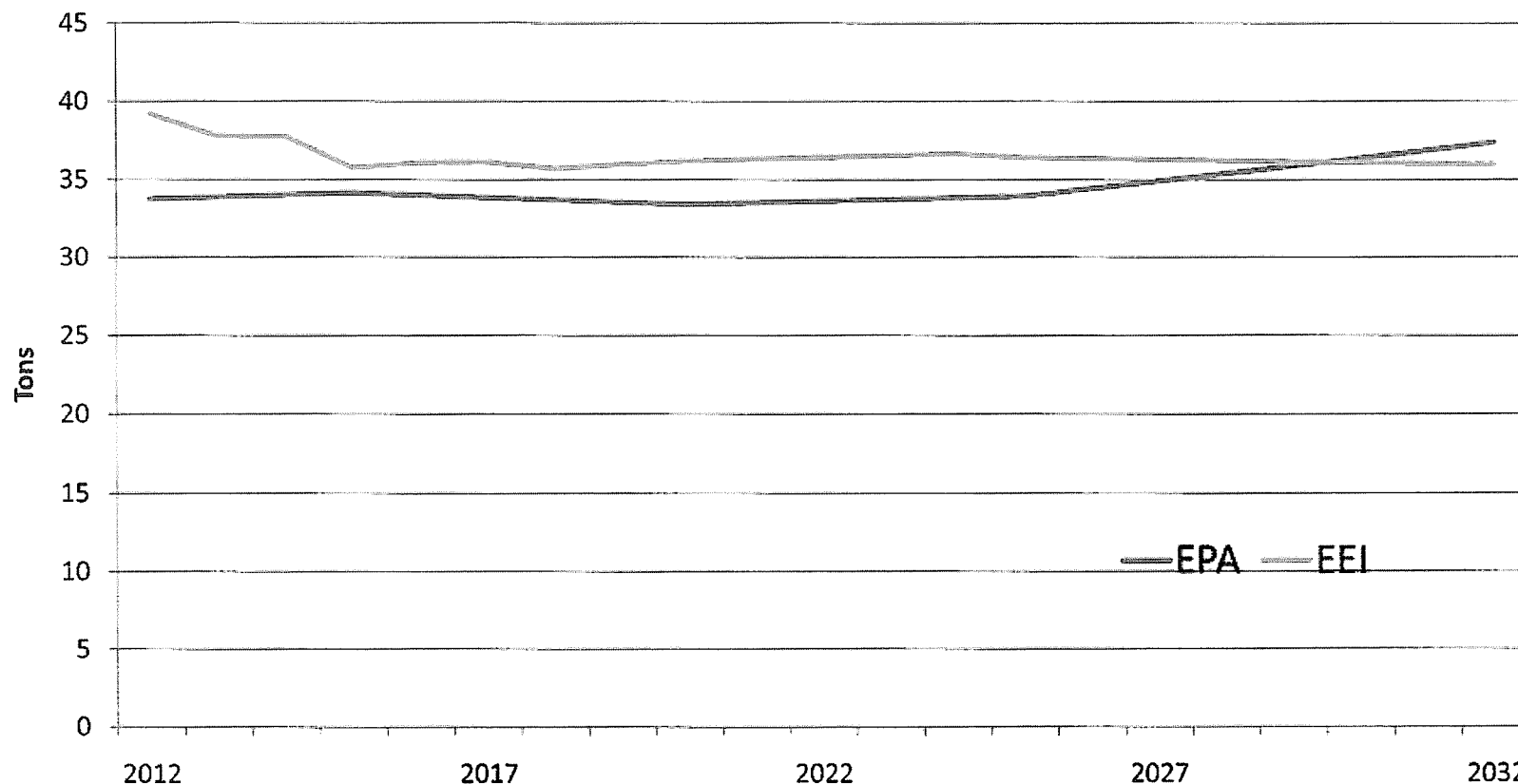


NATIONAL RESULTS COMPARISON

National Mercury Emissions



National Mercury Emissions

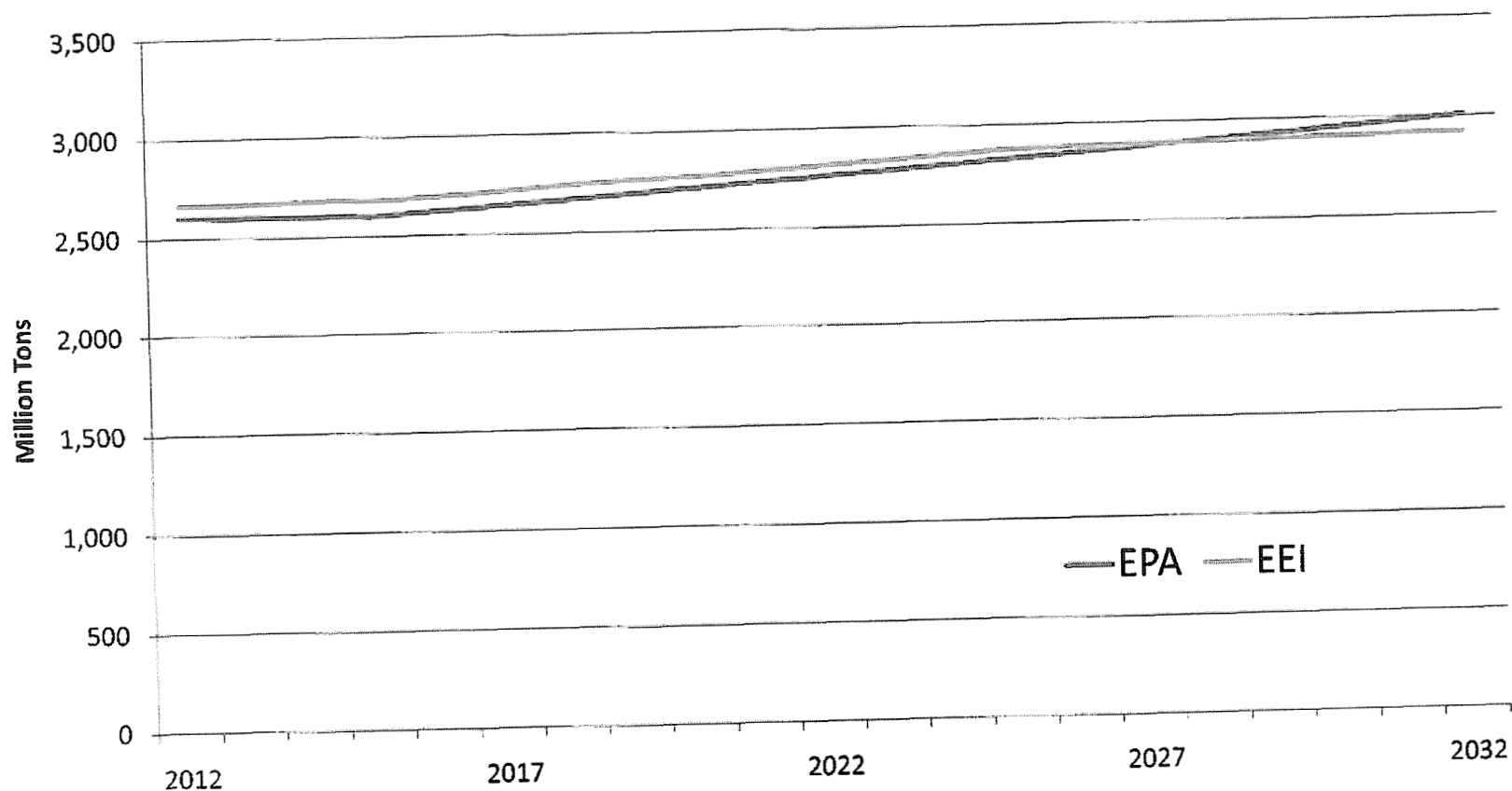


NATIONAL RESULTS COMPARISON

National CO₂ Emissions



National CO₂ Emissions





EEl Scenario Results

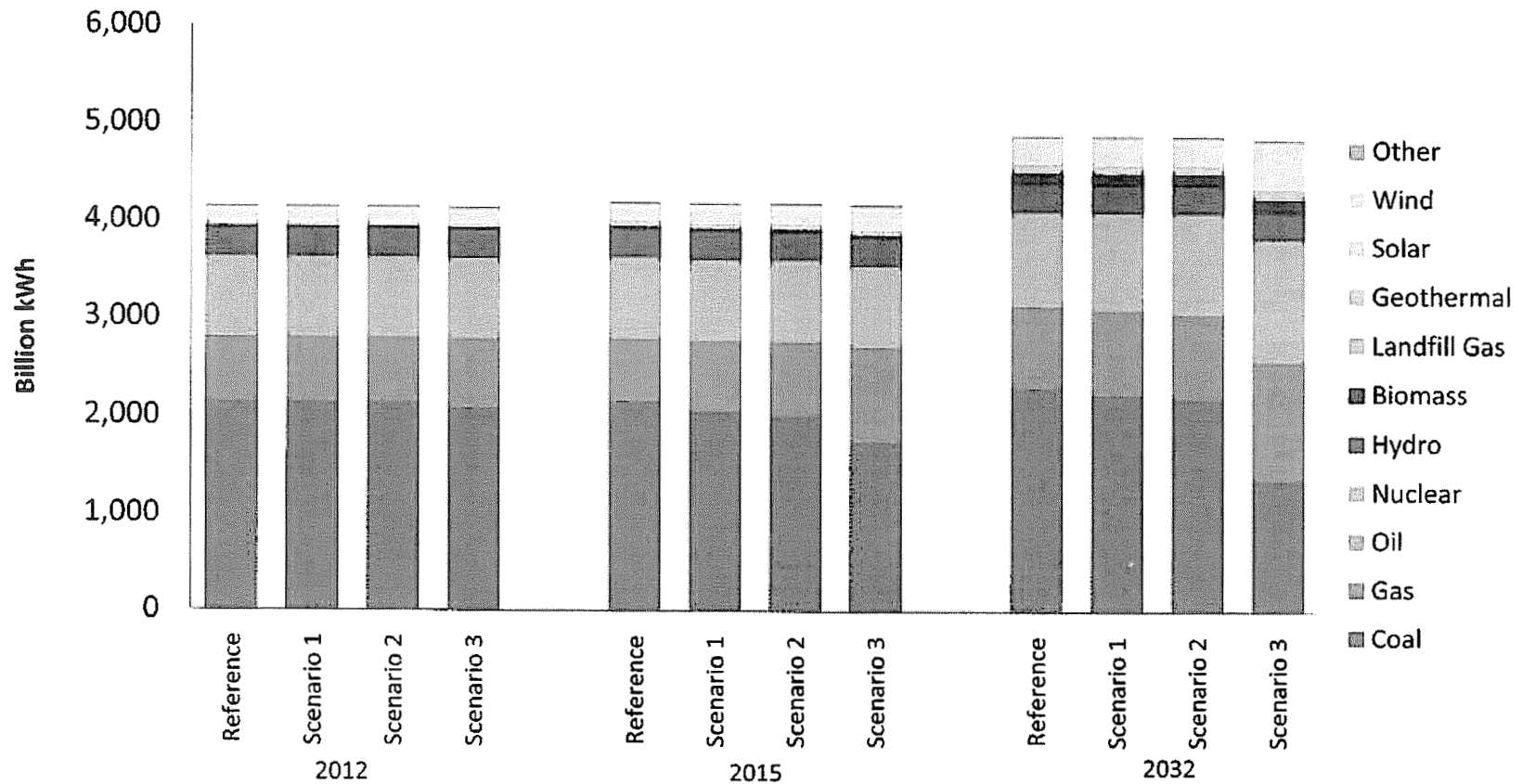
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NATIONAL RESULTS COMPARISON

National Generation By Type



National Generation



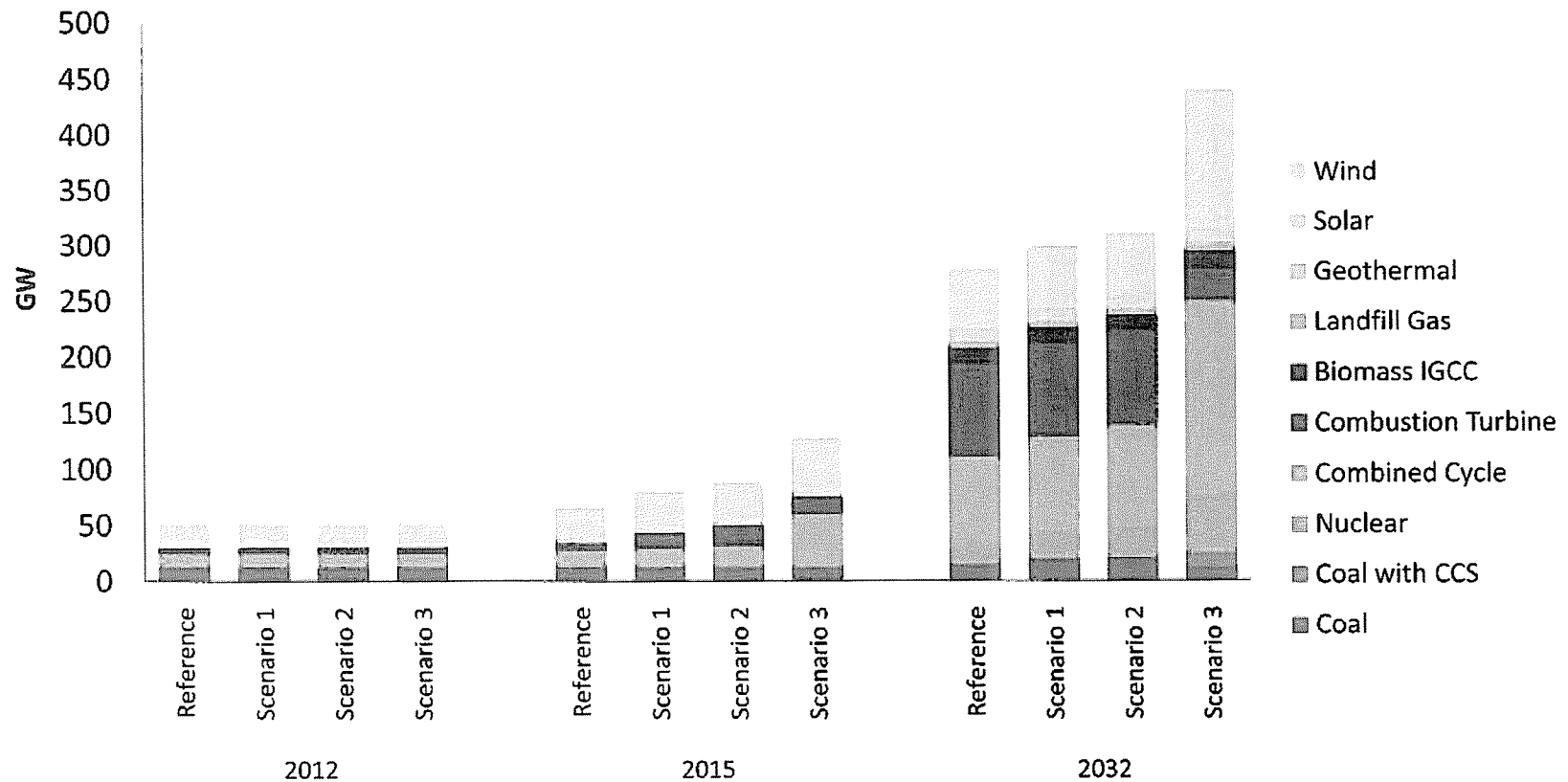
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NATIONAL RESULTS COMPARISON

National Cumulative Capacity Additions by Scenario (Firm + Economic)



National Capacity Additions

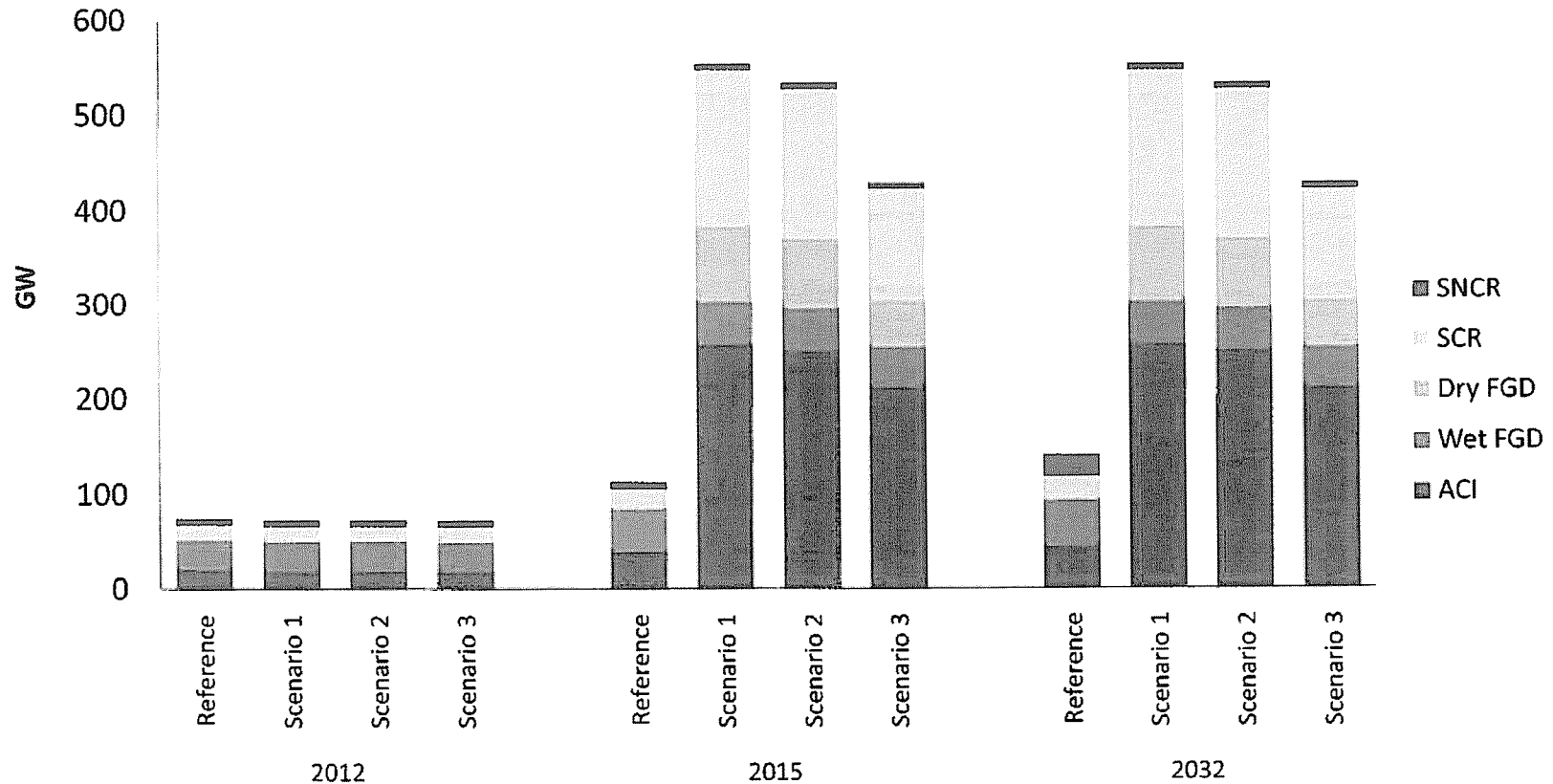


NATIONAL RESULTS COMPARISON

National Cumulative Pollution Control Installations by Scenario (Firm + Economic)



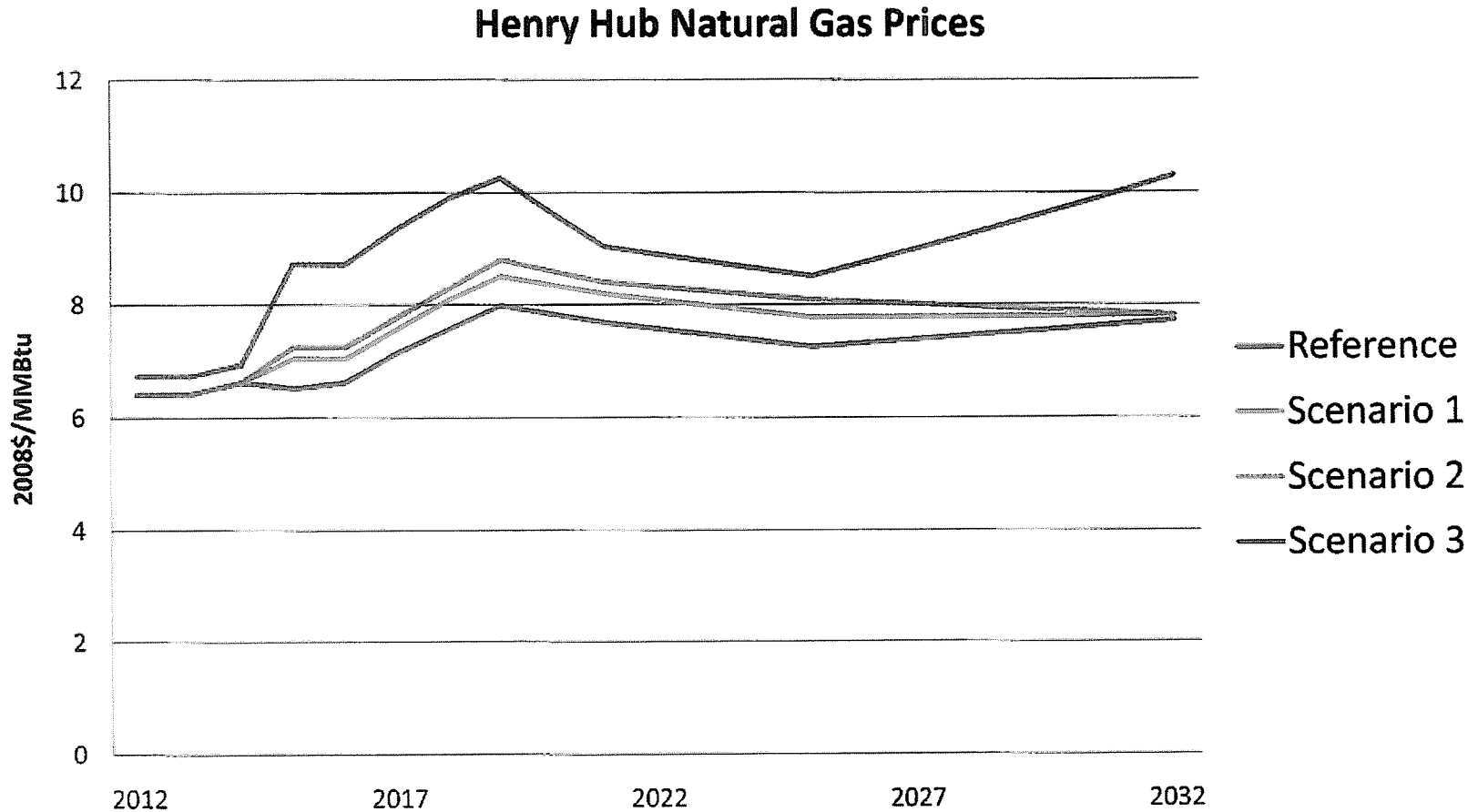
National Cumulative Pollution Control Installations



Note: Units may install more than one control and their capacity will be reported separately for each control.

NATIONAL RESULTS COMPARISON

Henry Hub Natural Gas Prices

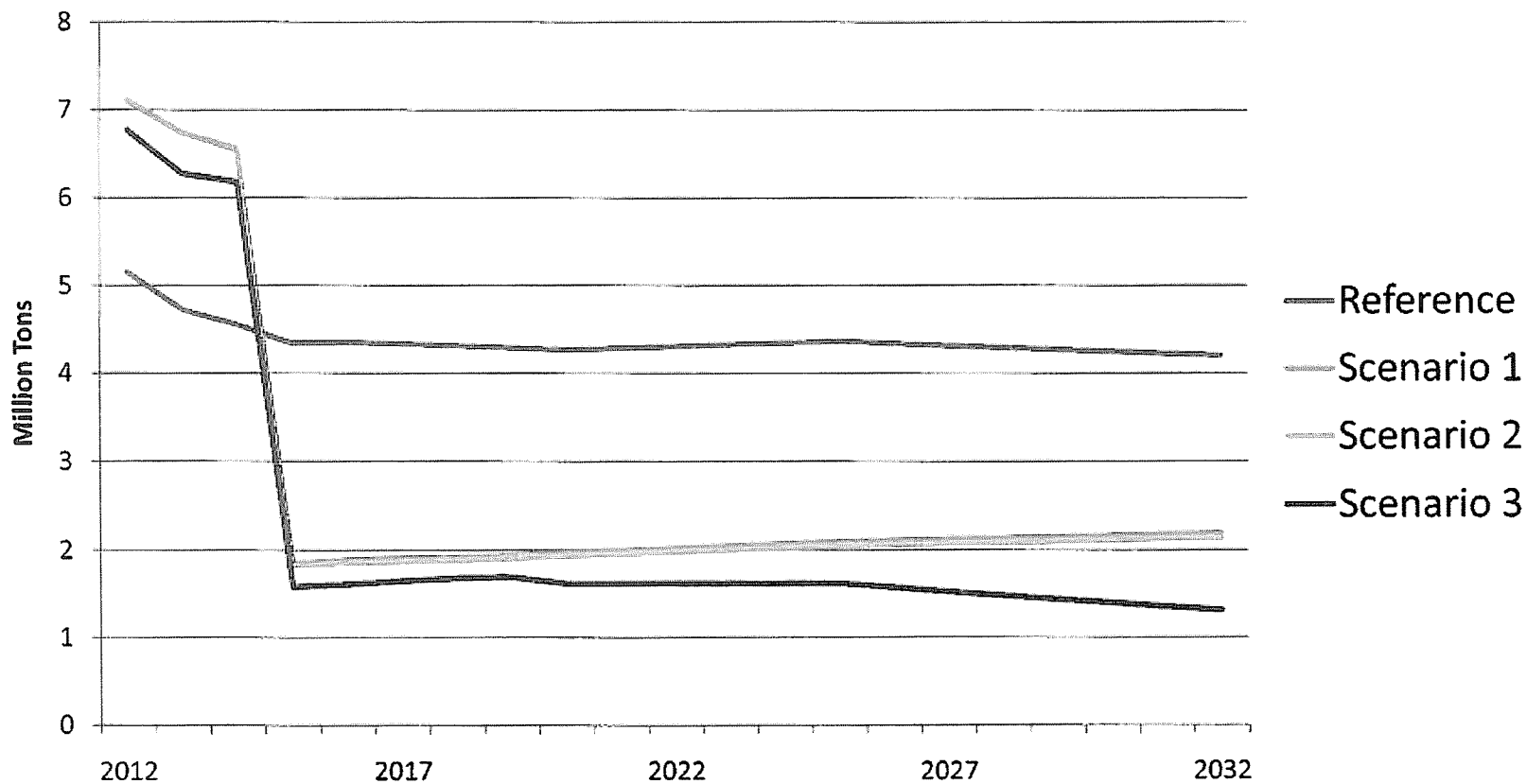


NATIONAL RESULTS COMPARISON

SO₂ Emissions



National SO₂ Emissions

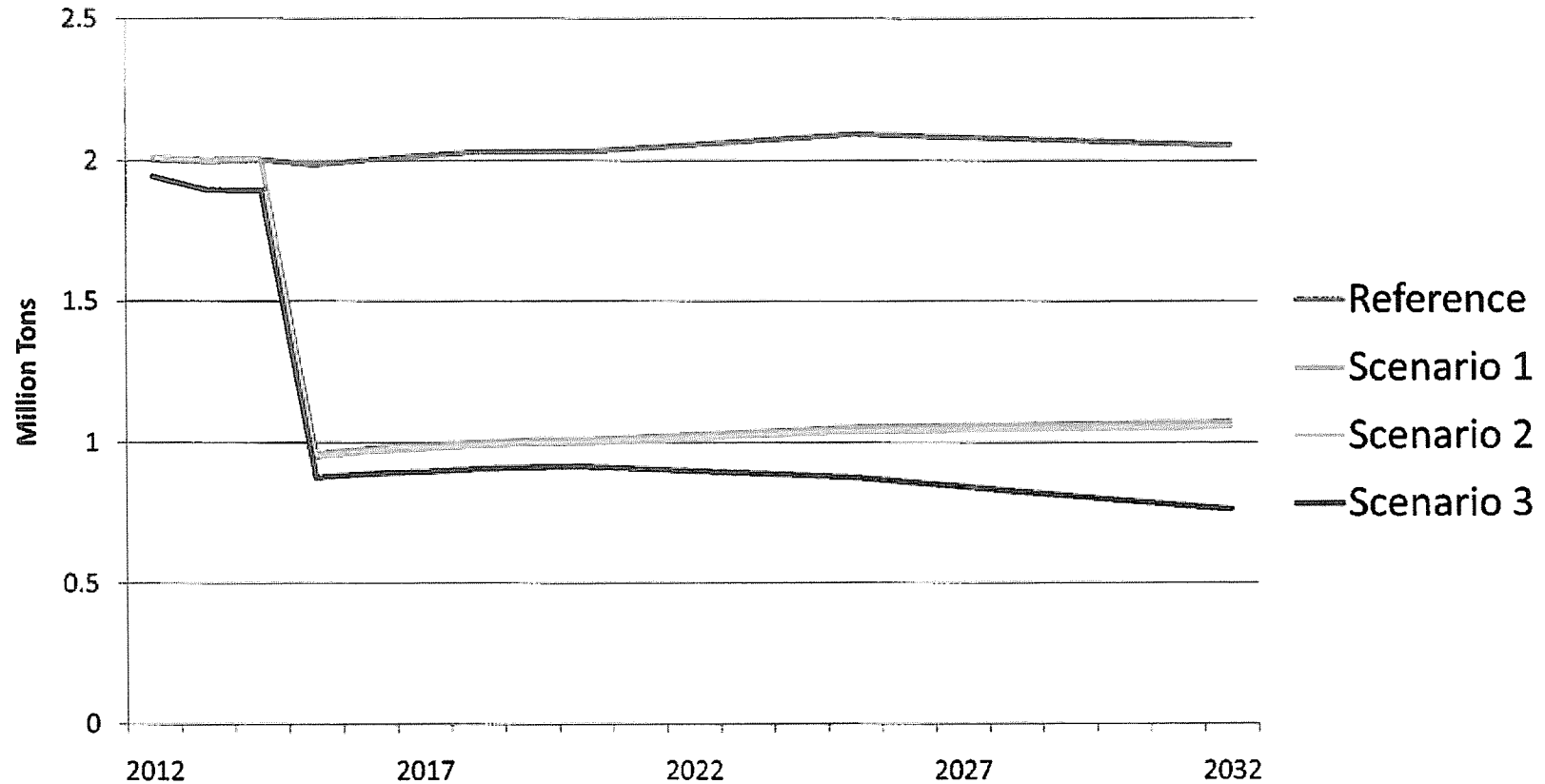


NATIONAL RESULTS COMPARISON

NO_x Emissions



National NO_x Emissions

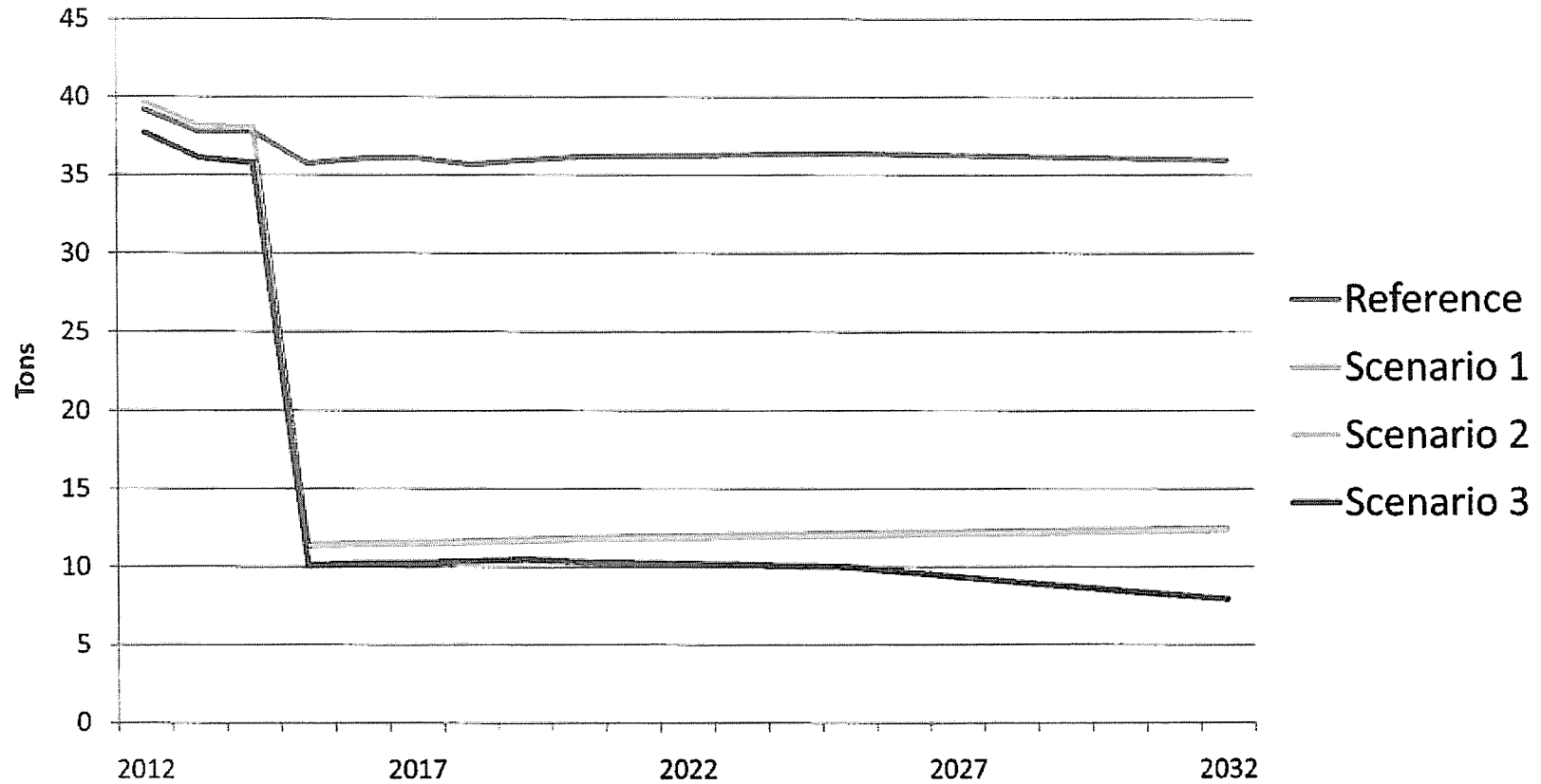


NATIONAL RESULTS COMPARISON

National Mercury Emissions



National Mercury Emissions

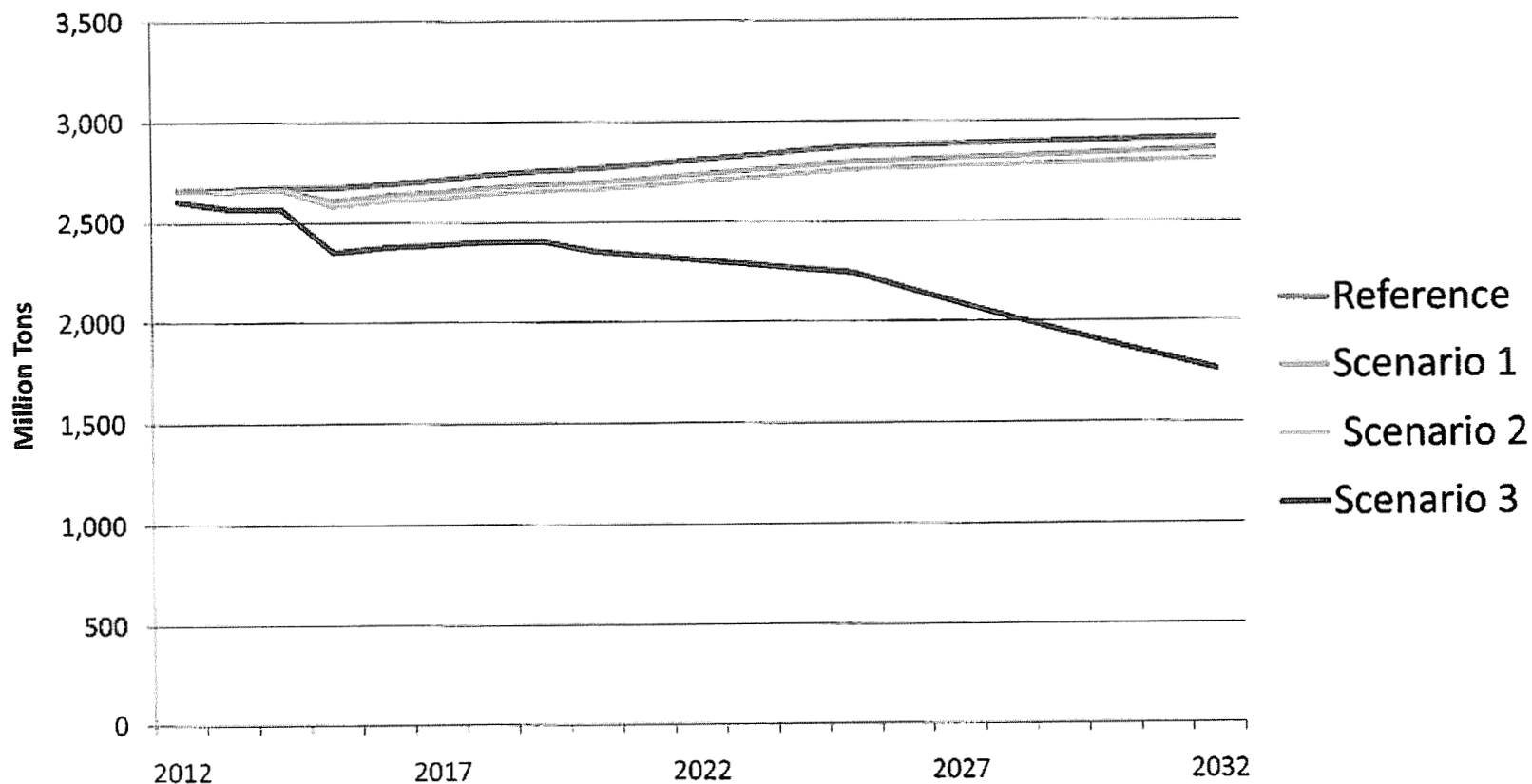


NATIONAL RESULTS COMPARISON

National CO₂ Emissions



National CO₂ Emissions



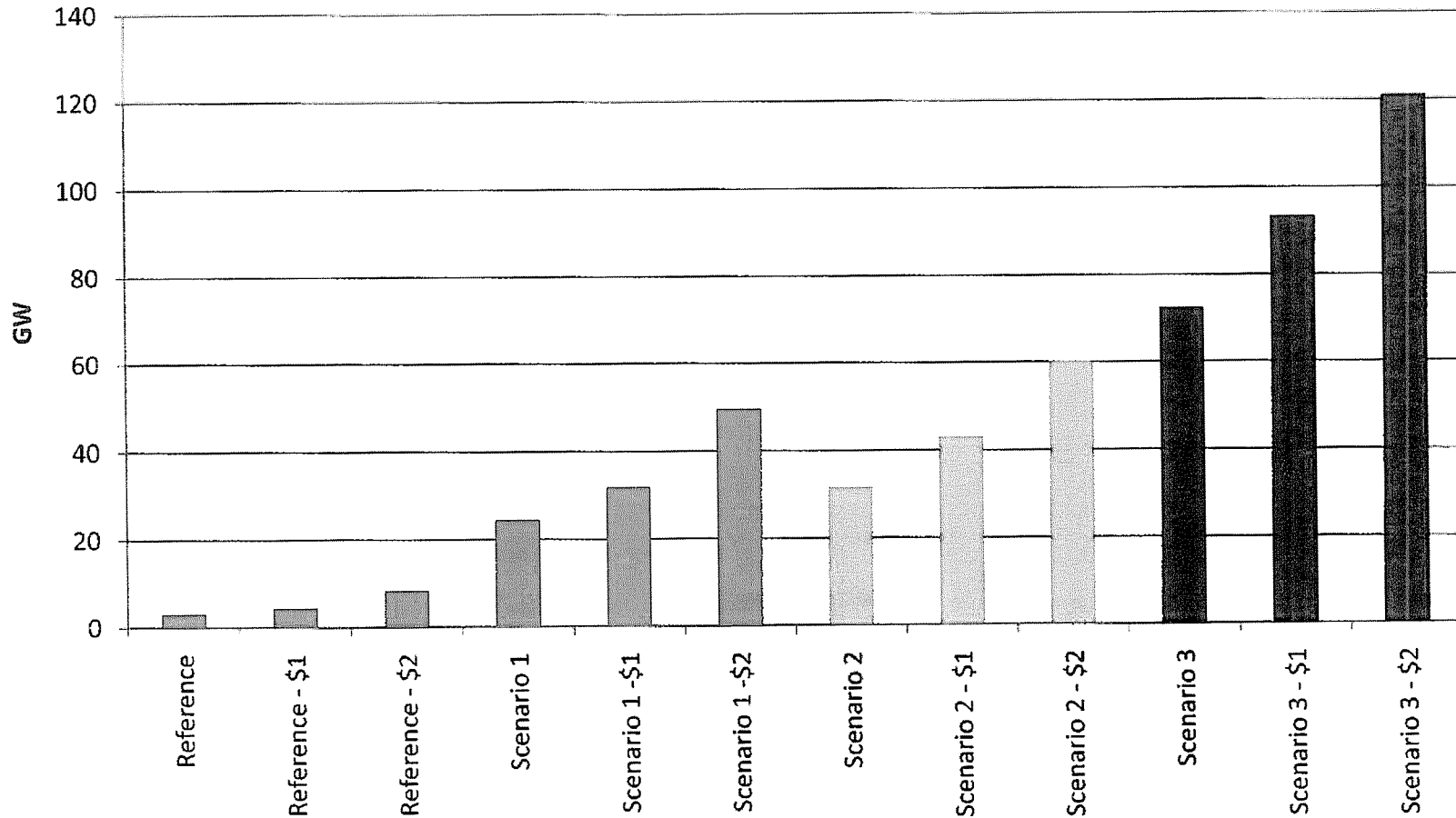


Retirements

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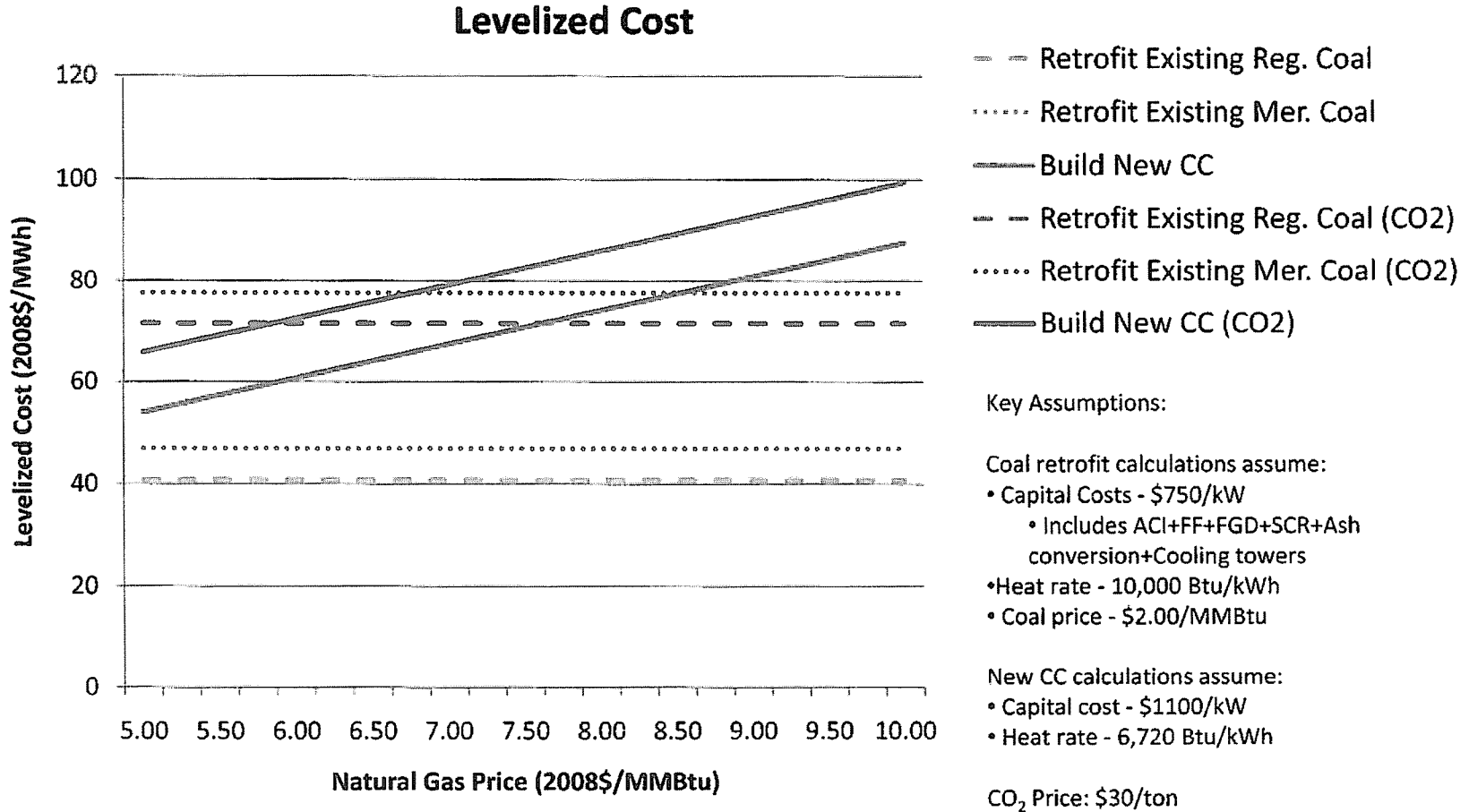
RETIREMENTS

Gas Price Sensitivities - Cumulative Coal Retirements through 2015



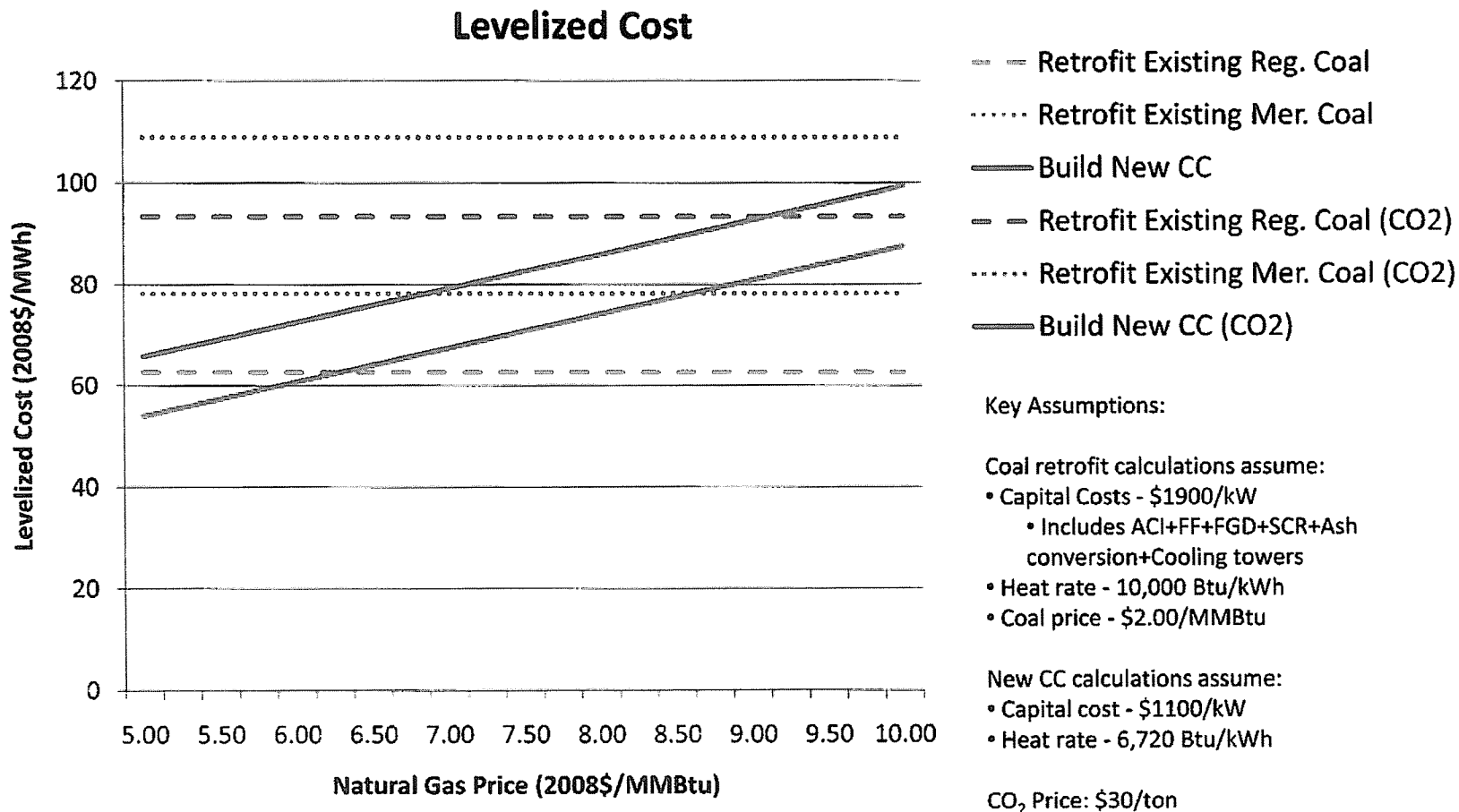
RETIREMENTS

Natural Gas Prices Impact the Economics of Retrofitting Existing Coal vs. Building New – Avg. Compliance Cost



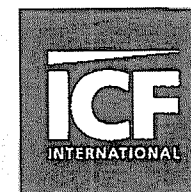
RETIREMENTS

Natural Gas Prices Impact the Economics of Retrofitting Existing Coal vs. Building New – High Compliance Cost

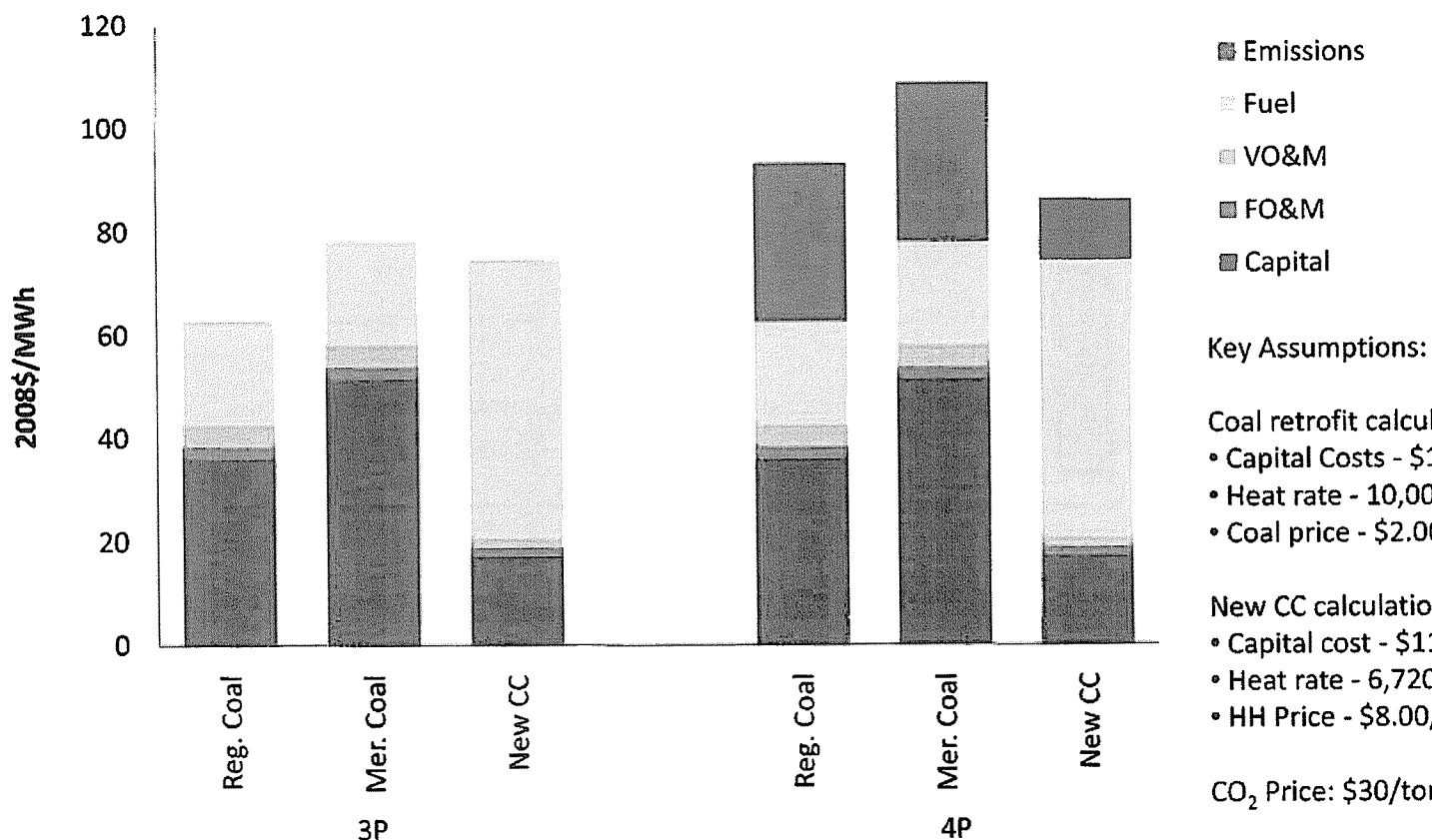


RETIREMENTS

Coal vs. CC Levelized Cost Components



Levelized Cost Components

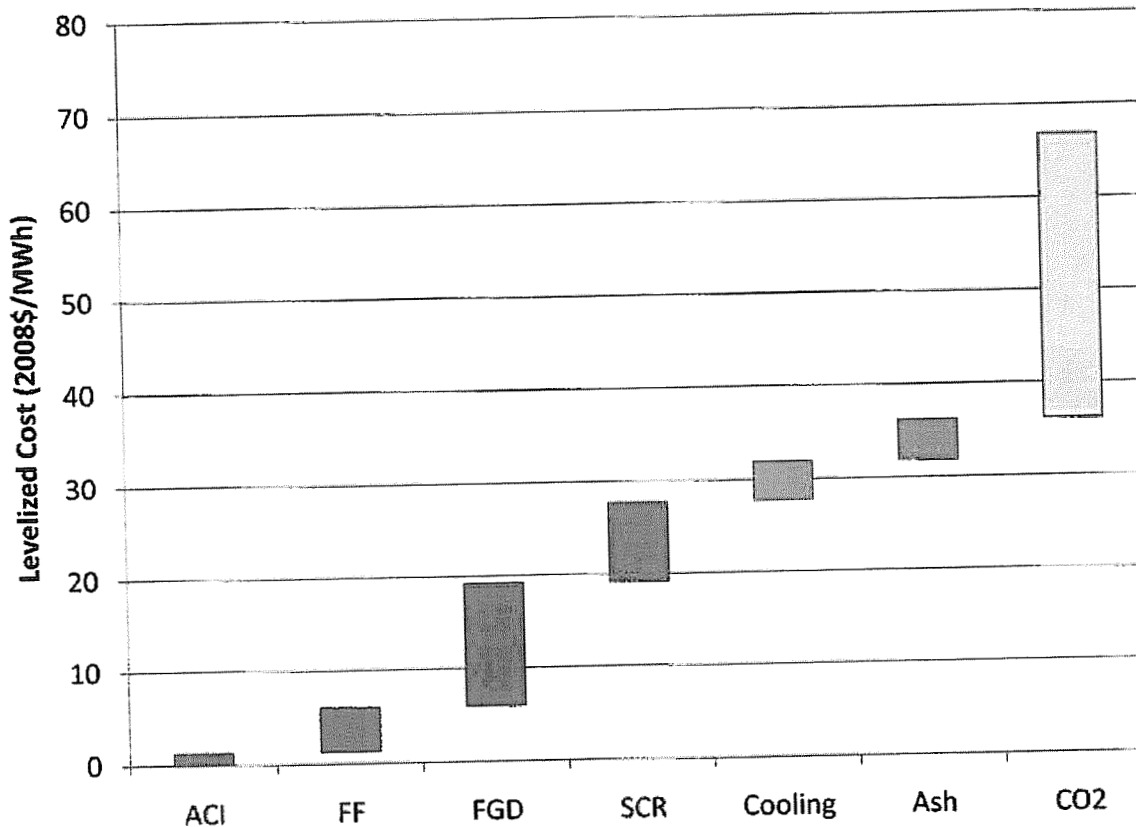


RETIREMENTS

Levelized Regulated Coal Unit Compliance Costs



Levelized Cost

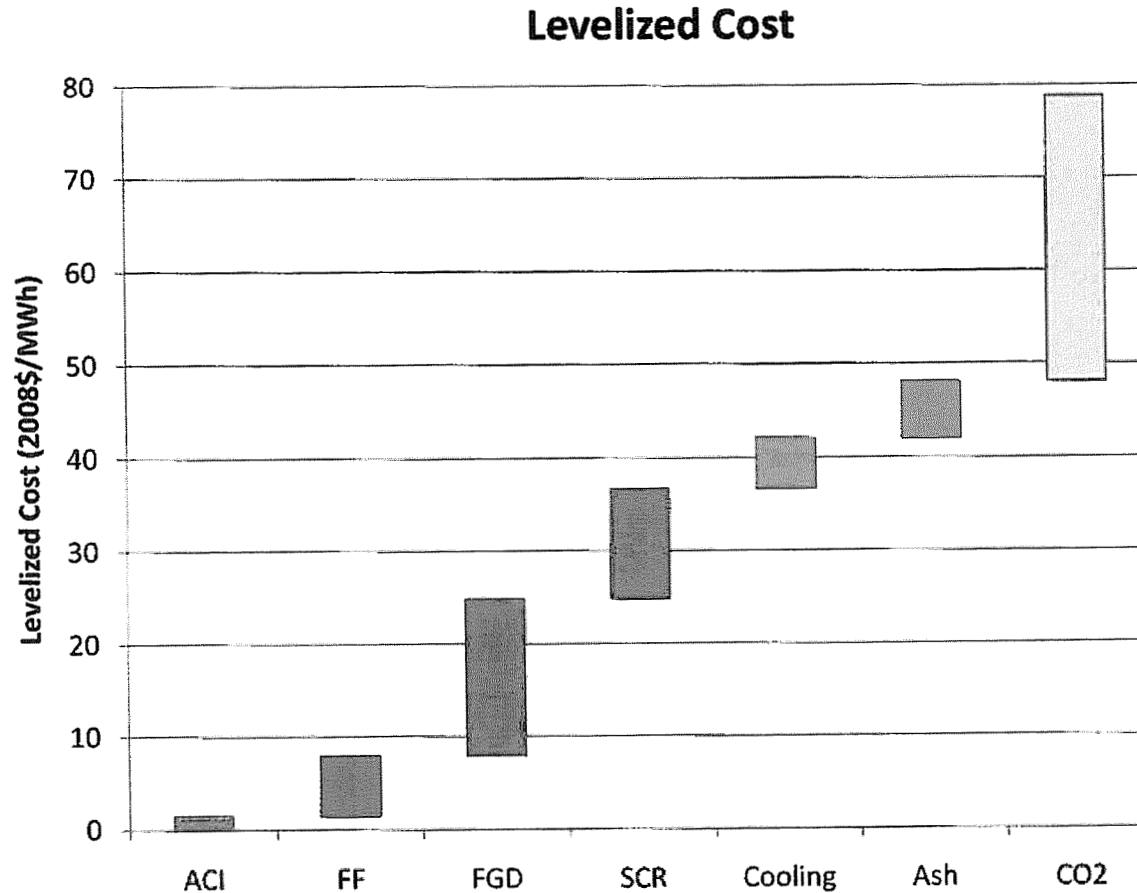


Key Assumptions:

- Capacity – 500 MW
- Heat Rate – 10,000 Btu/kWh
- CO₂ Price - \$30/ton
- Regulated Unit

RETIREMENTS

Levelized Merchant Coal Unit Compliance Costs



- Key Assumptions:**
- Capacity – 500 MW
 - Heat Rate – 10,000 Btu/kWh
 - CO₂ Price - \$30/ton
 - Merchant Unit



Appendix

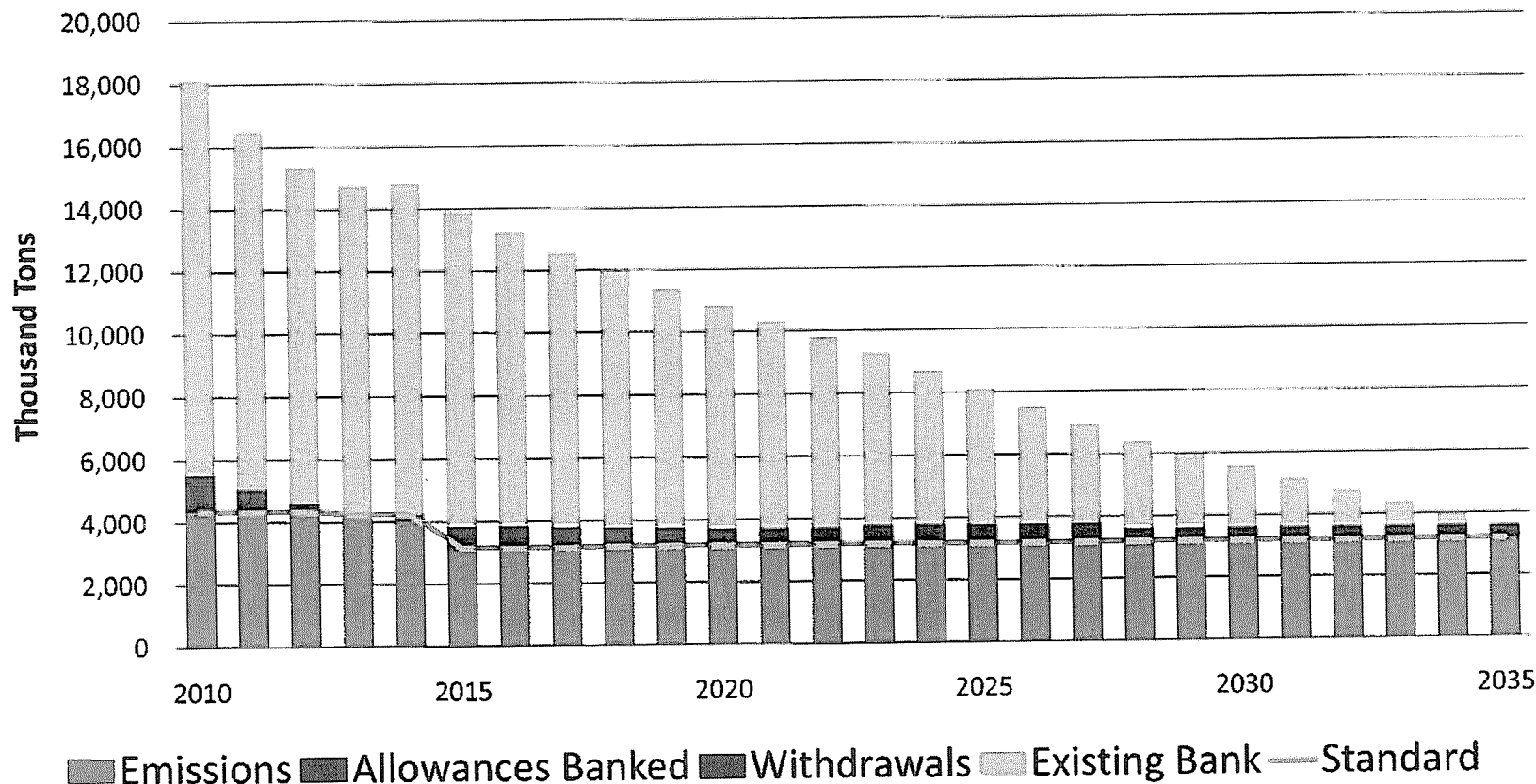
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NATIONAL RESULTS COMPARISON

Reference Case SO₂ Banking and Withdrawals



SO₂ Banking and Withdrawals

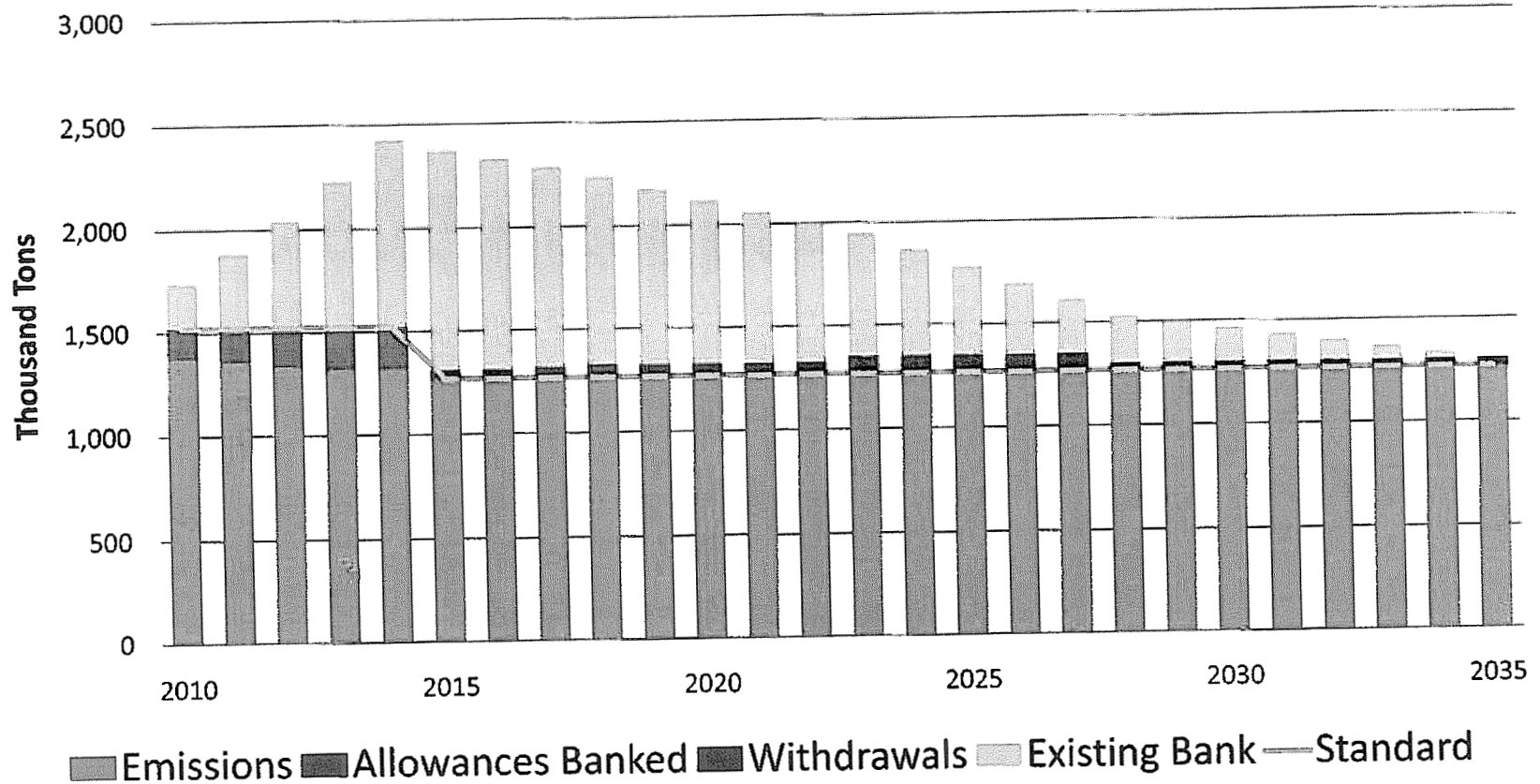


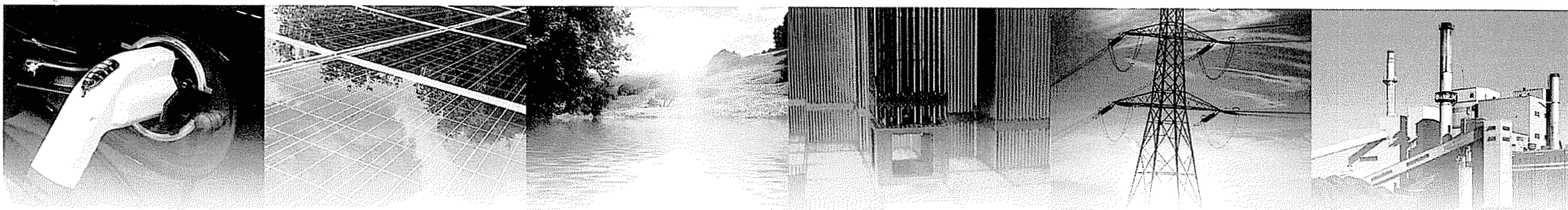
NATIONAL RESULTS COMPARISON

Reference Case NO_x Banking and Withdrawals



NO_x Banking and Withdrawals





Analysis of Current and Pending EPA Regulations on the U.S. Electric Sector

May 31, 2012

PRISM 2.0: Regional Energy and Economic Model Development and Initial Application

Develop a new energy-economy model of the U.S. with a special focus on the electric power sector:

U.S. Regional Economy, Greenhouse Gas, and Energy (US-REGEN) model (completed)

Develop appropriate sectoral data and detail in electric power production and in energy demand, taking into account regional differences in generating costs and resources, especially for renewables, carbon capture and storage, and land use

Perform detailed analysis:

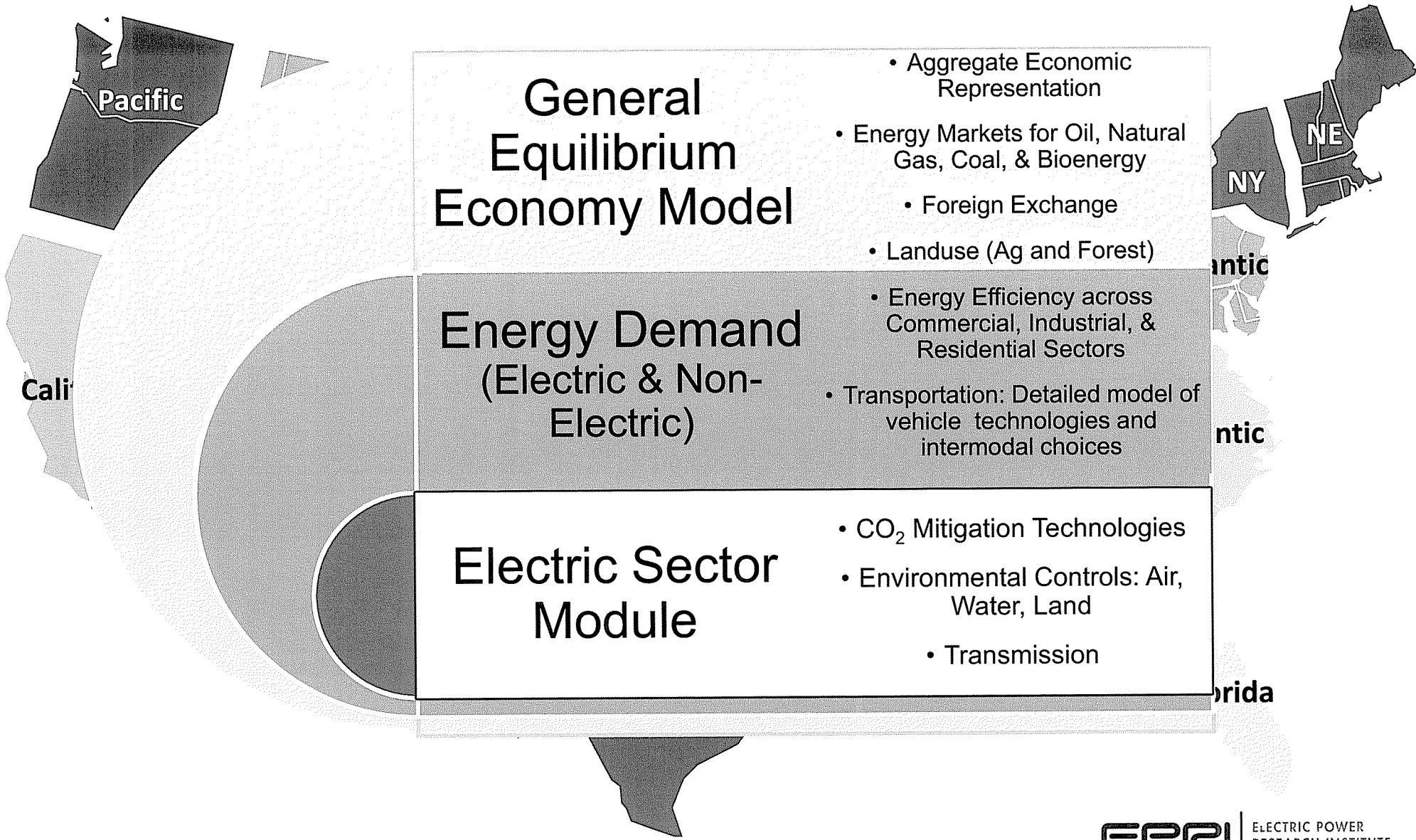
1st Phase – Current and Pending Environmental Controls (completed)

2nd Phase – Clean Energy Standard proposals (Summer 2012)

3rd Phase – preliminary analysis on the Impact of CO₂ Constraints on the Electric Power Sector (Fall 2012)

Communicate results at on-site member briefings and via public reports and presentations

US-REGEN Model Description



Key Messages

- The confluence of multiple environmental control requirements requiring retrofits on existing coal-fired power plants has significant implications for asset management and generation planning decisions, and substantial effects on electricity generation costs
- Decisions about whether to retrofit or retire existing coal-fired power plants are complex, with multiple uncertainties, interactions, and implications for electricity generators and the broader economy
- With phased compliance more time can facilitate testing and application of new and existing lower-cost technologies with significant savings, and with little change in overall emission reductions

Baseline Scenario

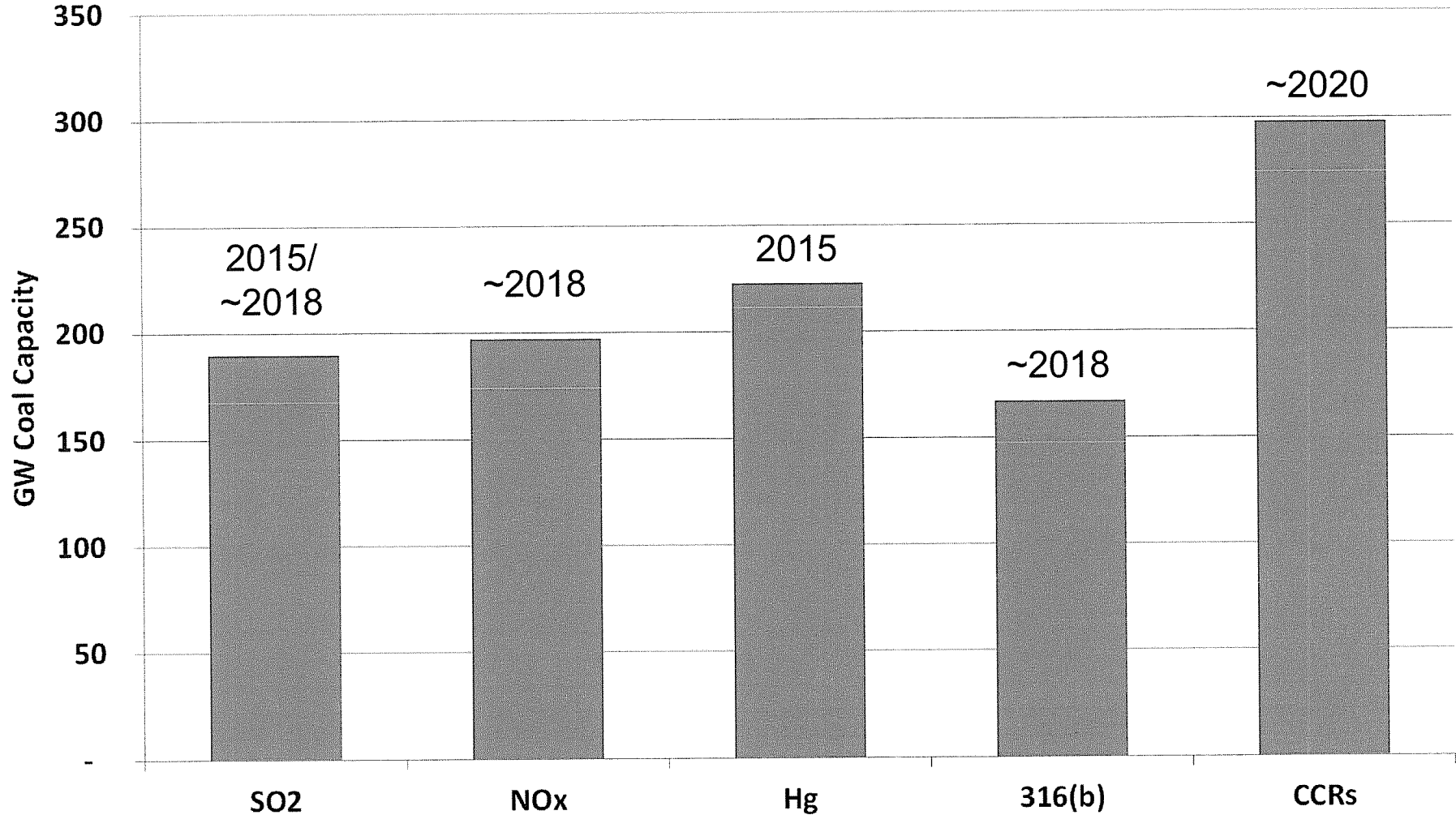
- Economic growth and energy supply and demand based on EIA's Annual Energy Outlook 2011
- Economic and electric power unit data based on 2009 and 2010 datasets, respectively, 2010 is the model's base year
- Electric sector policies, and assumptions:
 - Include state RPS Programs
 - State (CA, RGGI) or federal (CAA) GHG regulations not included
 - Include Cross-State Air Pollution Rule (CSAPR) by 2015 Aims to Reduce SO₂ emissions by 73 percent and NOx emissions by 54 percent from 2005 levels. Final rule.
 - New coal additions limited to units currently under construction

Reference (Environmental Controls) Scenario

- Starting from the Baseline Scenario, then adding
- Electric Sector Policies
 - Mercury and Air Toxics Standard (MATs) Rule by 2015, more stringent SO₂, and SO₃ control by 2018) (Dry/wet scrubbing with increased particulate control)
 - Ozone and haze regulations by 2018 (Stringent NOx control with SCRs for all coal)
 - SO₂ NAAQS, haze regulations by 2018
 - Clean Water Act (CWA) 316(b) Controls by 2018 (closed-cycle cooling on facilities with intake flow > 125)
 - Coal Combustion Residuals (CCRs) Controls by 2020 (RCRA Subtitle D “non-hazardous”)

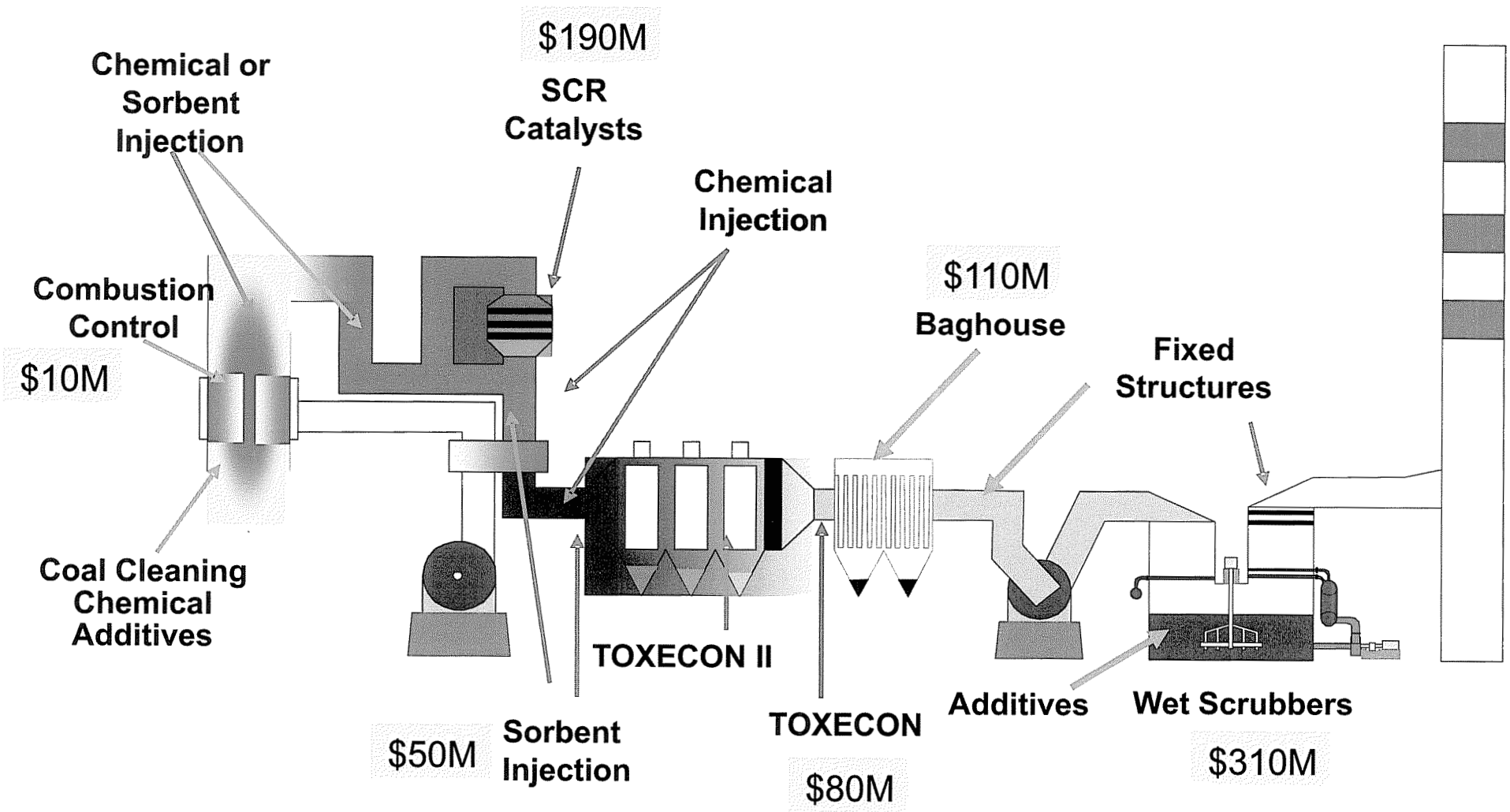
Hundreds of GW of Existing Coal Units Facing Multiple Compliance Obligations by 2015

Reference Case Capacity Requiring Retrofits



Controlling Emissions from Power Plants

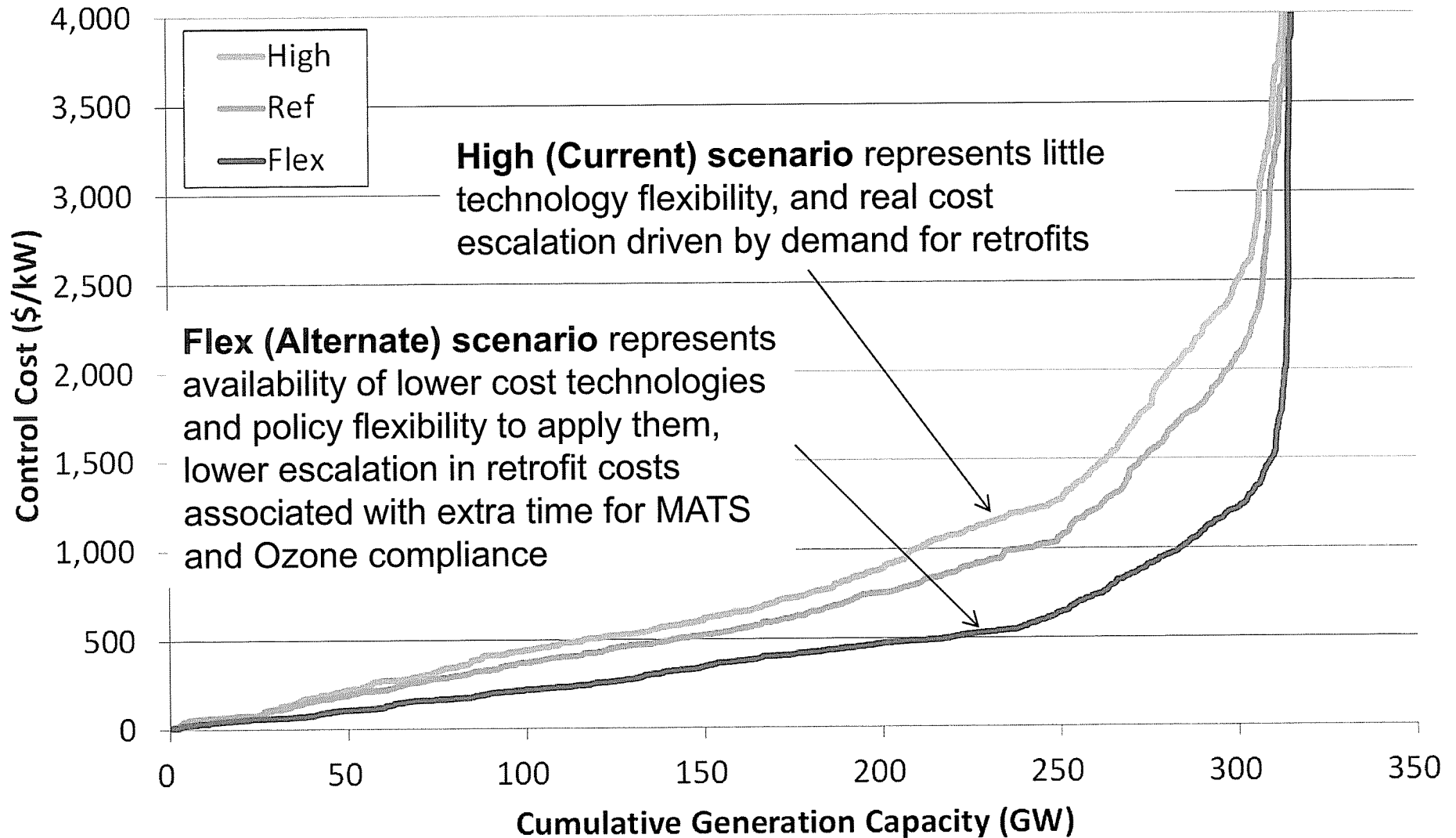
Example Costs – 400 MW, Bituminous Coal



Integrated Analysis of Retrofit Decision in Light of Full Set of Air (non-GHG), Water, Ash Policies

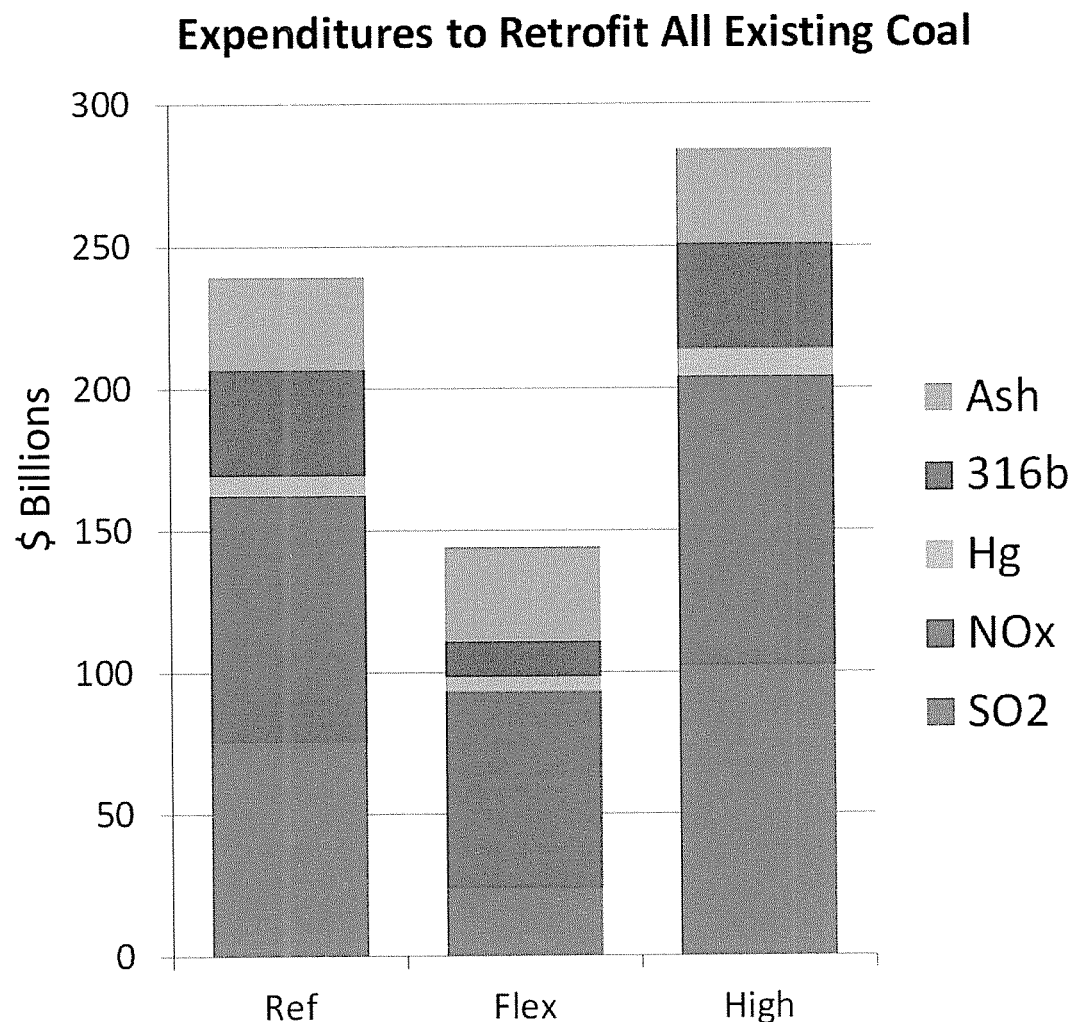
- Full Control policy defined as stringent control of SO₂, NO_x, Hg, entrainment (316b), and coal combustion residuals (CCRs) but not recent proposed CO₂ performance standards.
- Assume asset owner make single retrofit-retire decision in 2015 based on full mix of requirements.
- Retrofit cost scenarios reflect broad cost and policy uncertainty:
 - Ref uses reference costs
 - Flex has lower costs, less stringent aquatic entrainment controls, less retrofit cost escalation, and additional time for compliance for SO₂ and NO_x to allow for newer control technology options
 - High costs with less policy flexibility to choose low-cost technologies and higher retrofit cost escalation to meet stringent deadlines

Scenarios Represent Uncertainty Ranges in Costs for Technology, Policy, and Escalation



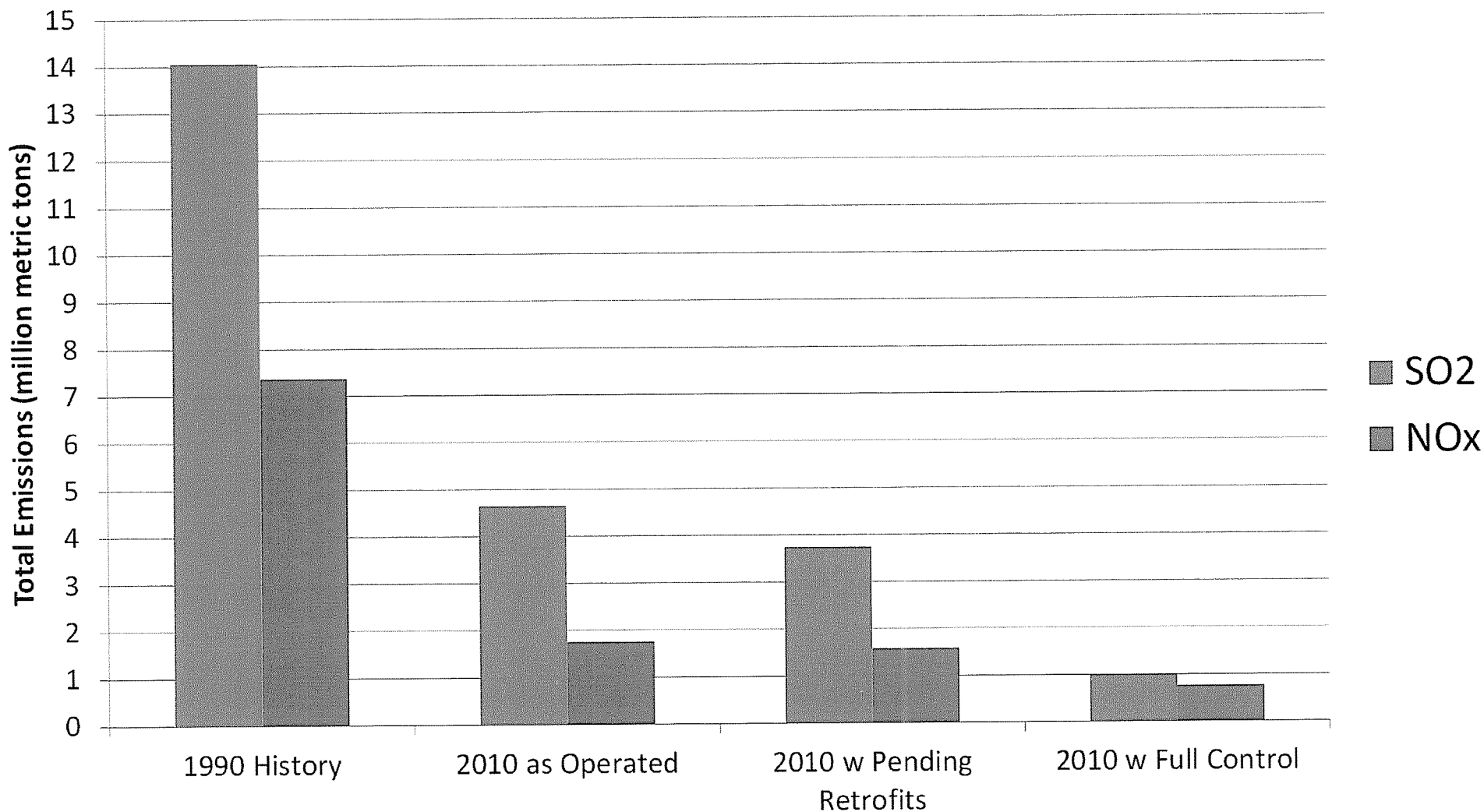
Cost to Retrofit Entire Fleet Uncertain but Several \$100 Billions

- Chart show investment cost to retrofit entire existing fleet (sum of unit costs input to model)
- Existing coal
 - 316 GW
 - 40% of electric supply
 - 1,100 generating units
 - Diverse size/age mix
- Age, size, and market impact retrofit/retire decisions
- Many units poor candidates for environmental retrofits
- ~ 40 GW of coal retirements announced to date

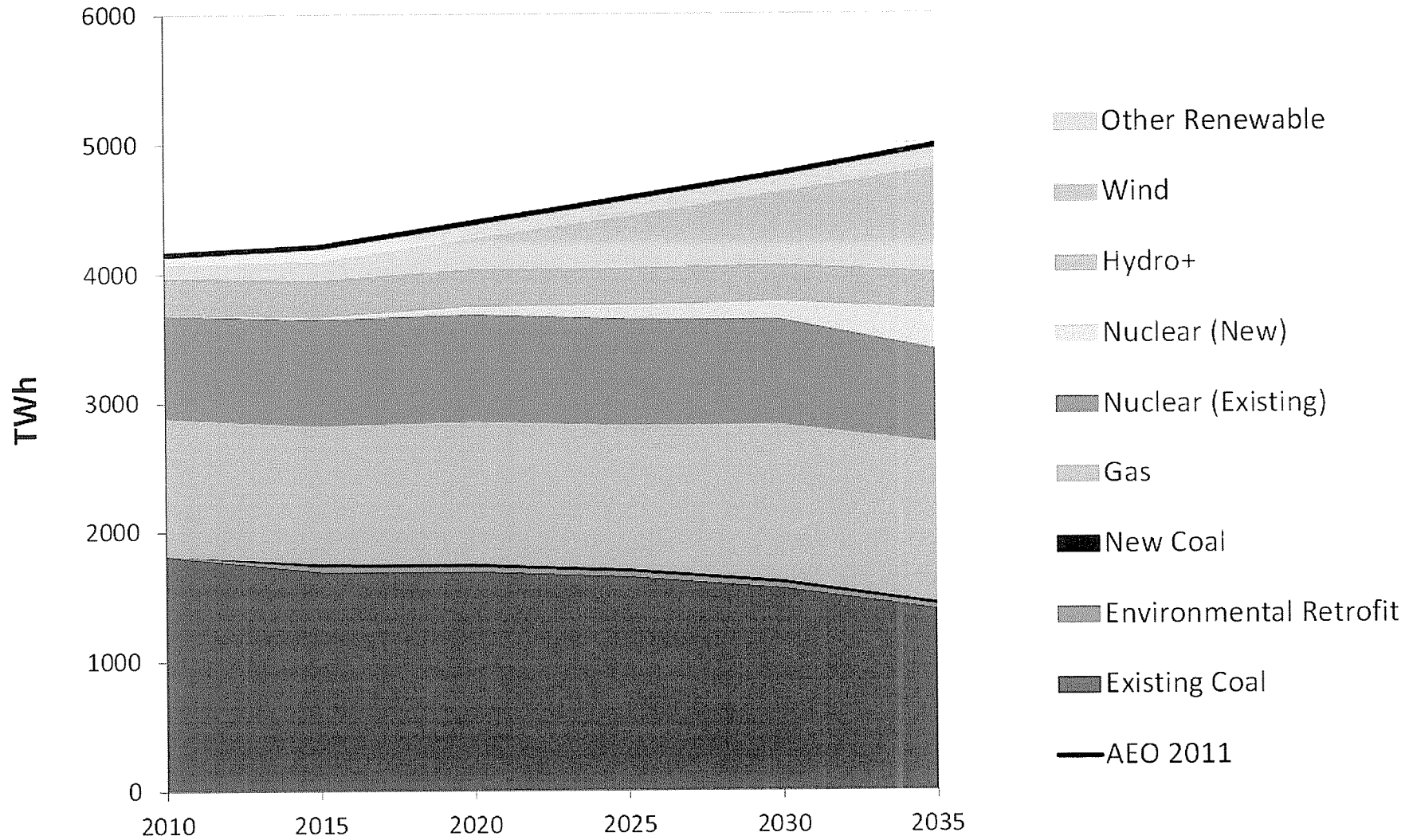


Comparisons Show How Retrofits Will Cut Emissions

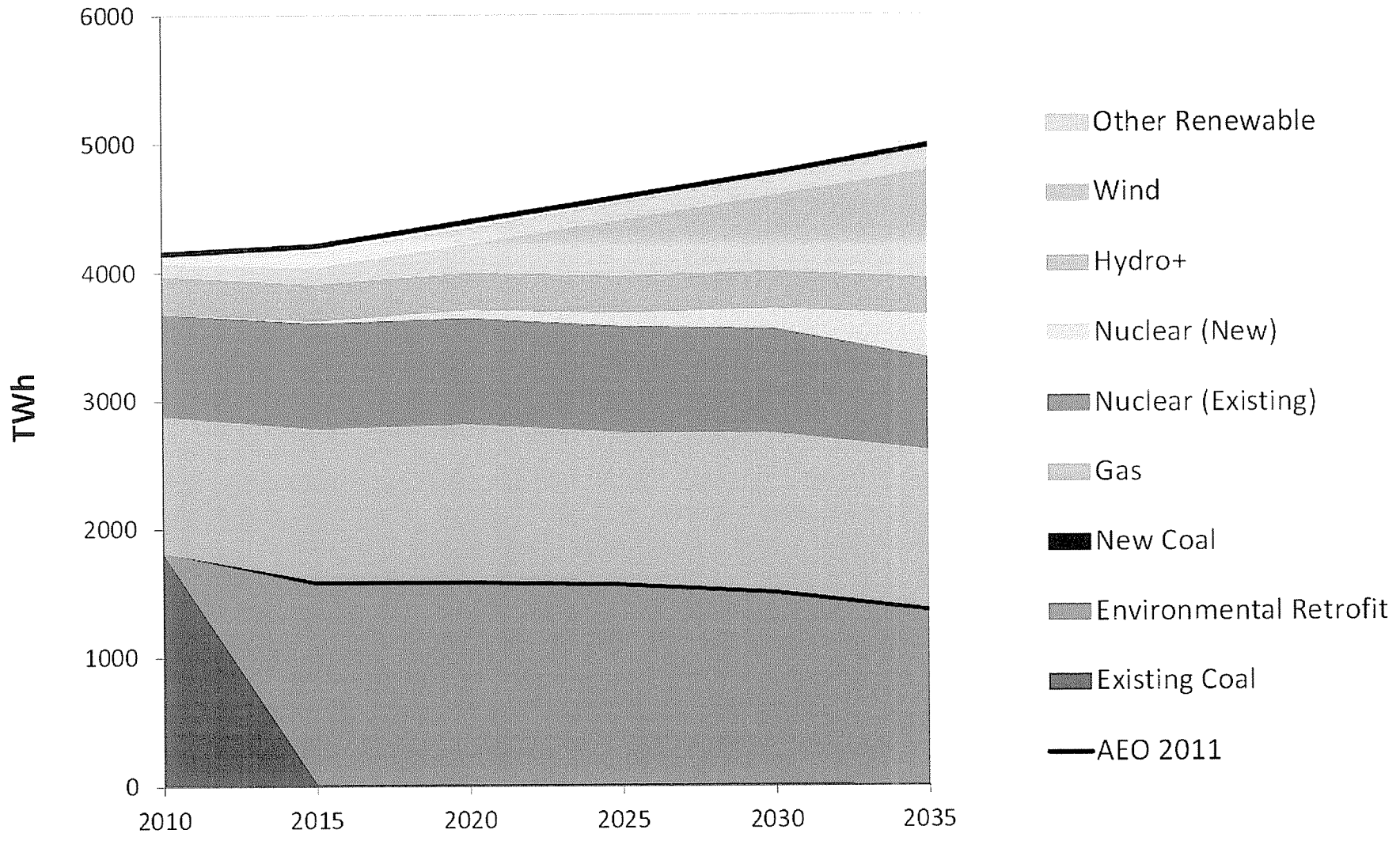
Comparison of Emissions by Level of Retrofits - High Scenario



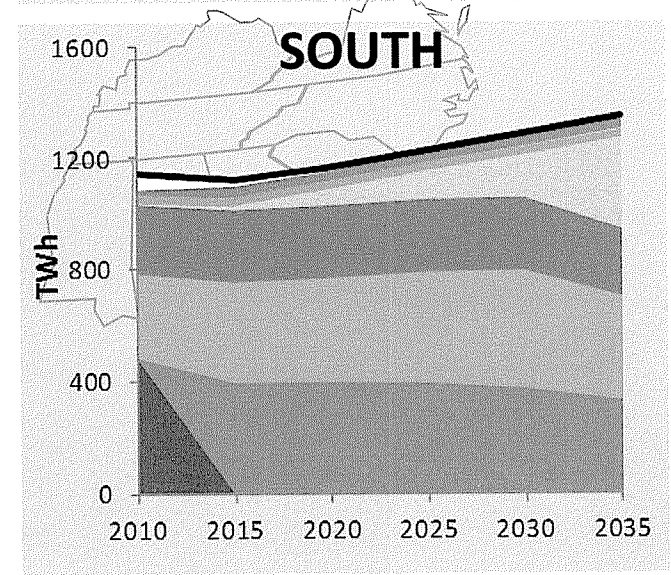
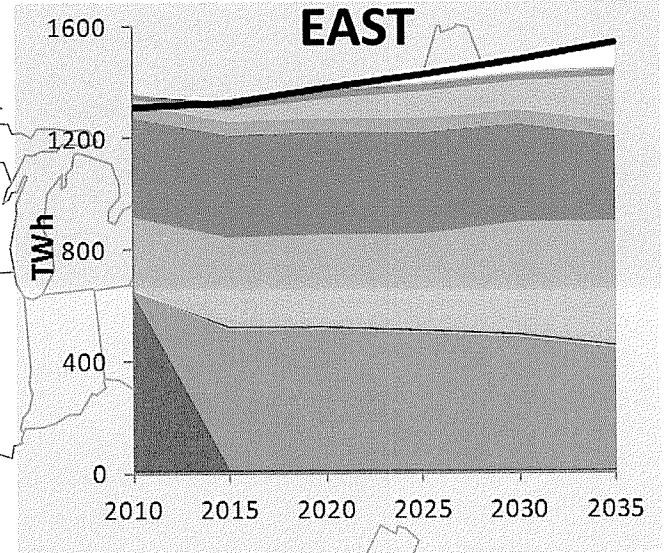
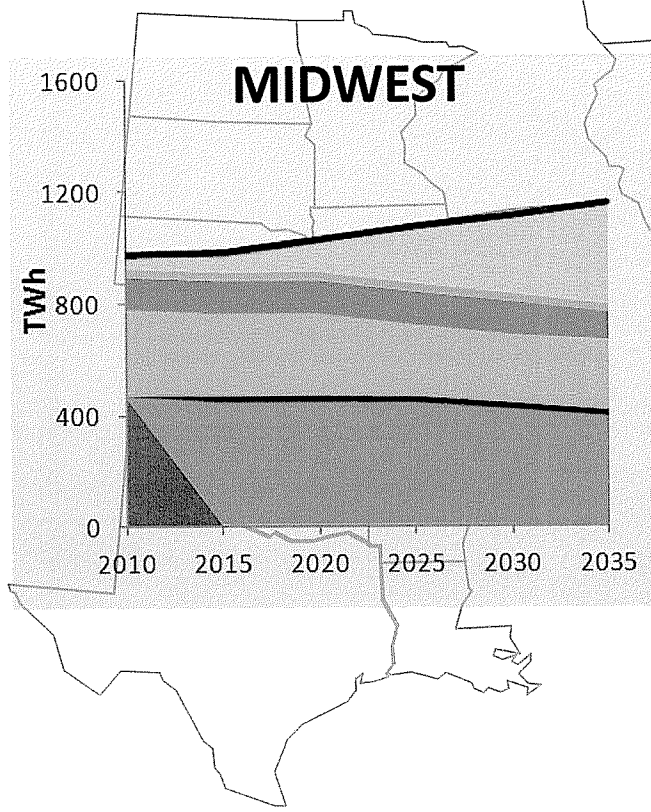
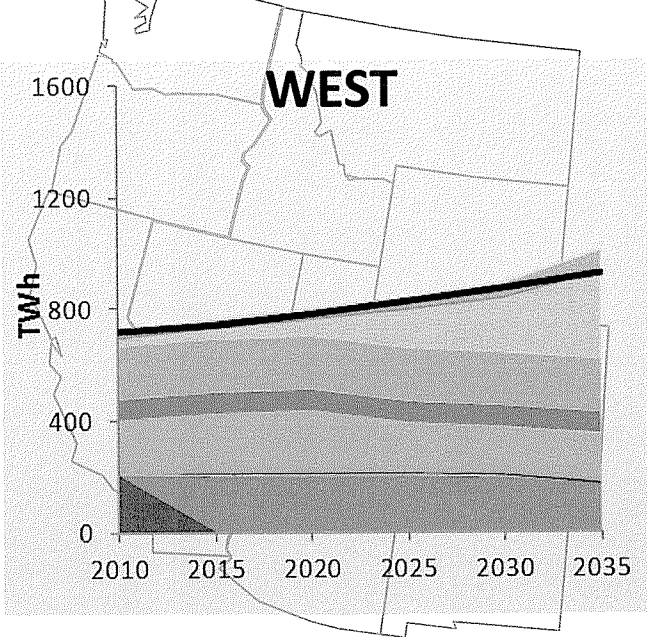
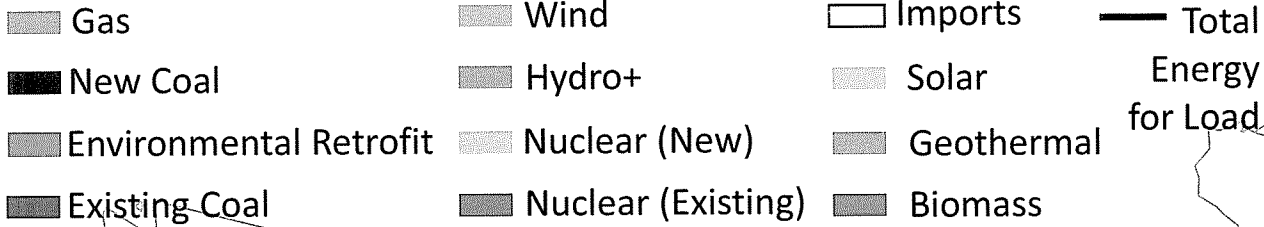
U.S. Electric Generation in Baseline



U.S. Electric Generation in Controls (Ref)



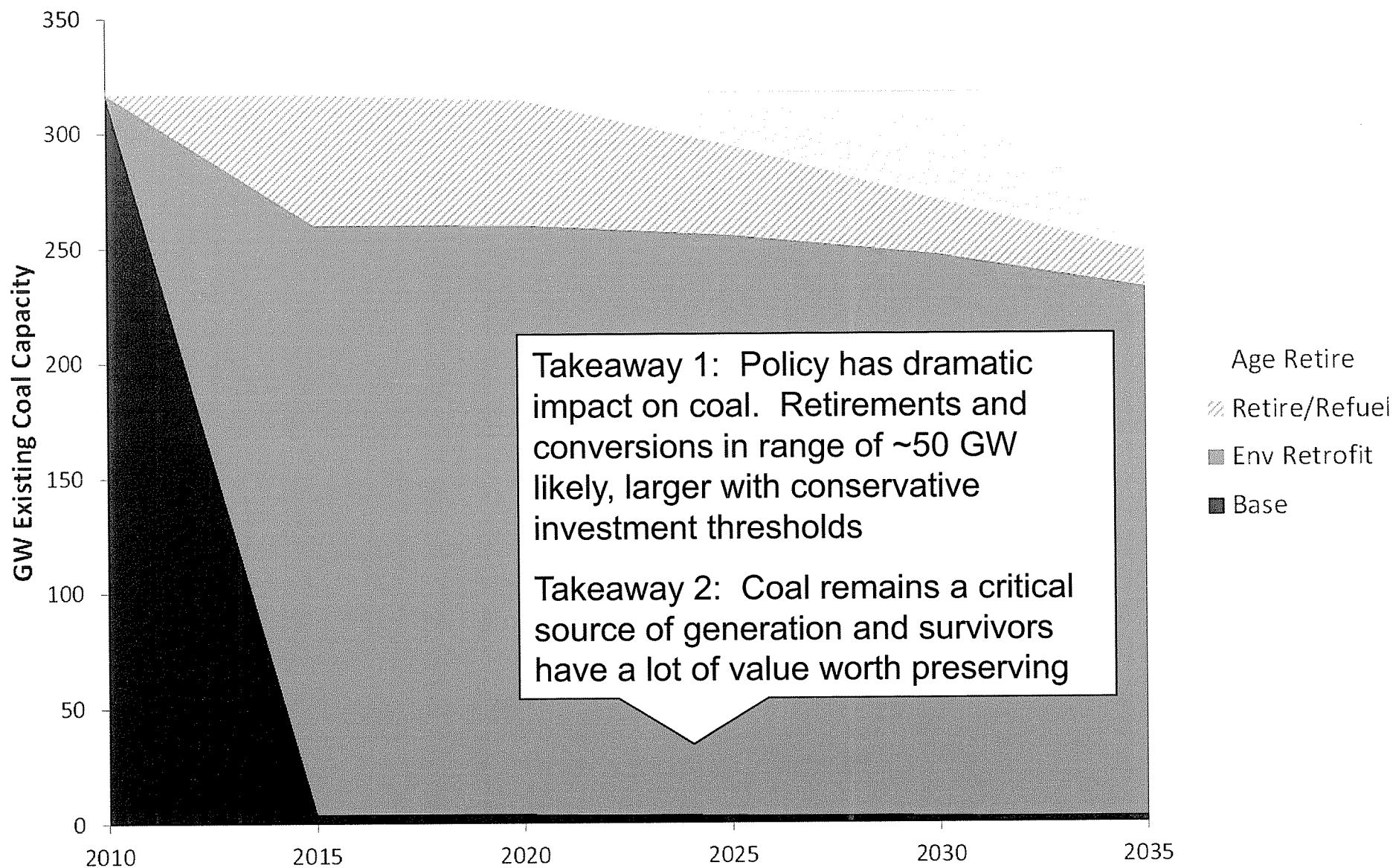
Regional Generation in Controls (Ref)



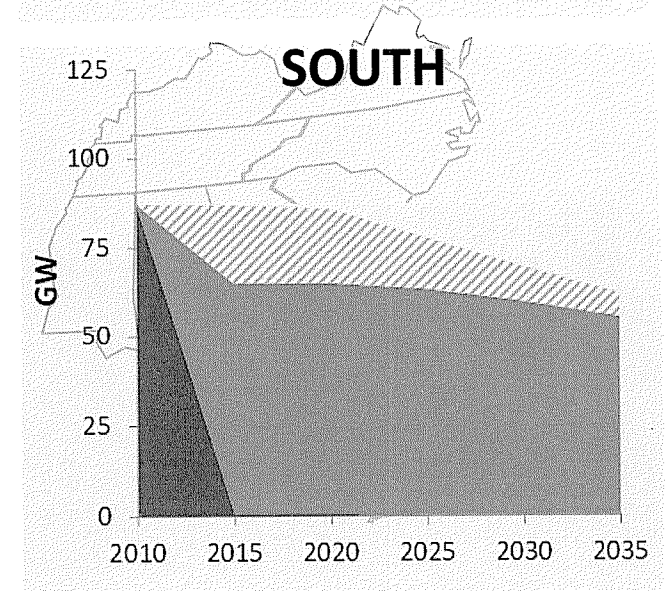
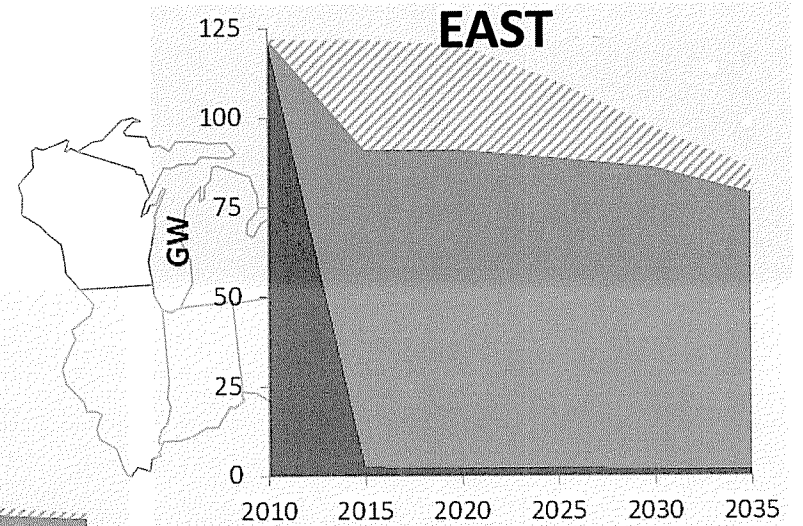
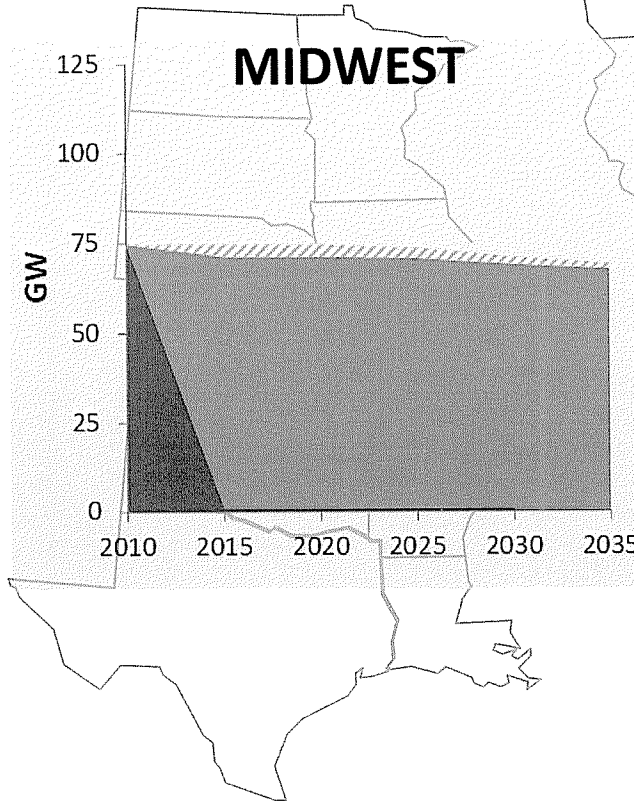
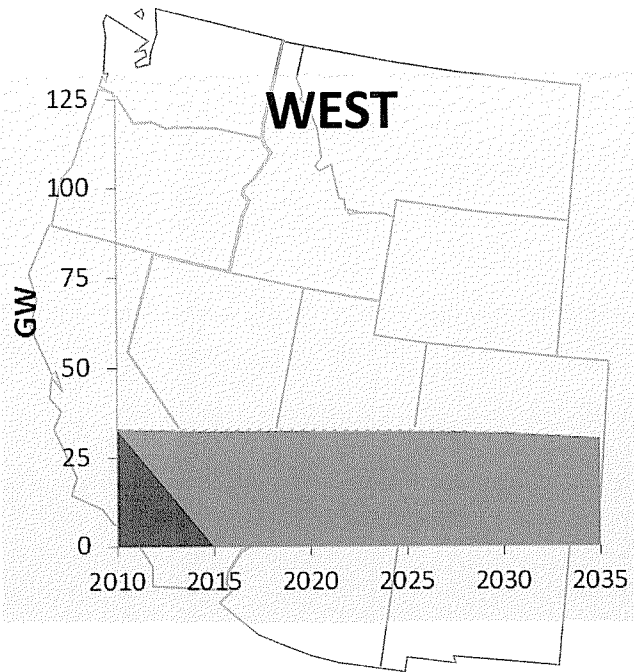
Coal Units May Cease to Operate Coal Due to Retirements as Well as Conversions to Gas

- Economics to retire or convert to gas or biomass can be very close
- Conversions can buy cheap capacity
- Capacity value depends on regional capacity needs and operating limitations of converted capacity
- Cost of conversion to gas can vary widely with distance to gas lines
- Many economically viable gas conversions may prove infeasible (e.g., siting, access to gas)
- As consequence we group units that cease to operate as coal into a Retire/Refuel category

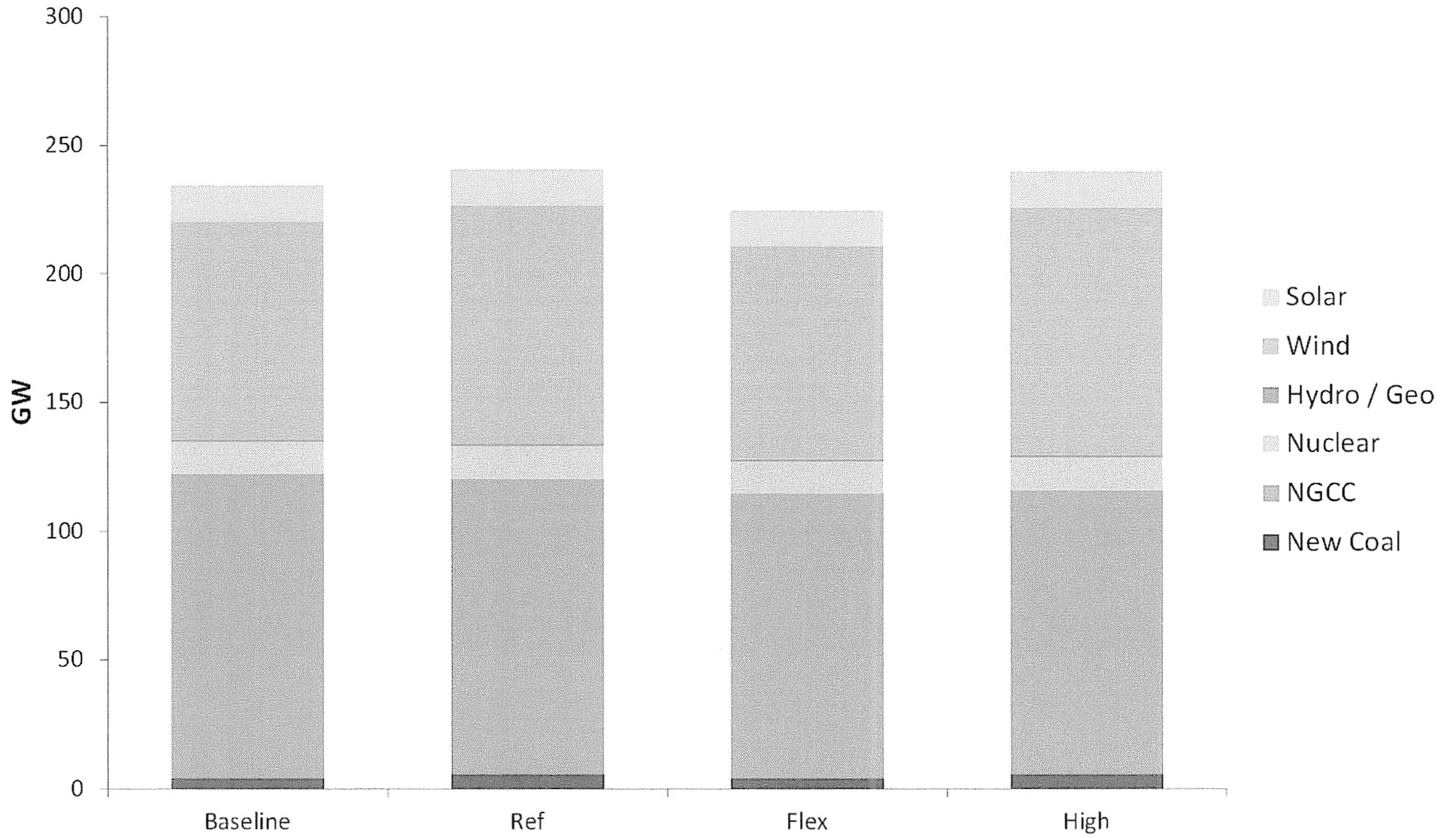
Existing Coal Disposition in Controls (Ref)



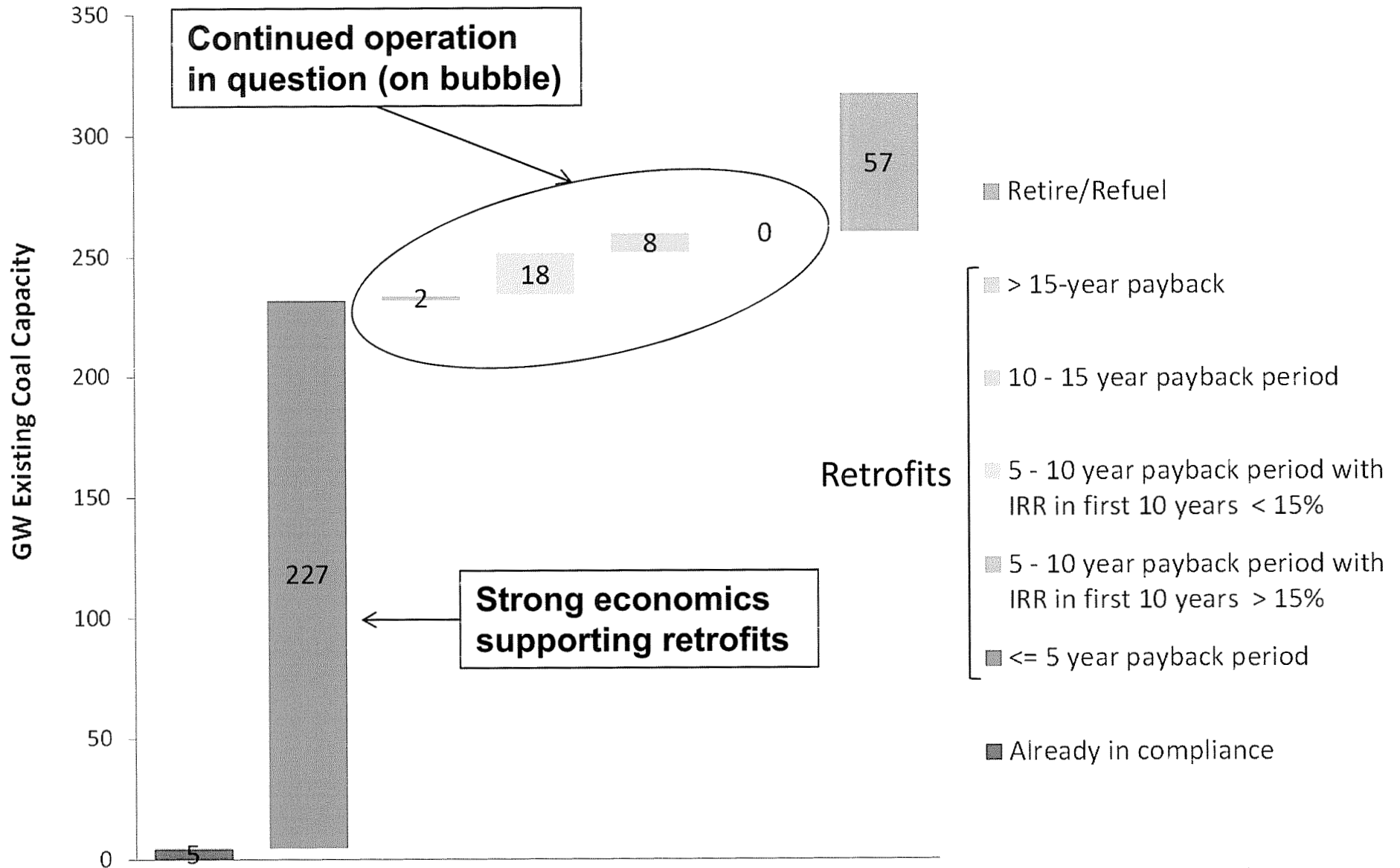
Regional Coal Disposition in Controls (Ref)



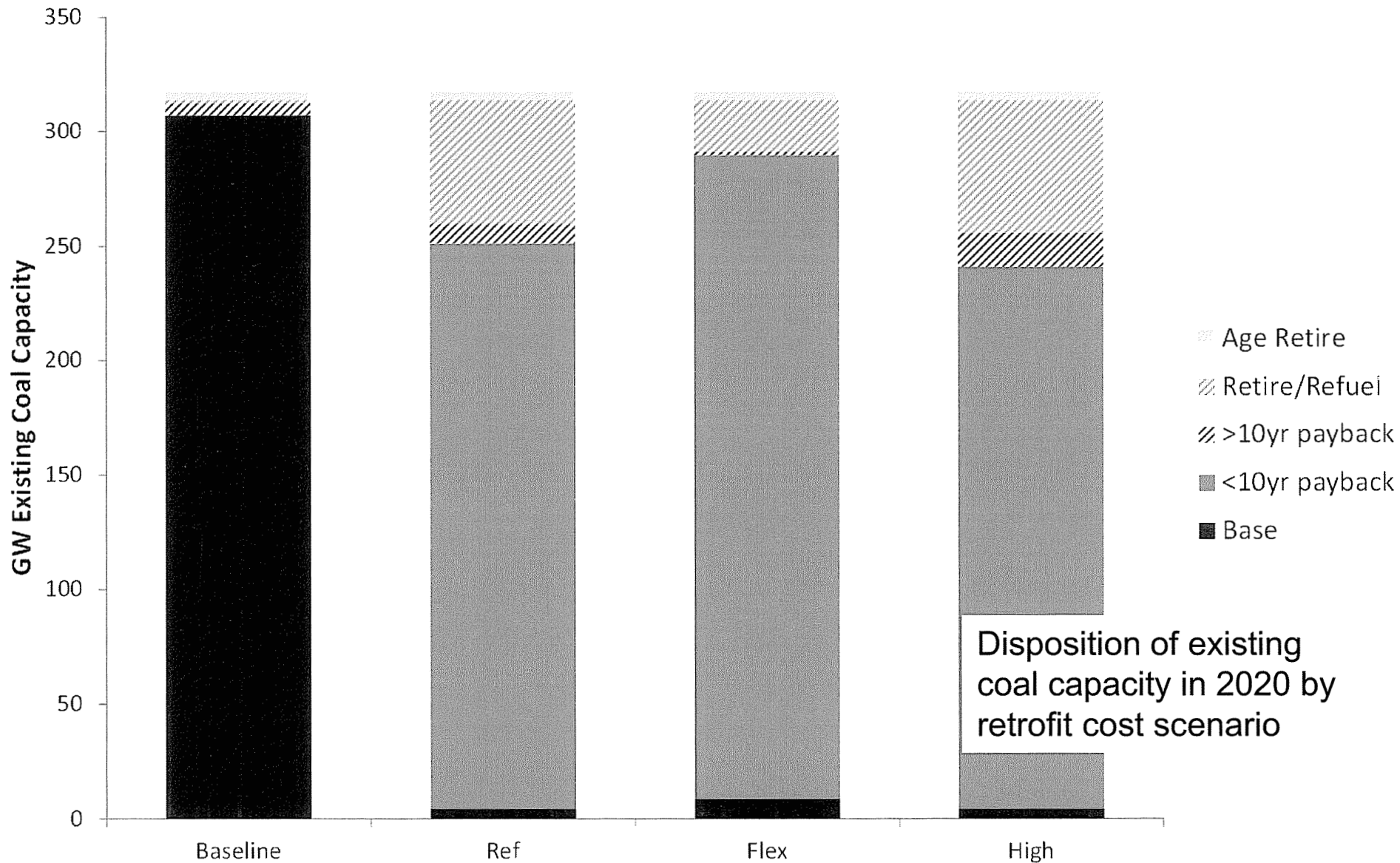
New Capacity Additions Through 2025



Broad Distribution of Pay-offs for Retrofits of Existing Coal (Ref)

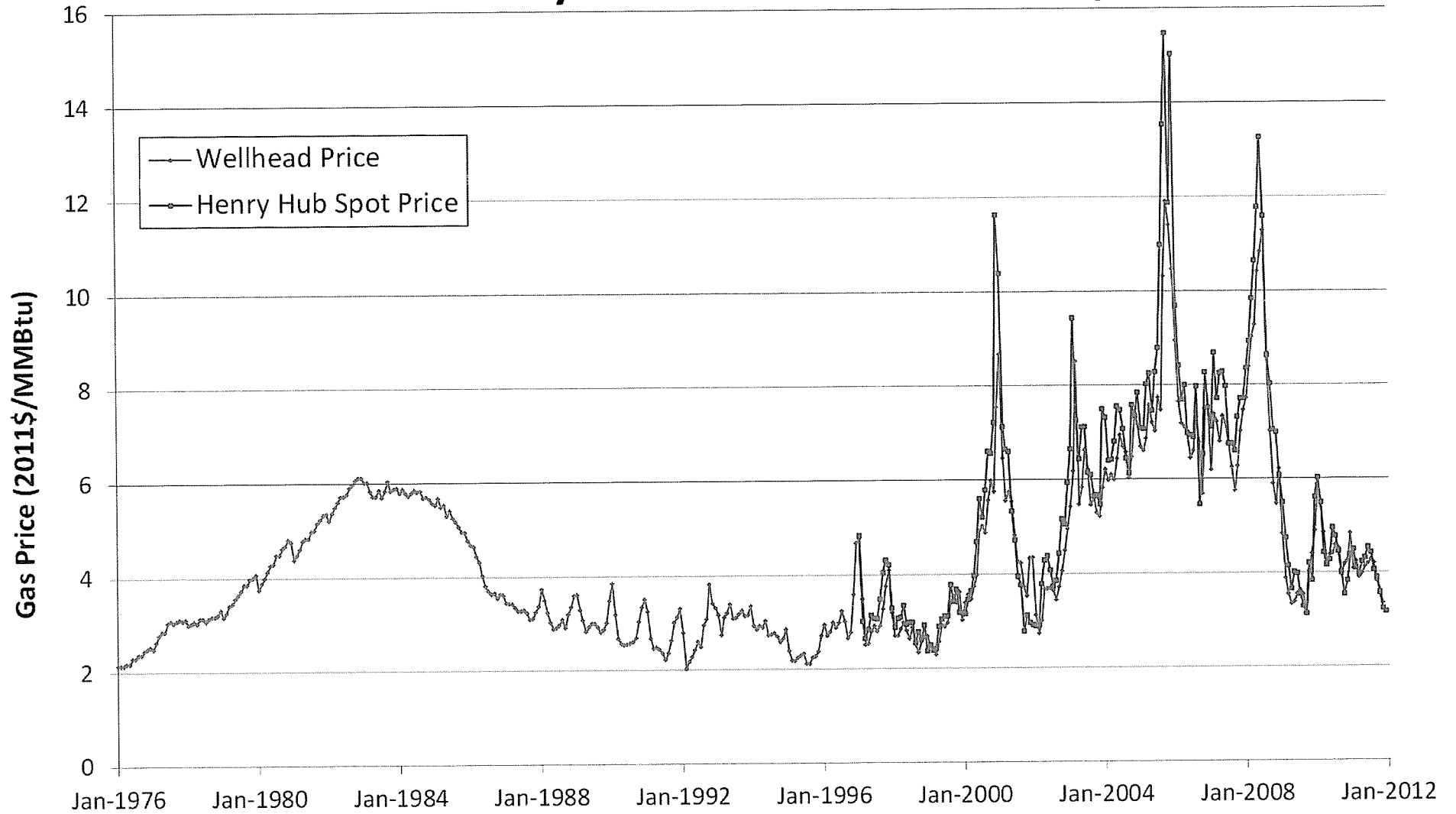


Potentially Large Fraction of Existing Coal Fleet May Retire or Refuel with Bio Energy or Gas

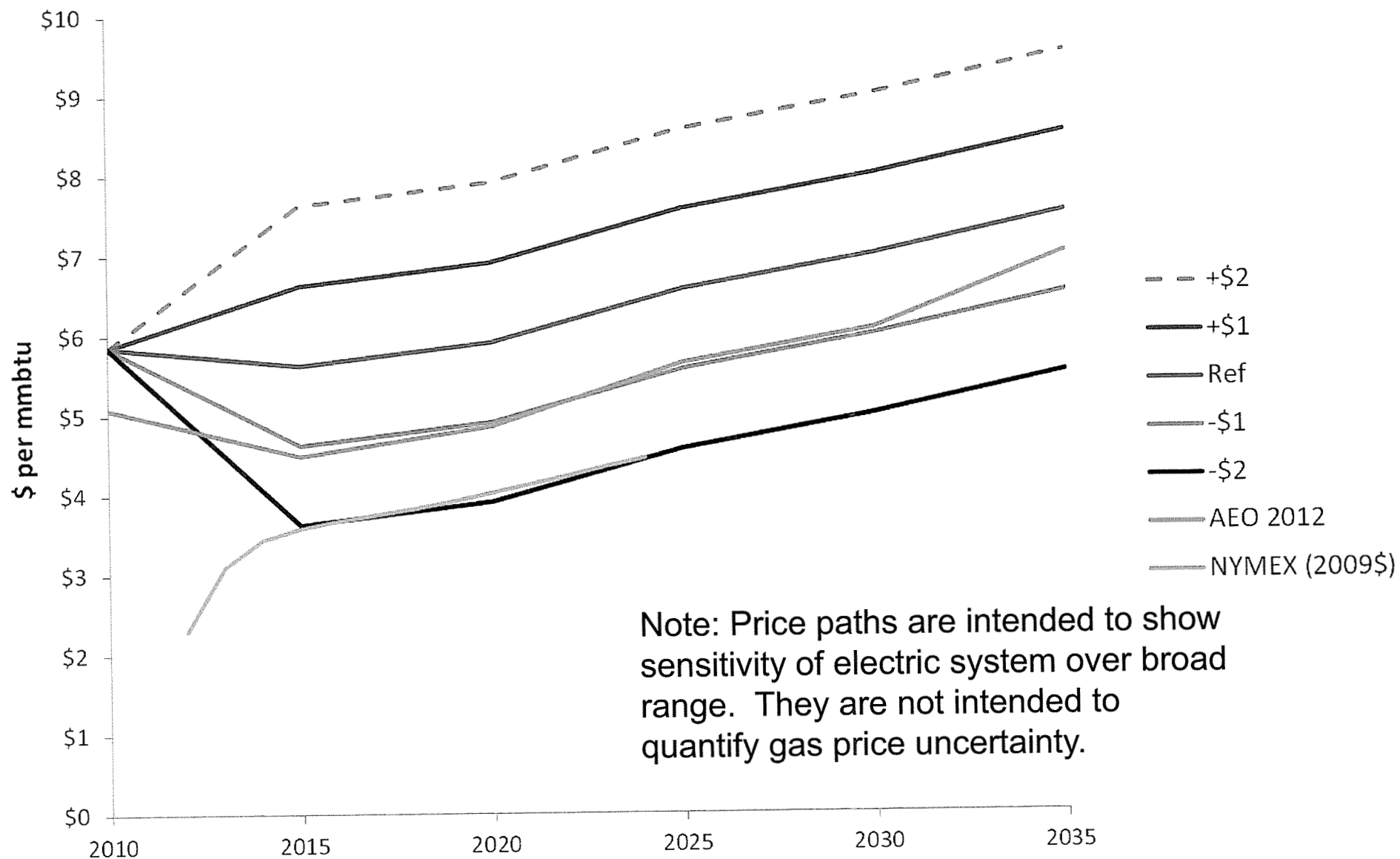


Long-term History of Natural Gas Prices Shows High Level of Variability

Historical Monthly U.S. Natural Gas Prices (2011\$)

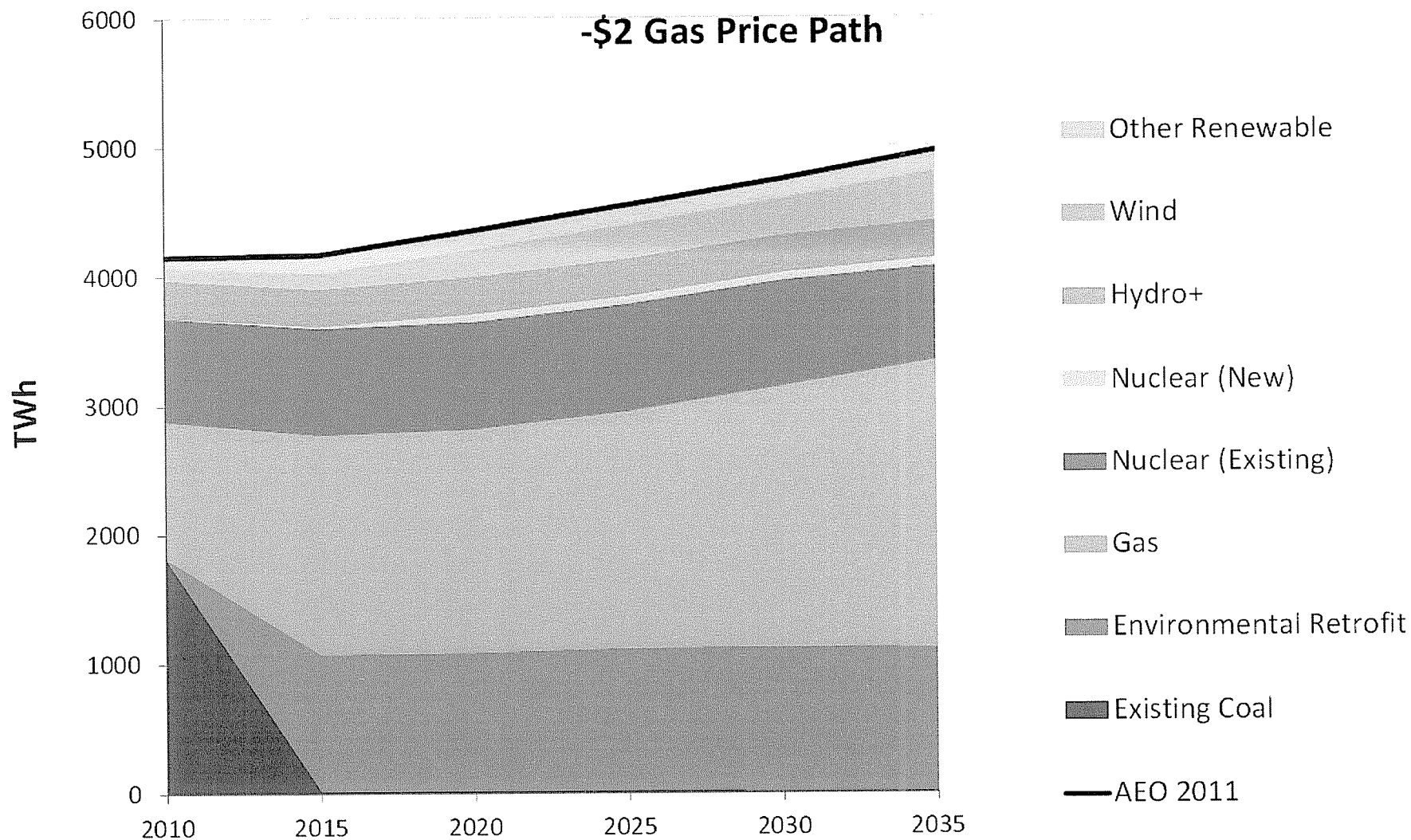


Sensitivity Analysis on Natural Gas Prices

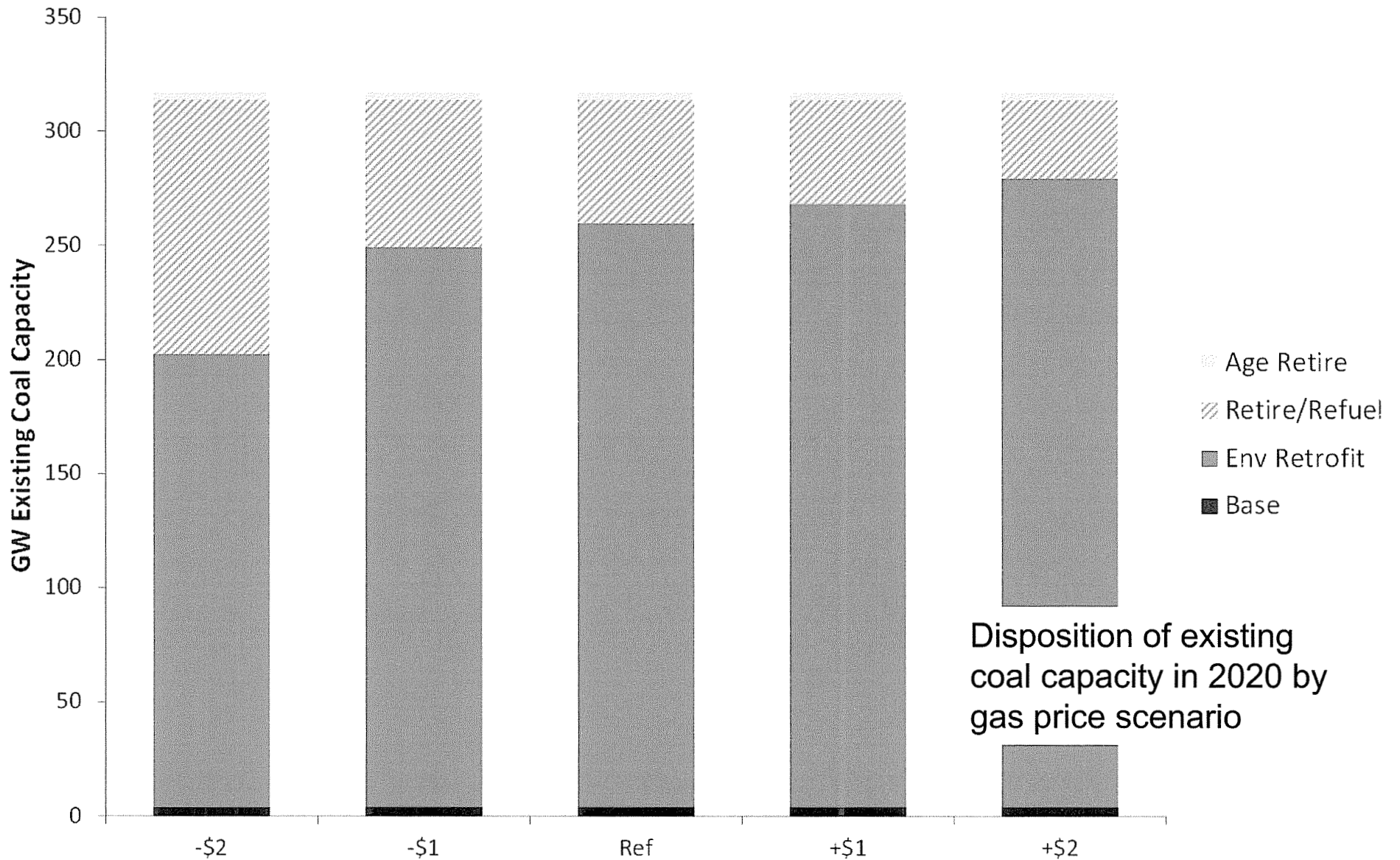


Note: Price paths are intended to show sensitivity of electric system over broad range. They are not intended to quantify gas price uncertainty.

Generation with low gas prices



Gas Price Scenarios Show Critical Role of Gas Price Expectations for How Much Coal Survives



Disposition of existing coal capacity in 2020 by gas price scenario

Natural Gas Price is the Dominant Uncertainty

Uncertainty level is very high

- Price range over last decade shows over 5 to 1 ratio
- Are NYMEX futures and AEO 2012 projections going to continue to decline?

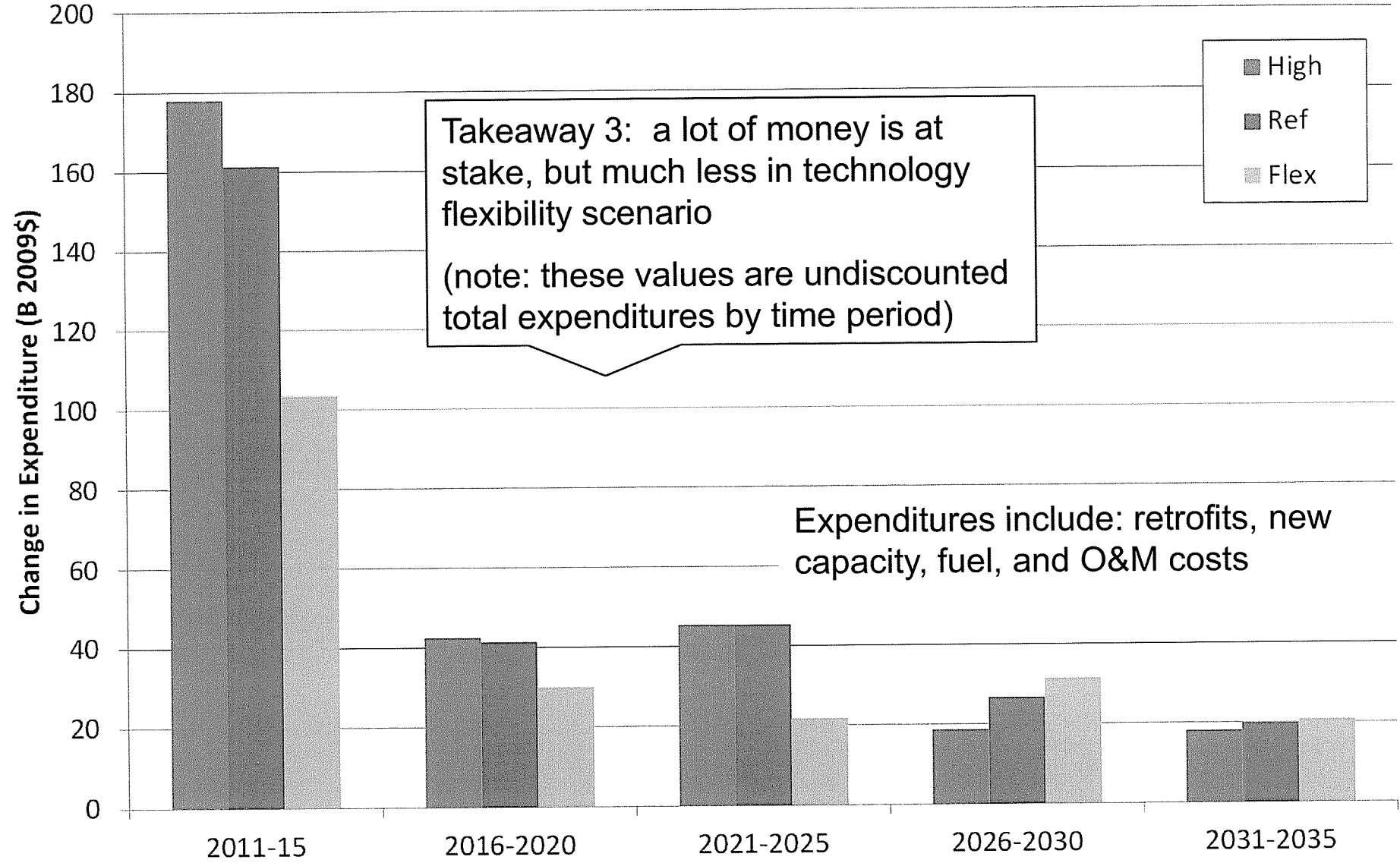
Dramatic consequences

- Average power prices show ~\$6/MWh swing for each \$1 change in gas prices
- Low price paths have particularly large impact on retrofit vs. retire/refuel decisions

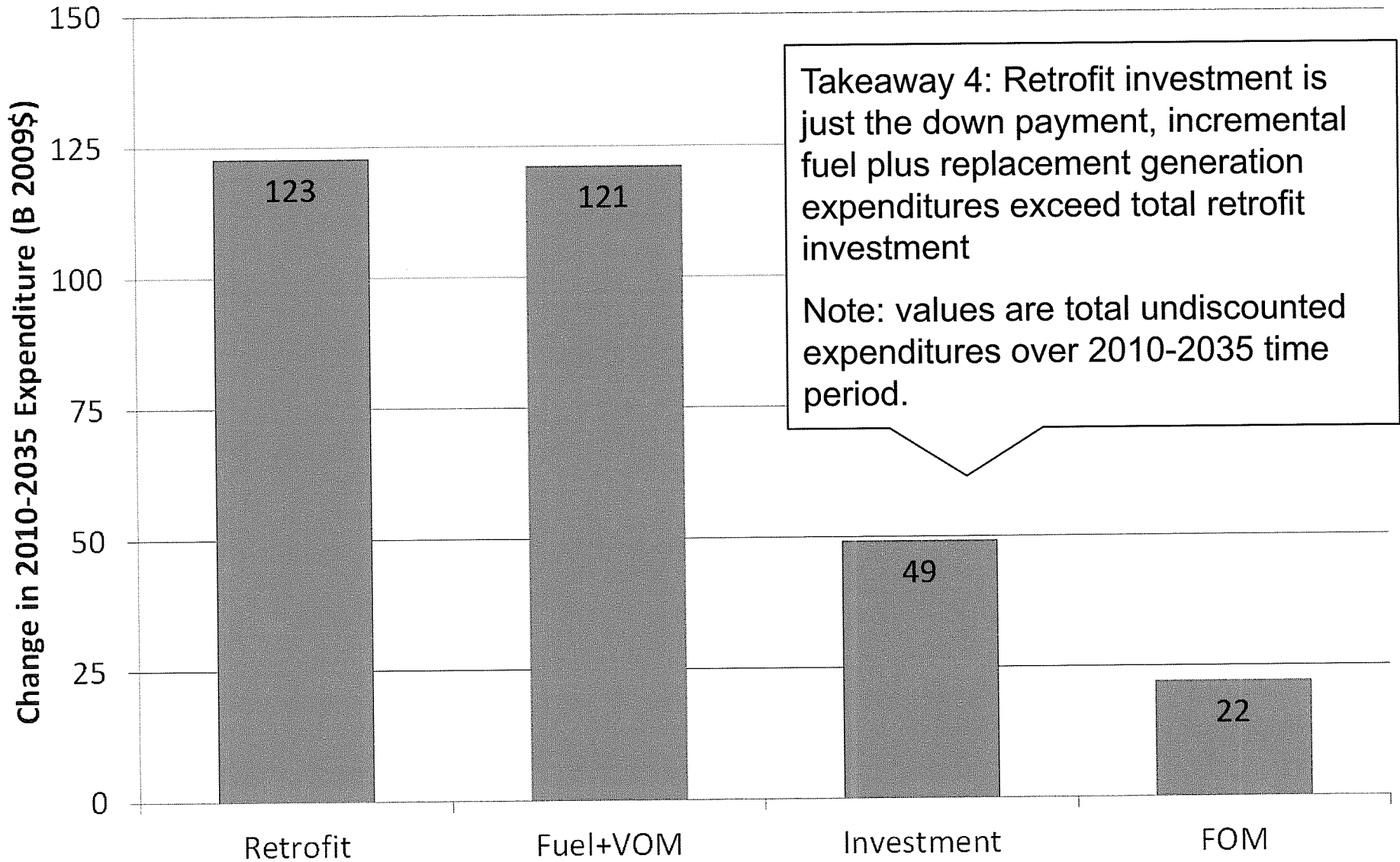
Implications for decisions

- Flexible compliance strategies with lower fixed costs (despite higher operating costs) reduce risk or regrets

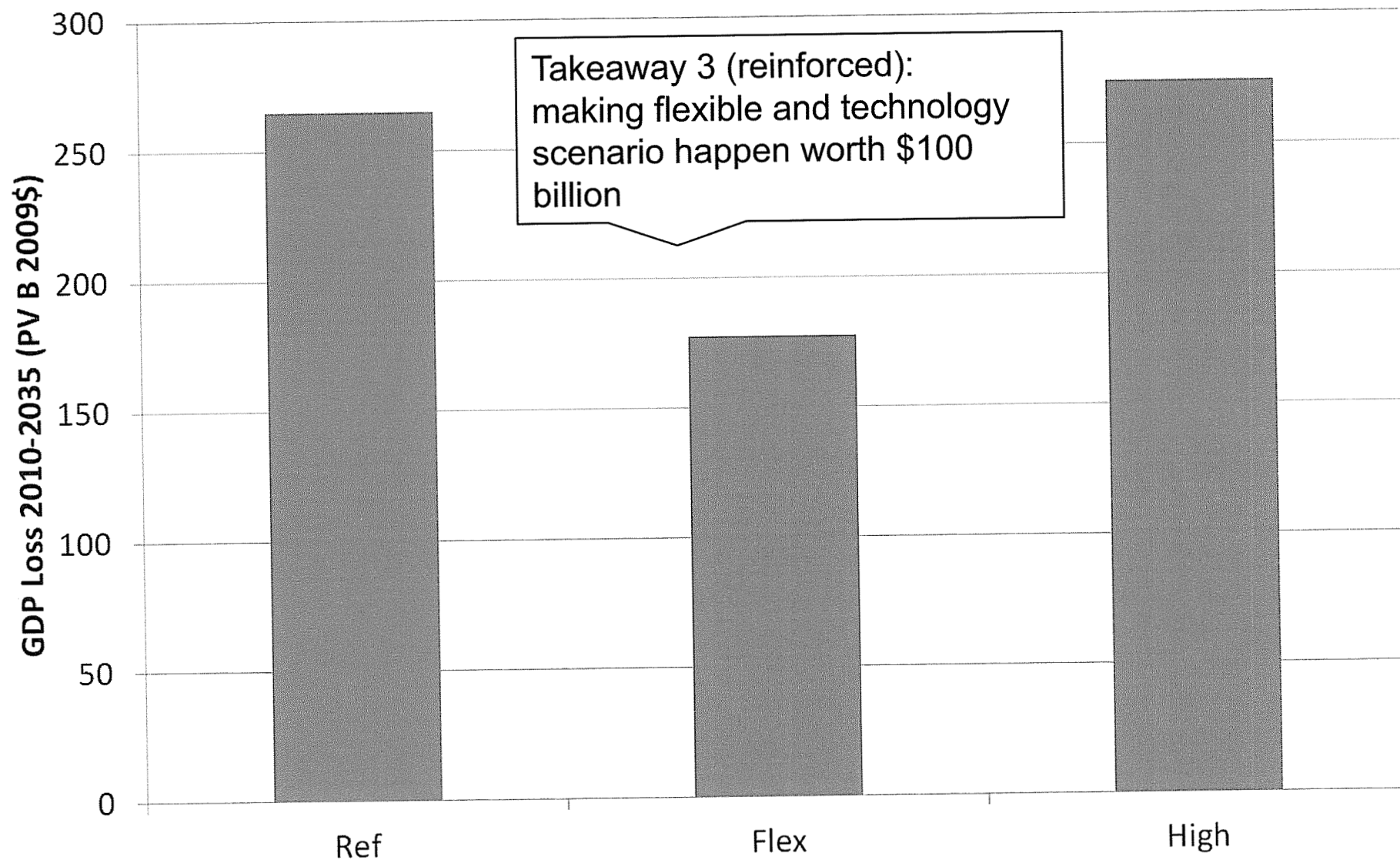
100's of Billions of Dollars in Possible Electric Sector Expenditures



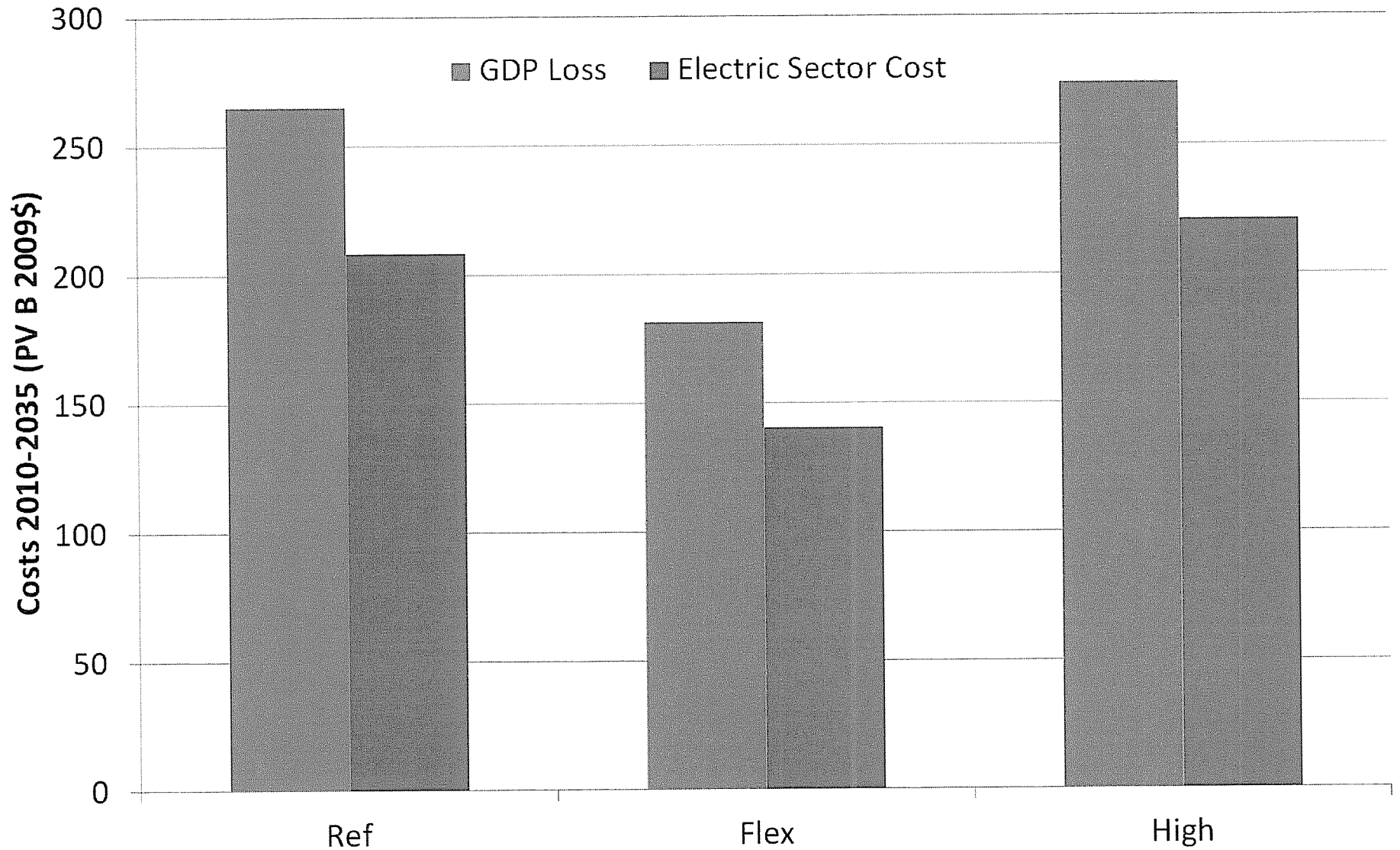
Retrofit Investment is Only Part of Policy Expenditure Costs (Ref)



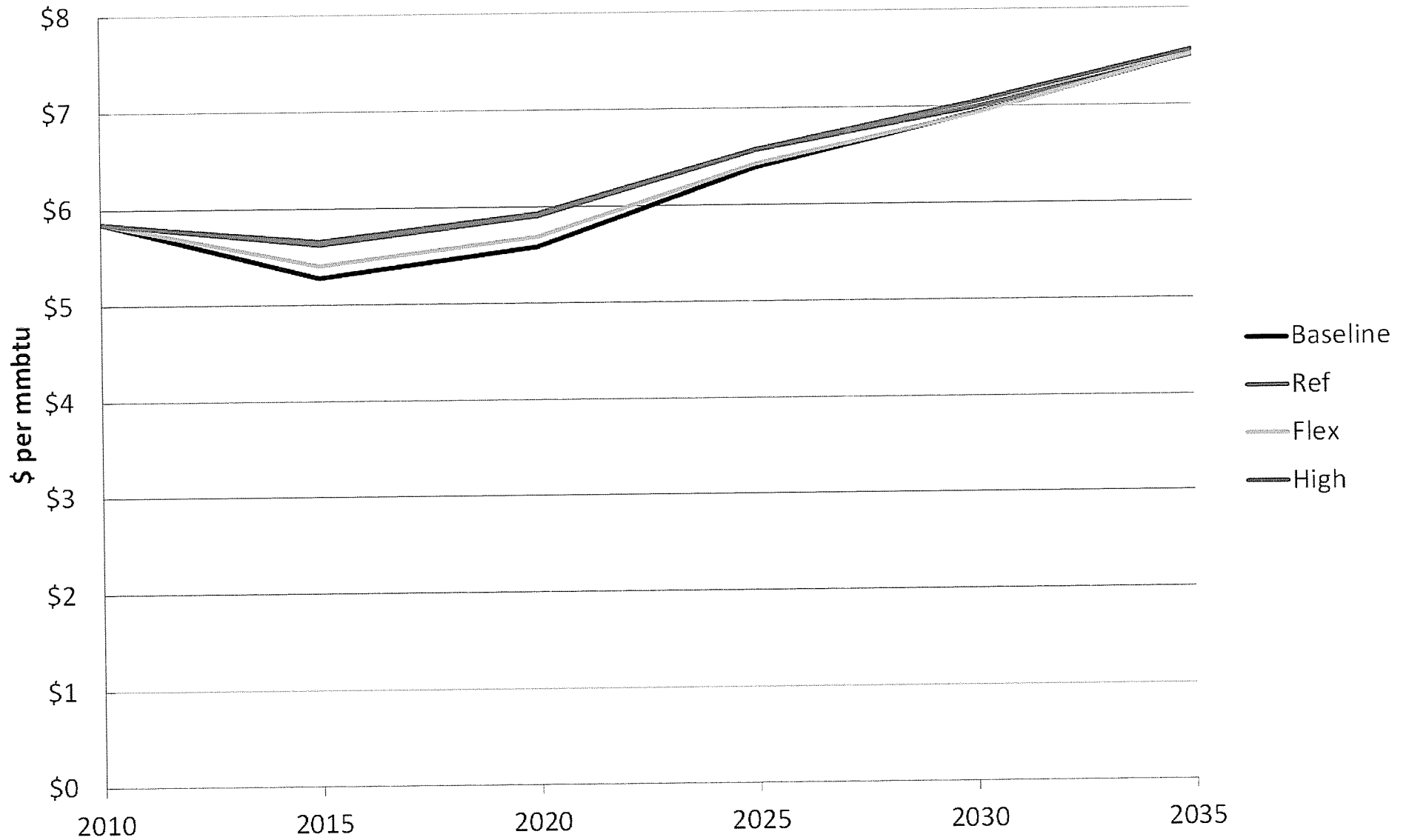
GDP Impacts Show Magnitude of Costs and Opportunity in Flexibility



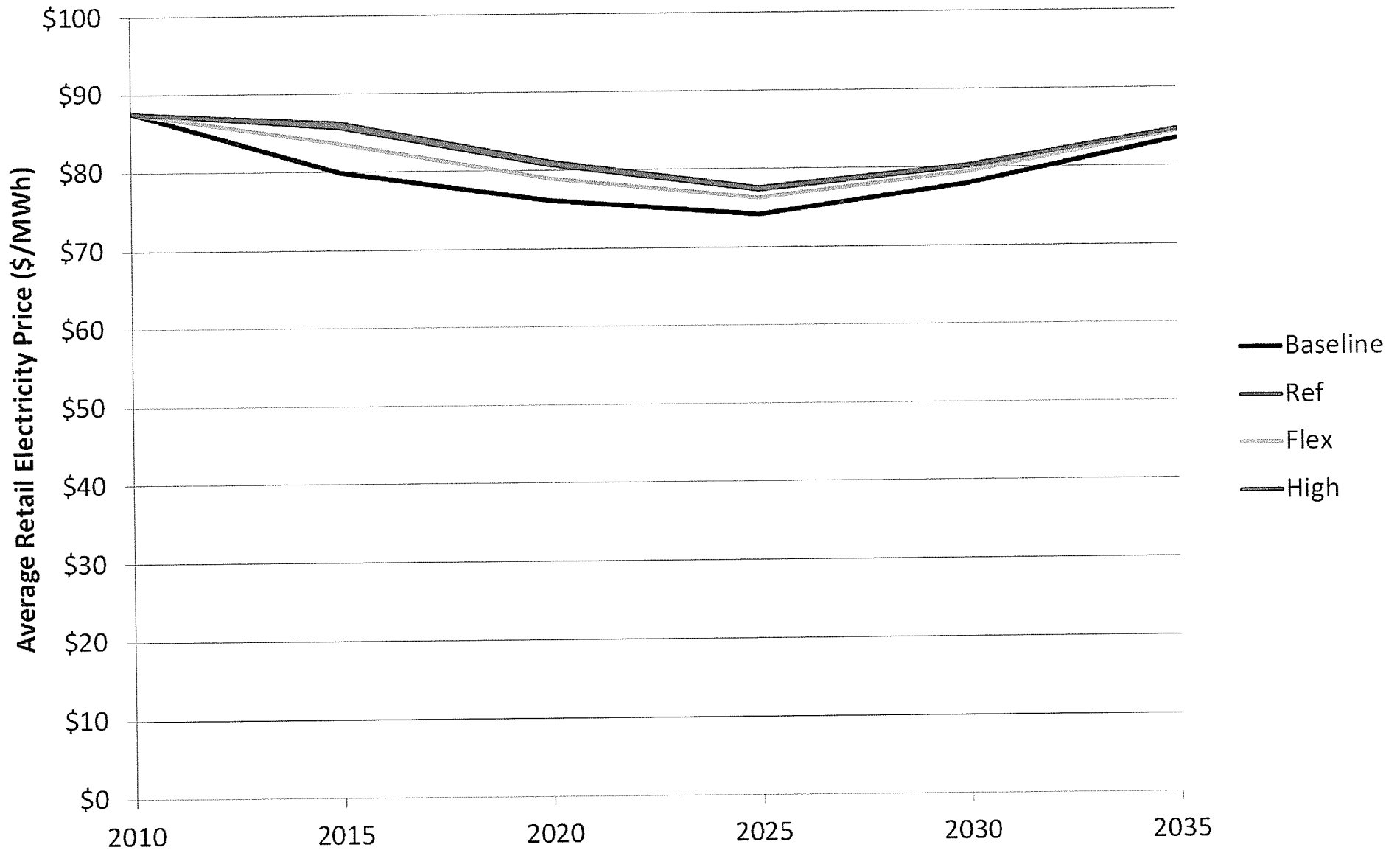
Note That Total GDP Impacts ~25% Greater Than Increased Cost to Electric Sector



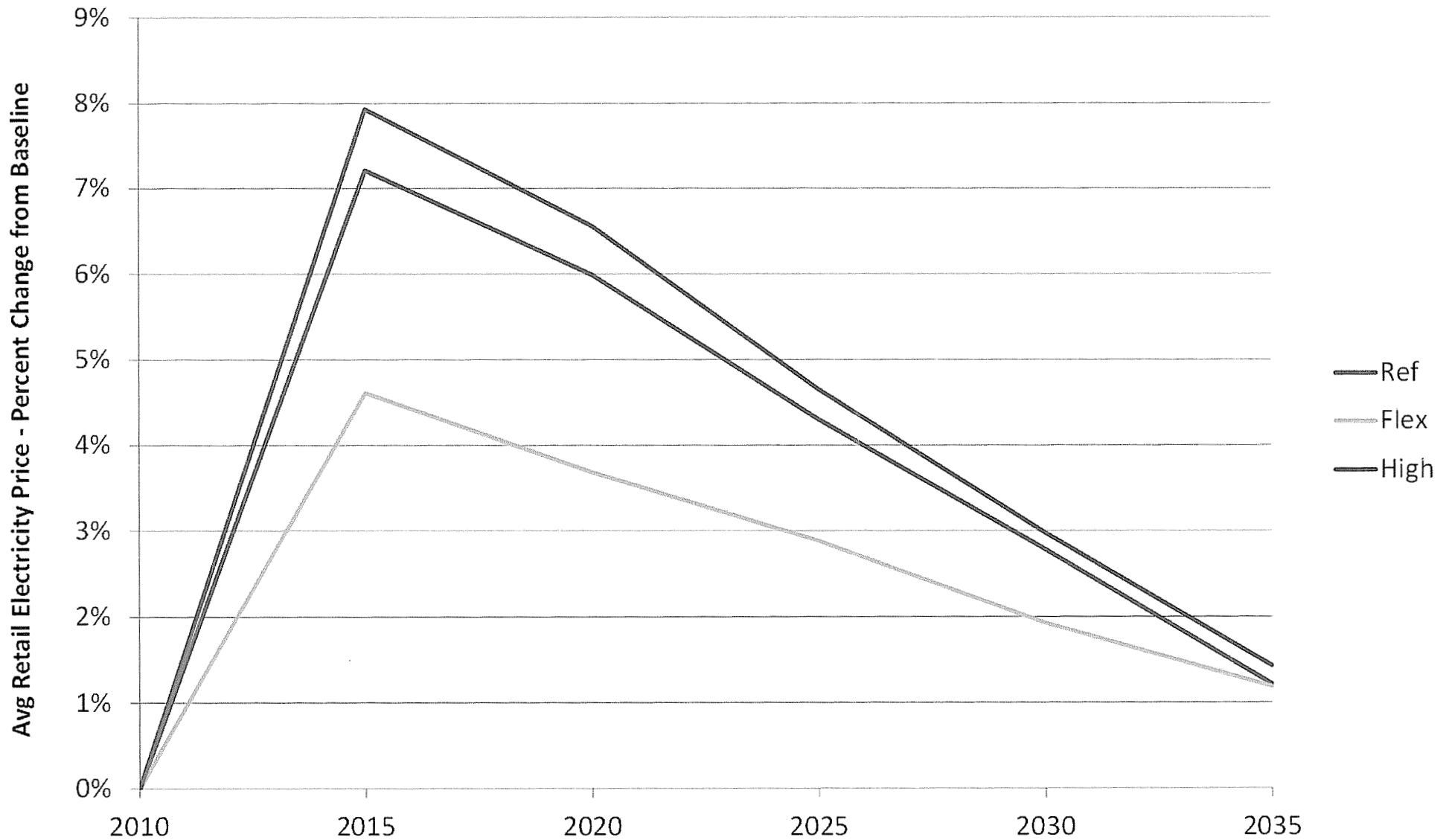
U.S. Average Power Producers' Gas Price



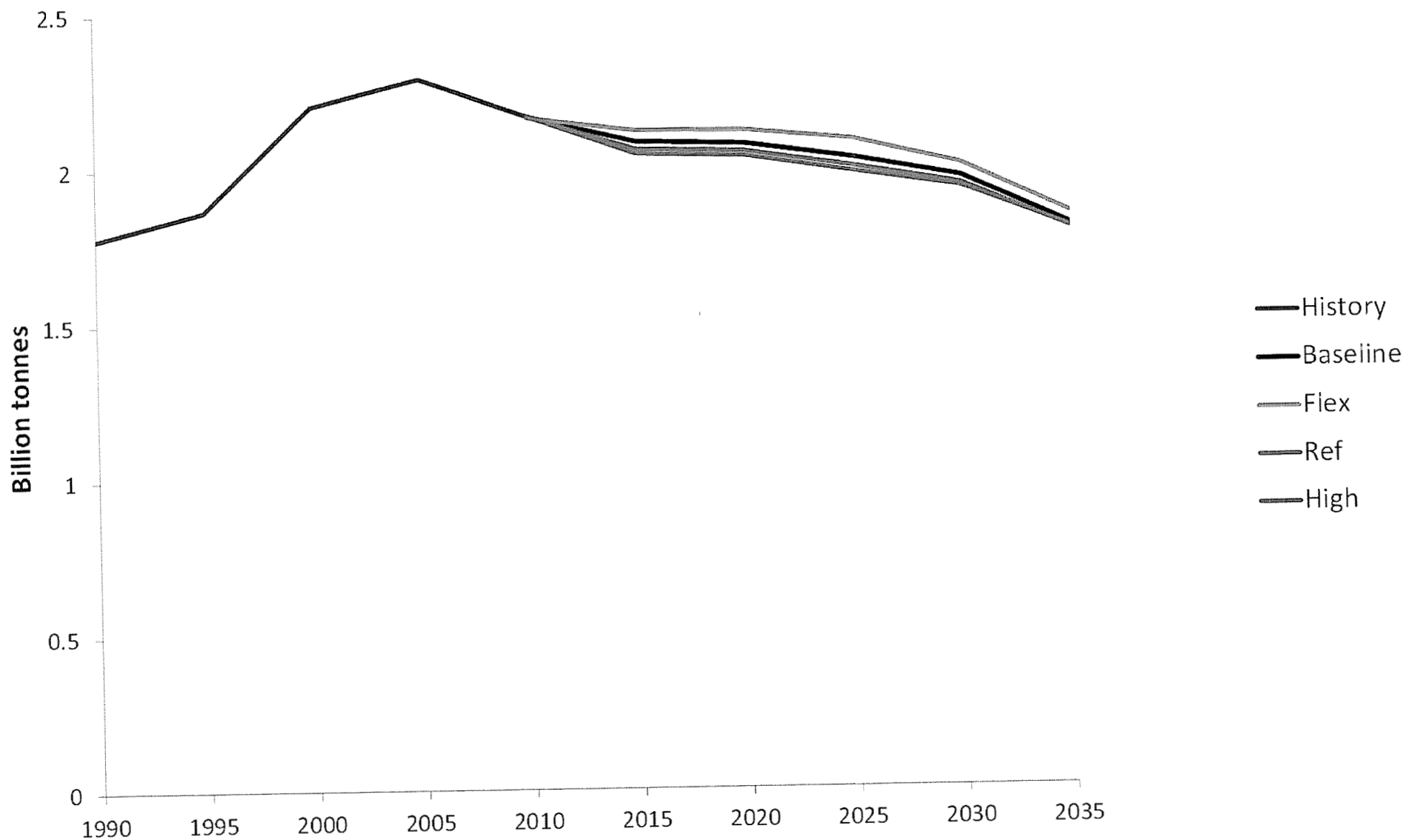
U.S. Average Retail Electricity Price



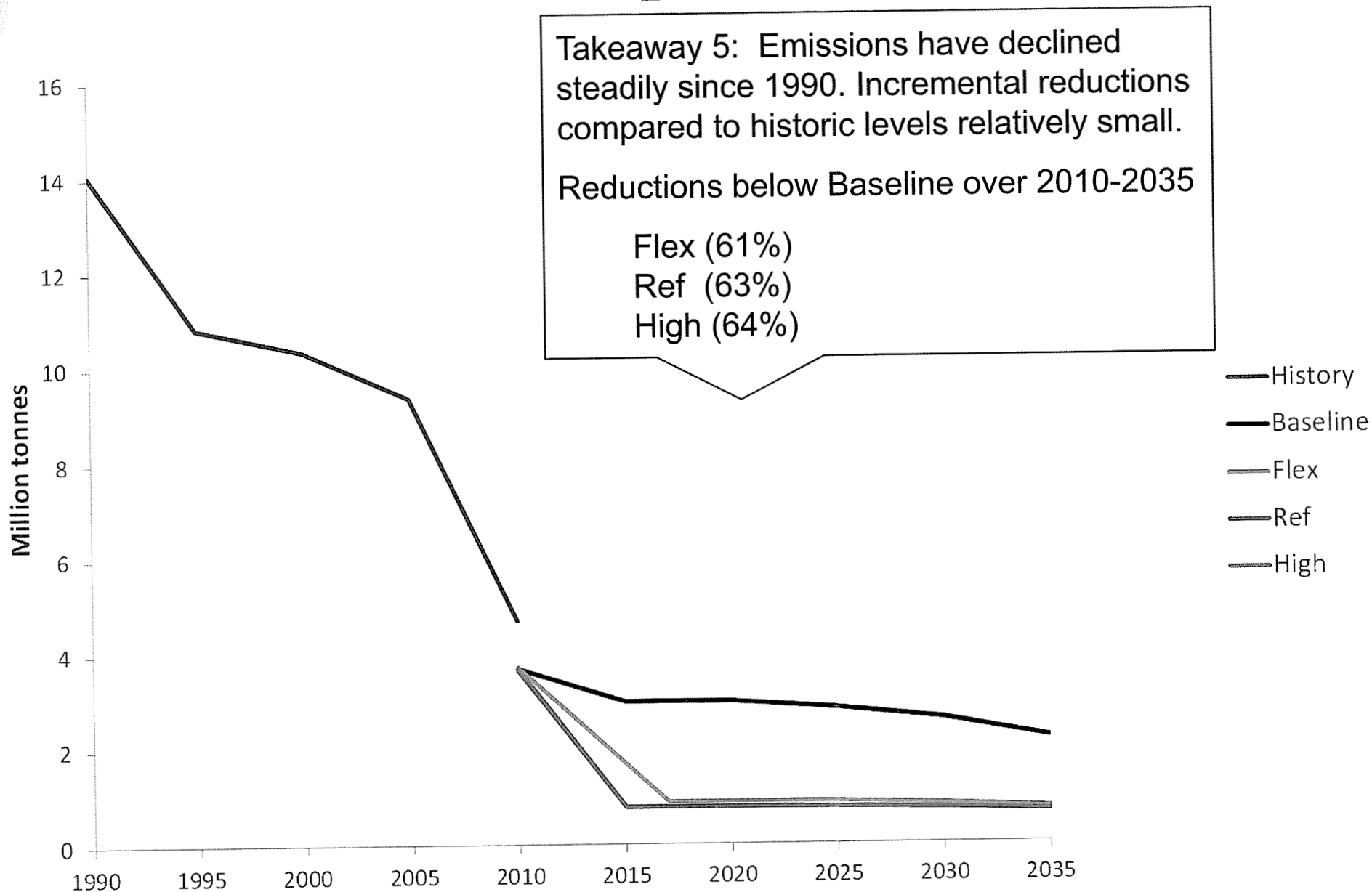
U.S. Average Retail Electricity Price - Percent Change from Baseline



U.S. Electric Sector CO₂ Emissions



U.S. Electric Sector SO₂ Emissions

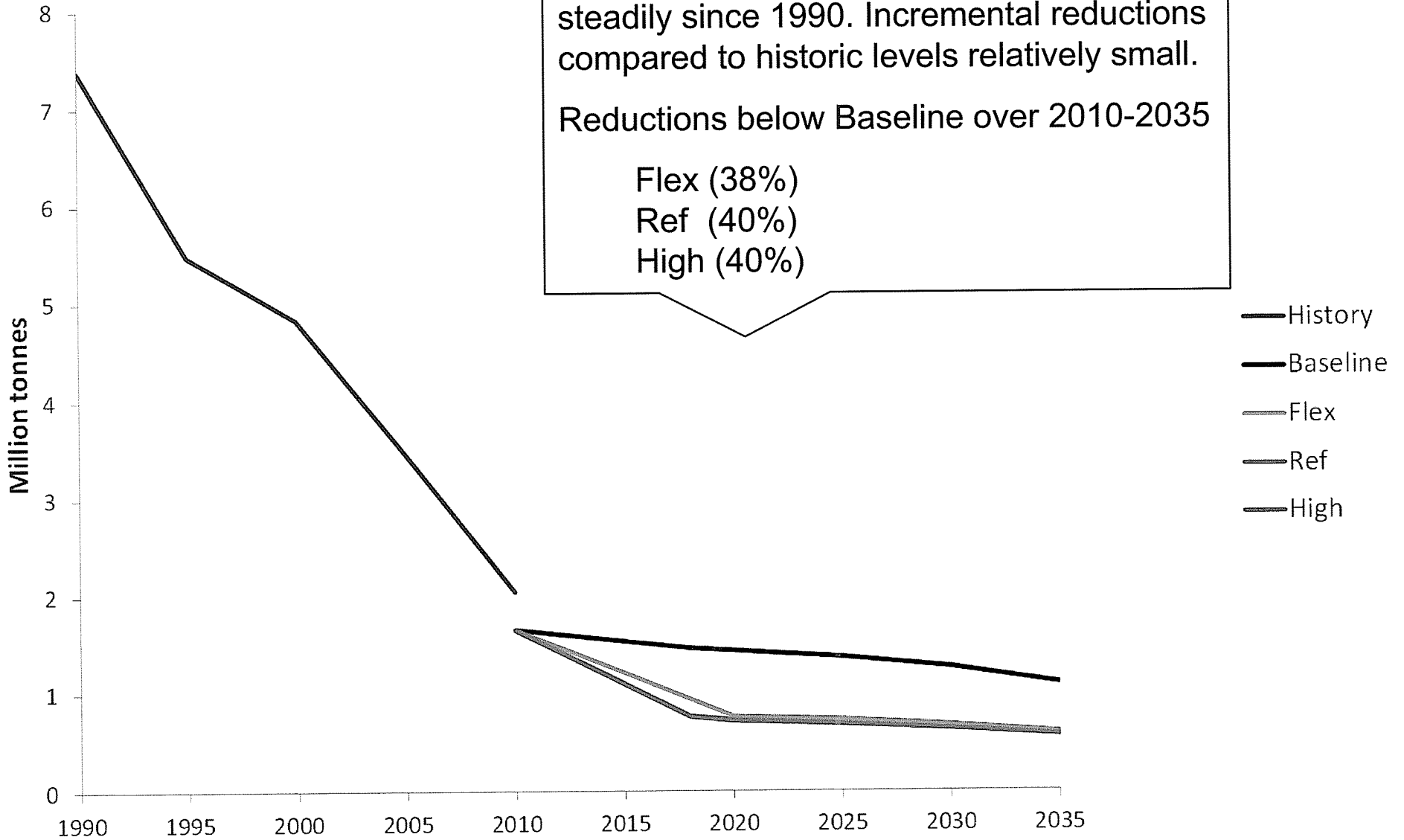


U.S. Electric Sector NO_x Emissions

Takeaway 5: Emissions have declined steadily since 1990. Incremental reductions compared to historic levels relatively small.

Reductions below Baseline over 2010-2035

- Flex (38%)
- Ref (40%)
- High (40%)



Concluding Observations

- Economic cost of full control policy is \$175B to \$275B (PV 2010-2035)
- Cost range driven by ability to deploy low-cost technologies, which may require policy flexibility and extra time to assess
- Cost impacts greatest in high-coal regions
- Compliance decisions dependent on gas price expectations
- 50 to 100+ GW of coal may retire or convert fuels
- Most of existing coal continues to play key role
- SO₂/NO_x emissions drop to less than 30% of 2010 levels
- If emission reductions phased in over an extra two years the relative impact on cumulative emissions is modest

Contact Information

Bryan Hannegan

Vice President, Environment and Renewables

Electric Power Research Institute

(650) 855-2459

bhannegan@epri.com

Energy and Environmental Analysis Group

Tom Wilson

Senior Program Manager

(650) 855-7928

twilson@epri.com

Victor Niemeyer

Technical Executive

650-855-2262

Niemeyer@epri.com

Geoffrey Blanford

Program Manager

(650) 855-2126

gblanford@epri.com

Francisco de la Chesnaye

Program Manager

(202) 293-6347

fdelachesnaye@epri.com

Together...Shaping the Future of Electricity

Utility CO₂ Price References

Ameren Missouri. (2011). 2011 Integrated Resource Plan.

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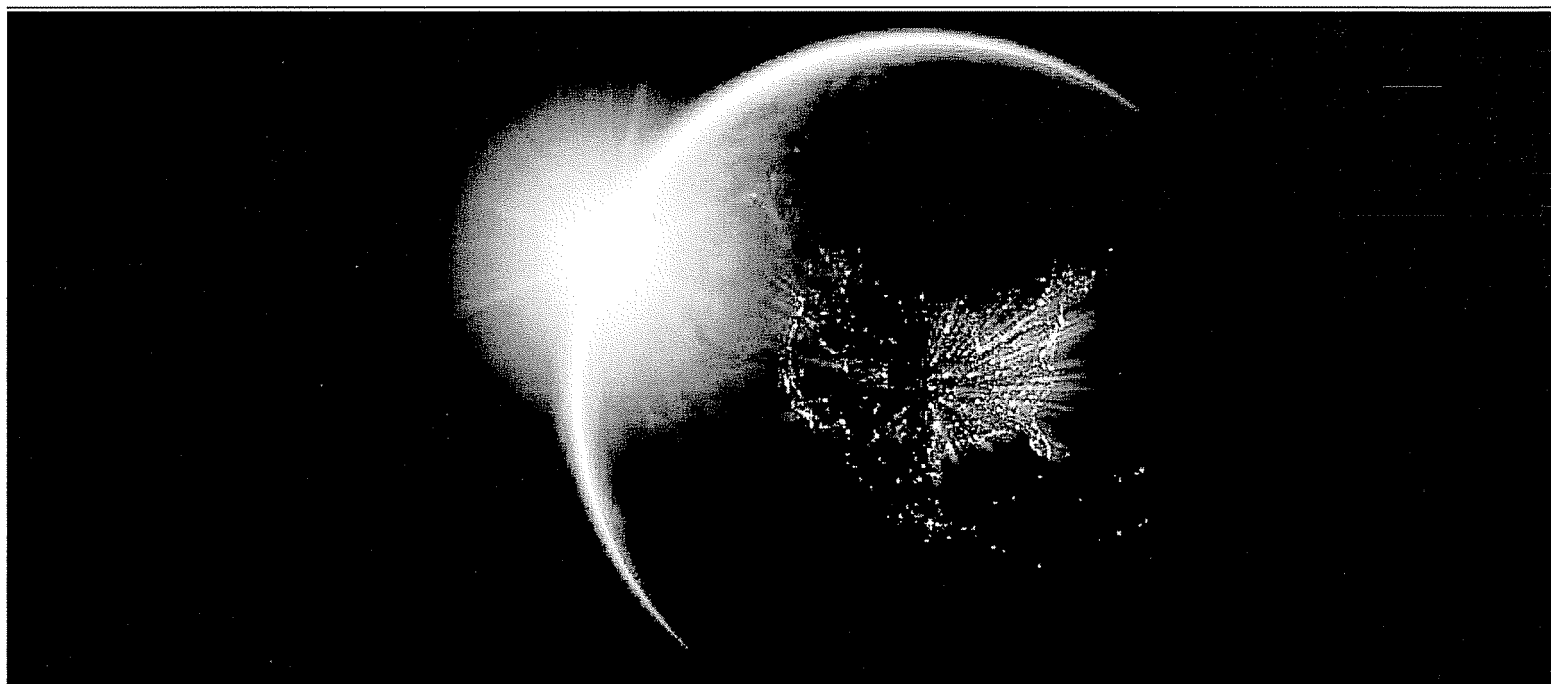
Utility CO₂ Price References

- Ameren Missouri. (2011). 2011 Integrated Resource Plan.
- Avista. (2011). 2011 Electric Integrated Resource Plan.
- CT Light and Power. (2010). Integrated Resource Plan for Connecticut.
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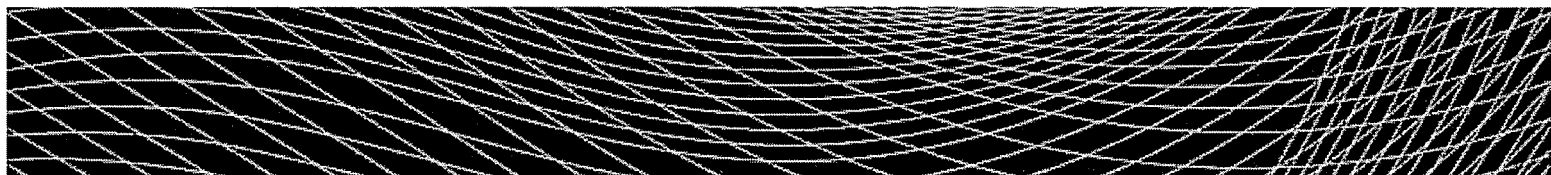
DOE/EIA-0383(2012) | June 2012

Annual Energy Outlook 2012

with Projections to 2035



Department of Energy
U.S. Energy Information
Administration



For further information . . .

The *Annual Energy Outlook 2012* was prepared by the U.S. Energy Information Administration (EIA), under the direction of John J. Conti (john.conti@eia.gov, 202/586-2222), Assistant Administrator of Energy Analysis; Paul D. Holtberg (paul.holtberg@eia.gov, 202/586-1284), Team Leader, Analysis Integration Team, Office of Integrated and International Energy Analysis; Joseph A. Beamon (joseph.beamon@eia.gov, 202/586-2025), Director, Office of Electricity, Coal, Nuclear, and Renewables Analysis; Sam A. Napolitano (sam.napolitano@eia.gov, 202/586-0687), Director, Office of Integrated and International Energy Analysis; A. Michael Schaal (michael.schaal@eia.gov, 202/586-5590), Director, Office of Petroleum, Natural Gas, and Biofuels Analysis; and James T. Turnure (james.turnure@eia.gov, 202/586-1762), Director, Office of Energy Consumption and Efficiency Analysis.

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Office of Communications, EI-40
Forrestal Building, Room 1E-210
1000 Independence Avenue, S.W.
Washington, DC 20585

Telephone: 202/586-8800 Fax: 202/586-0727
(24-hour automated information line) Website: www.eia.gov
E-mail: infoctr@eia.gov

Specific questions about the information in this report may be directed to:

General questions	Paul D. Holtberg (paul.holtberg@eia.gov , 202-586-1284)
National Energy Modeling System	Dan H. Skelly (daniel.skelly@eia.gov , 202-586-2222)
Executive summary	Paul D. Holtberg (paul.holtberg@eia.gov , 202/586-1284)
Economic activity	Kay A. Smith (kay.smith@eia.gov , 202/586-1132)
World oil prices	John L. Staub (john.staub@eia.gov , 202-586-6344)
International oil production	James P. O'Sullivan (james.osullivan@eia.gov , 202/586-2728)
International oil demand	Linda E. Doman (linda.doman@eia.gov , 202/586-1041)
Residential demand	Owen Comstock (owen.comstock@eia.gov , 202/586-4752)
Commercial demand	Erin E. Boedecker (erin.boedecker@eia.gov , 202/586-4791)
Industrial demand	Kelly A. Perl (kelly.perl@eia.gov , 202/586-1743)
Transportation demand	John D. Maples (john.maples@eia.gov , 202/586-1757)
Electricity generation, capacity	Jeff S. Jones (jeffre.jones@eia.gov , 202/586-2038)
Electricity generation, emissions	Michael T. Leff (michael.leff@eia.gov , 202/586-1297)
Electricity prices	Lori B. Aniti (lori.aniti@eia.gov , 202/586-2867)
Nuclear energy	Laura K. Martin (laura.martin@eia.gov , 202/586-1494)
Renewable energy	Chris R. Namovicz (chris.namovicz@eia.gov , 202/586-7120)
Oil and natural gas production	Philip Budzik (phillip.budzik@eia.gov , 202/586-2847)
Wholesale natural gas markets	Chetha Phang (chetha.phang@eia.gov , 202-586-4821)
Oil refining and markets	William S. Brown (william.brown@eia.gov , 202/586-8181)
Ethanol and biodiesel	Mac J. Statton (mac.statton@eia.gov , 202-586-7105)
Coal supply and prices	Michael L. Mellish (michael.mellish@eia.gov , 202/586-2136)
Carbon dioxide emissions	Diane R. Kearney (diane.kearney@eia.gov , 202/586-2415)

The *Annual Energy Outlook 2012* is available on the EIA website at www.eia.gov/forecasts/aec. Assumptions underlying the projections, tables of regional results, and other detailed results will also be available, at www.eia.gov/forecasts/aec/assumptions. Model documentation reports for the National Energy Modeling System are available at website www.eia.gov/analysis/model-documentation.cfm and will be updated for the *Annual Energy Outlook 2012* during 2012.

Other contributors to the report include Vipin Arora, Justine Barden, Joseph Benneche, Tina Bowers, Gwendolyn Bredehoeft, Phillip Budzik, Nicholas Chase, John Cochener, Michael Cole, Jim Diefenderfer, Robert Eynon, Laurie Falter, Mindi Farber-DeAnda, Adrian Geagla, Peter Gross, James Hewlett, Behjat Hojjati, Sean Hill, Kevin Jarzomski, Jim Joosten, Paul Kondis, Angelina LaRose, Thomas Lee, Tanc Lidderdale, Perry Lindstrom, Vishakh Mantri, Phyllis Martin, Elizabeth May, Carrie Milton, David Peterson, Chetha Phang, Marie Rinkowski-Spangler, Mark Schipper, Elizabeth Sendich, Joanne Shore, Robert Smith, Glen Sweetnam, Matthew Tanner, Russell Tarver, Dana Van Wagener, Diwakar Vashishat, Steven Wade, William Watson, and Peggy Wells.

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With Projections to 2035

June 2012

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Preface

The *Annual Energy Outlook 2012 (AEO2012)*, prepared by the U.S. Energy Information Administration (EIA), presents long-term projections of energy supply, demand, and prices through 2035, based on results from EIA's National Energy Modeling System (NEMS). EIA published an "early release" version of the AEO2012 Reference case in January 2012.

The report begins with an "Executive summary" that highlights key aspects of the projections. It is followed by a "Legislation and regulations" section that discusses evolving legislative and regulatory issues, including a summary of recently enacted legislation and regulations, such as: the Mercury and Air Toxics Standards (MATS) issued by the U.S. Environmental Protection Agency (EPA) in December 2011 [1]; the Cross-State Air Pollution Rule (CSAPR) as finalized by the EPA in July 2011 [2], the new fuel efficiency standards for medium- and heavy-duty vehicles published by the EPA and the National Highway Traffic Safety Administration (NHTSA) in September 2011 [3], and regulations pertaining to the power sector in California Assembly Bill 32 (AB 32), the Global Warming Solutions Act of 2006 [4].

The "Issues in focus" section contains discussions of selected energy topics, including a discussion of the results in two cases that adopt different assumptions about the future course of existing policies: one case assumes the extension of a selected group of existing public policies—corporate average fuel economy (CAFE) standards, appliance standards, production tax credits, and the elimination of sunset provisions in existing energy policies; the other case assumes only the elimination of sunset provisions. Other discussions include: oil price and production trends in the AEO2012; potential efficiency improvements and their impacts on end-use energy demand, energy impacts of proposed CAFE standards for light-duty vehicles (LDVs), model years (MYs) 2017 to 2025; impacts of a breakthrough in battery vehicle technology; heavy-duty (HD) natural gas vehicles (NGVs); changing structure of the refining industry; changing environment for fuel use in electricity generation; nuclear power in AEO2012; potential impact of minimum pipeline throughput constraints on Alaska North Slope oil production; U.S. crude oil and natural gas resource uncertainty; and evolving Marcellus shale gas resource estimates.

The "Market trends" section summarizes the projections for energy markets. The analysis in AEO2012 focuses primarily on a Reference case, Low and High Economic Growth cases, and Low and High Oil Price cases. Results from a number of other alternative cases also are presented, illustrating uncertainties associated with the Reference case projections for energy demand, supply, and prices. Complete tables for the five primary cases are provided in Appendixes A through C. Major results from many of the alternative cases are provided in Appendix D. Complete tables for all the alternative cases are available on EIA's website in a table browser at www.eia.gov/oiaf/asep/tabletop02.asp.

AEO2012 projections are based generally on Federal, State, and local laws and regulations in effect as of the end of December 2011. The potential impacts of pending or proposed legislation, regulations, and standards (and sections of existing legislation that require implementing regulations or funds that have not been appropriated) are not reflected in the projections. In certain situations, however, where it is clear that a law or regulation will take effect shortly after the AEO is completed, it may be considered in the projection.

AEO2012 is published in accordance with Section 205c of the U.S. Department of Energy (DOE) Organization Act of 1977 (Public Law 95-91), which requires the EIA Administrator to prepare annual reports on trends and projections for energy use and supply.

Projections by EIA are not statements of what will happen but of what might happen, given the assumptions and methodologies used for any particular scenario. The Reference case projection is a business-as-usual trend estimate, given known technology and technological and demographic trends. EIA explores the impacts of alternative assumptions in other scenarios with different macroeconomic growth rates, world oil prices, and rates of technology progress. The main cases in AEO2012 generally assume that current laws and regulations are maintained throughout the projections. Thus, the projections provide policy-neutral baselines that can be used to analyze policy initiatives.

While energy markets are complex, energy models are simplified representations of energy production and consumption, regulations, and producer and consumer behavior. Projections are highly dependent on the data, methodologies, model structures, and assumptions used in their development. Behavioral characteristics are indicative of real-world tendencies rather than representations of specific outcomes.

Energy market projections are subject to much uncertainty. Many of the events that shape energy markets are random and cannot be anticipated. In addition, future developments in technologies, demographics, and resources cannot be foreseen with certainty. Many key uncertainties in the AEO2012 projections are addressed through alternative cases.

EIA has endeavored to make these projections as objective, reliable, and useful as possible; however, they should serve as an adjunct to, not a substitute for, a complete and focused analysis of public policy initiatives.

Updated *Annual Energy Outlook 2012* Reference case (June 2012)

The *Annual Energy Outlook 2012* (AEO2012) Reference case included as part of this complete report, released in June 2012, was updated from the Reference case released as part of the AEO2012 Early Release Overview in January 2012. The Reference case was updated to incorporate modeling changes and reflect new legislation or regulation that was not available when the Early Release Overview version of the Reference case was published. Major changes made in the Reference include:

- The Mercury and Air Toxics Standards (MATS) issued by the EPA in December 2011 was incorporated.
- The long-term macroeconomic projection was revised, based on the November 2011 long-term projection from IHS Global Insights, Inc.
- The Cross-State Air Pollution Rule (CSAPR), which was included in the Early Release Reference case, was kept in the final Reference case. In December 2011, a District Court delayed the rule from going into effect while in litigation.
- The California Low Carbon Fuel Standard (LCFS) was removed from the final Reference case, given the Federal court ruling in December 2011 that found some aspects of it to be unconstitutional.
- Historical data and equations for the transportation sector were revised to reflect revised data from NHTSA and FHWA.
- A new cement model was incorporated in the industrial sector.
- Photovoltaic capacity estimates for recent historical years (2009 and 2010) were updated to line up more closely with Solar Energy Industries Association (SEIA) and Interstate Renewable Energy Council (IREC) reports.
- Gulf of Mexico production data were revised downward to reflect data reported by the Bureau of Ocean Energy Management more closely.
- Data in the electricity model were revised to reflect 2009 electric utility financial data (electric utility plant in service, operations and maintenance costs, etc.) and refine the breakdown of associated costs between the generation, transmission, and distribution components.
- Higher capital costs for fabric filters were adopted in the analysis of MATS, based on EPA data.
- Reservoir-level oil data were updated to improve the API gravity and sulfur content data elements.
- The assumed volume of natural gas used at export liquefaction facilities was revised.

Future analyses using the AEO2012 Reference case will start from the version of the Reference case released with this complete report.

Endnotes for Preface

Links current as of June 2012

1. U.S. Environmental Protection Agency, "Mercury and Air Toxics Standards," website www.epa.gov/mats.
2. U.S. Environmental Protection Agency, "Cross-State Air Pollution Rule (CSAPR)," website epa.gov/air/transport.
3. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule," *Federal Register*, Vol. 76, No. 179 (September 15, 2011), pp. 57106-57513, website www.gpo.gov/fdsys/pkg/FR-2011-09-15/html/2011-20740.htm.
4. California Environmental Protection Agency, Air Resources Board, "Assembly Bill 32: Global Warming Solutions Act of 2006," website www.arb.ca.gov/cc/ab32/ab32.htm.

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Executive summary

Energy demand

The projections in the U.S. Energy Information Administration’s (EIA’s) *Annual Energy Outlook 2012 (AEO2012)* focus on the factors that shape the U.S. energy system over the long term. Under the assumption that current laws and regulations remain unchanged throughout the projections, the *AEO2012* Reference case provides the basis for examination and discussion of energy production, consumption, technology, and market trends and the direction they may take in the future. It also serves as a starting point for analysis of potential changes in energy policies. But *AEO2012* is not limited to the Reference case. It also includes 29 alternative cases (see Appendix E, Table E1), which explore important areas of uncertainty for markets, technologies, and policies in the U.S. energy economy. Many of the implications of the alternative cases are discussed in the “Issues in focus” section of this report.

Key results highlighted in *AEO2012* include continued modest growth in demand for energy over the next 25 years and increased domestic crude oil and natural gas production, largely driven by rising production from tight oil and shale resources. As a result, U.S. reliance on imported oil is reduced, domestic production of natural gas exceeds consumption, allowing for net exports; a growing share of U.S. electric power generation is met with natural gas and renewables; and energy-related carbon dioxide emissions remain below their 2005 level from 2010 to 2035, even in the absence of new Federal policies designed to mitigate greenhouse gas (GHG) emissions.

The rate of growth in energy use slows over the projection period, reflecting moderate population growth, an extended economic recovery, and increasing energy efficiency in end-use applications

Overall U.S. energy consumption grows at an average annual rate of 0.3 percent from 2010 through 2035 in the *AEO2012* Reference case. The U.S. does not return to the levels of energy demand growth experienced in the 20 years prior to the 2008-2009 recession, because of more moderate projected economic growth and population growth, coupled with increasing levels of energy efficiency. For some end uses, current Federal and State energy requirements and incentives play a continuing role in requiring more efficient technologies. Projected energy demand for transportation grows at an annual rate of 0.1 percent from 2010 through 2035 in the Reference case, and electricity demand grows by 0.7 percent per year, primarily as a result of rising energy consumption in the buildings sector. Energy consumption per capita declines by an average of 0.6 percent per year from 2010 to 2035 (Figure 1). The energy intensity of the U.S. economy, measured as primary energy use in British thermal units (Btu) per dollar of gross domestic product (GDP) in 2005 dollars, declines by an average of 2.1 percent per year from 2010 to 2035. New Federal and State policies could lead to further reductions in energy consumption. The potential impact of technology change and the proposed vehicle fuel efficiency standards on energy consumption are discussed in “Issues in focus.”

Domestic crude oil production increases

Domestic crude oil production has increased over the past few years, reversing a decline that began in 1986. U.S. crude oil production increased from 5.0 million barrels per day in 2008 to 5.5 million barrels per day in 2010. Over the next 10 years, continued development of tight oil, in combination with the ongoing development of offshore resources in the Gulf of Mexico, pushes domestic crude oil production higher. Because the technology advances that have provided for recent increases in supply are still in the early stages of development, future U.S. crude oil production could vary significantly, depending on the outcomes of key uncertainties related to well placement and recovery rates. Those uncertainties are highlighted in this *Annual Energy Outlook’s* “Issues in focus” section, which includes an article examining impacts of uncertainty about current estimates of the crude oil and natural gas resources. The *AEO2012* projections considering variations in these variables show total U.S. crude oil production in 2035 ranging from 5.5 million barrels per day to 7.8 million barrels per day, and projections for U.S. tight oil production from eight selected plays in 2035 ranging from 0.7 million barrels per day to 2.8 million barrels per day (Figure 2).

Figure 1. Energy use per capita and per dollar of gross domestic product, 1980-2035 (index, 1980=1)

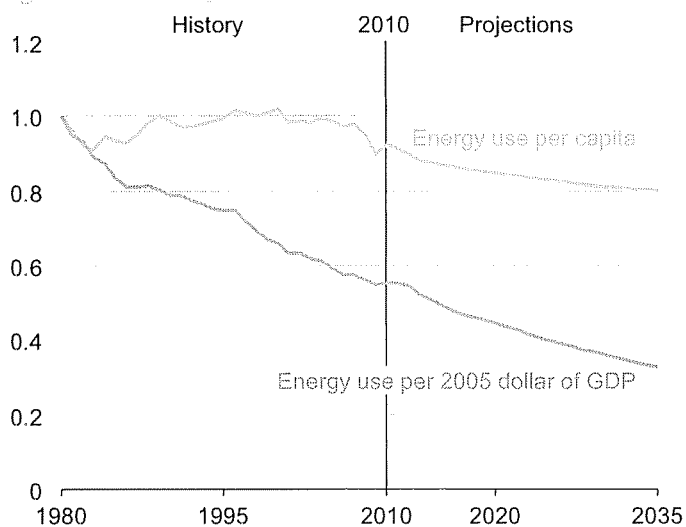
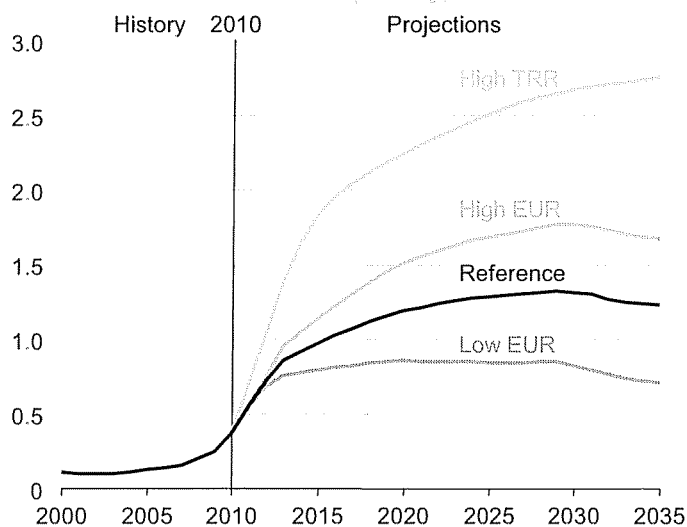


Figure 2. U.S. production of tight oil in four cases, 2000-2035 (million barrels per day)



With modest economic growth, increased efficiency, growing domestic production, and continued adoption of nonpetroleum liquids, net imports of petroleum and other liquids make up a smaller share of total U.S. energy consumption.

U.S. dependence on imported petroleum and other liquids declines in the AEO2012 Reference case, primarily as a result of rising energy prices; growth in domestic crude oil production to more than 1 million barrels per day above 2010 levels in 2020; an increase of 1.2 million barrels per day crude oil equivalent from 2010 to 2035 in the use of biofuels, much of which is produced domestically; and slower growth of energy consumption in the transportation sector as a result of existing corporate average fuel economy standards. Proposed fuel economy standards covering vehicle model years (MY) 2017 through 2025 that are not included in the Reference case would further reduce projected need for liquid imports.

Although U.S. consumption of petroleum and other liquid fuels continues to grow through 2035 in the Reference case, the reliance on imports of petroleum and other liquids as a share of total consumption declines. Total U.S. consumption of petroleum and other liquids, including both fossil fuels and biofuels, rises from 19.2 million barrels per day in 2010 to 19.9 million barrels per day in 2035 in the Reference case. The net import share of domestic consumption, which reached 60 percent in 2005 and 2006 before falling to 49 percent in 2010, continues falling in the Reference case to 36 percent in 2035 (Figure 3). Proposed light-duty vehicles (LDV) fuel economy standards covering vehicle MY 2017 through 2025, which are not included in the Reference case, could further reduce demand for petroleum and other liquids and the need for imports, and increased supplies from U.S. tight oil deposits could also significantly decrease the need for imports, as discussed in more detail in "Issues in focus."

Natural gas production increases throughout the projection period, allowing the United States to transition from a net importer to a net exporter of natural gas.

Much of the growth in natural gas production in the AEO2012 Reference case results from the application of recent technological advances and continued drilling in shale plays with high concentrations of natural gas liquids and crude oil, which have a higher value than dry natural gas in energy equivalent terms. Shale gas production increases in the Reference case from 5.0 trillion cubic feet per year in 2010 (23 percent of total U.S. dry gas production) to 13.6 trillion cubic feet per year in 2035 (49 percent of total U.S. dry gas production). As with tight oil, when looking forward to 2035, there are unresolved uncertainties surrounding the technological advances that have made shale gas production a reality. The potential impact of those uncertainties results in a range of outcomes for U.S. shale gas production from 9.7 to 20.5 trillion cubic feet per year when looking forward to 2035.

As a result of the projected growth in production, U.S. natural gas production exceeds consumption early in the next decade in the Reference case (Figure 4). The outlook reflects increased use of liquefied natural gas in markets outside North America, strong growth in domestic natural gas production, reduced pipeline imports and increased pipeline exports, and relatively low natural gas prices in the United States.

Power generation from renewables and natural gas continues to increase

In the Reference case, the natural gas share of electric power generation increases from 24 percent in 2010 to 28 percent in 2035, while the renewables share grows from 10 percent to 15 percent. In contrast, the share of generation from coal-fired power plants declines. The historical reliance on coal-fired power plants in the U.S. electric power sector has begun to wane in recent years.

Figure 3. Total U.S. petroleum and other liquids production, consumption, and net imports, 1970-2035 (million barrels per day)

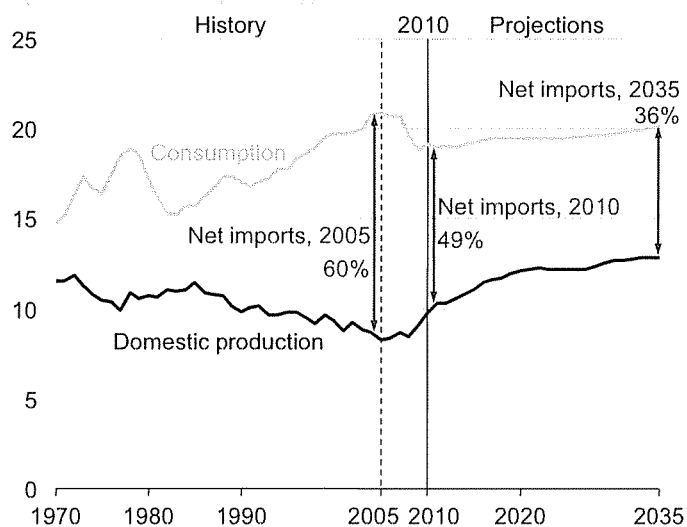
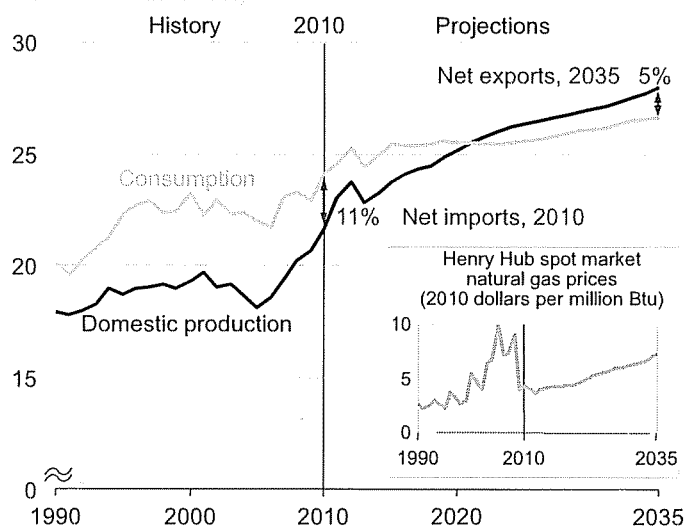


Figure 4. Total U.S. natural gas production, consumption, and net imports, 1990-2035 (trillion cubic feet)



Electricity generation

Over the next 25 years, the share of electricity generation from coal falls to 38 percent, well below the 48-percent share seen as recently as 2008, due to slow growth in electricity demand, increased competition from natural gas and renewable generation, and the need to comply with new environmental regulations. Although the current trend toward increased use of natural gas and renewables appears fairly robust, there is uncertainty about the factors influencing the fuel mix for electricity generation. AEO2012 includes several cases examining the impacts on coal-fired plant generation and retirements resulting from different paths for electricity demand growth, coal and natural gas prices, and compliance with upcoming environmental rules.

While the Reference case projects 49 gigawatts of coal-fired generation retirements over the 2011 to 2035 period, nearly all of which occurs over the next 10 years, the range for cumulative retirements of coal-fired power plants over the projection period varies considerably across the alternative cases (Figure 5), from a low of 34 gigawatts (11 percent of the coal-fired generator fleet) to a high of 70 gigawatts (22 percent of the fleet). The high end of the range is based on much lower natural gas prices than those assumed in the Reference case; the lower end of the range is based on stronger economic growth, leading to stronger growth in electricity demand and higher natural gas prices. Other alternative cases, with varying assumptions about coal prices and the length of the period over which environmental compliance costs will be recovered, but no assumption of new policies to limit GHG emissions from existing plants, also yield cumulative retirements within a range of 34 to 70 gigawatts. Retirements of coal-fired capacity exceed the high end of the range (70 gigawatts) when a significant GHG policy is assumed (for further description of the cases and results, see "Issues in focus").

Total energy-related emissions of carbon dioxide in the United States remain below their 2005 level through 2035

Energy-related carbon dioxide (CO₂) emissions grow slowly in the AEO2012 Reference case, due to a combination of modest economic growth, growing use of renewable technologies and fuels, efficiency improvements, slow growth in electricity demand, and increased use of natural gas, which is less carbon-intensive than other fossil fuels. In the Reference case, which assumes no explicit Federal regulations to limit GHG emissions beyond vehicle GHG standards (although State programs and renewable portfolio standards are included), energy-related CO₂ emissions grow by just over 2 percent from 2010 to 2035, to a total of 5,758 million metric tons in 2035 (Figure 6). CO₂ emissions in 2020 in the Reference case are more than 9 percent below the 2005 level of 5,996 million metric tons, and they still are below the 2005 level at the end of the projection period. Emissions per capita fall by an average of 1.0 percent per year from 2005 to 2035.

Projections for CO₂ emissions are sensitive to such economic and regulatory factors due to the pervasiveness of fossil fuel use in the economy. These linkages result in a range of potential GHG emissions scenarios. In the AEO2012 Low and High Economic Growth cases, projections for total primary energy consumption in 2035 are, respectively, 100.0 quadrillion Btu (6.4 percent below the Reference case) and 114.4 quadrillion Btu (7.0 percent above the Reference case), and projections for energy-related CO₂ emissions in 2035 are 5,356 million metric tons (7.0 percent below the Reference case) and 6,117 million metric tons (6.2 percent above the Reference case).

Figure 5. Cumulative retirements of coal-fired generating capacity, 2011-2035 (gigawatts)

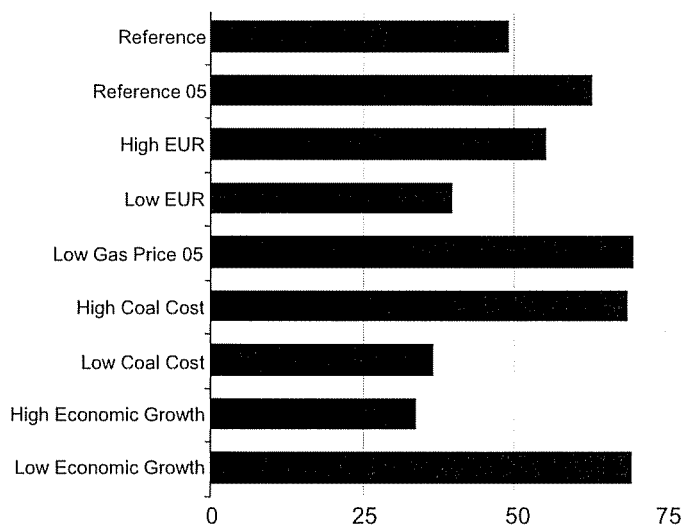
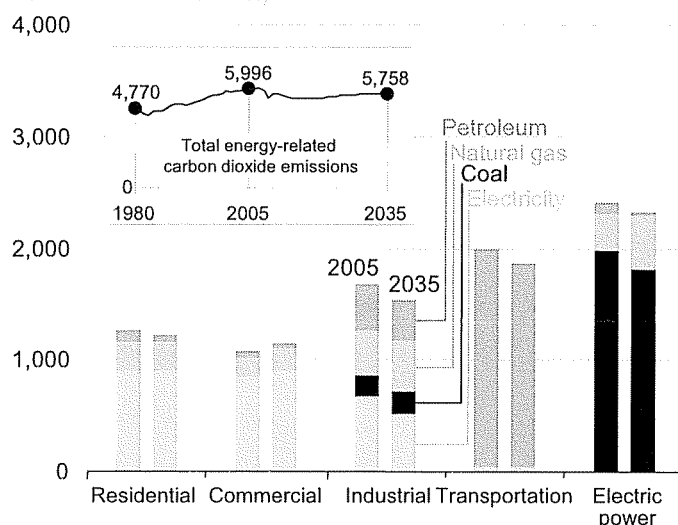


Figure 6. U.S. energy-related carbon dioxide emissions by sector and fuel, 2005 and 2035 (million metric tons)



Legislation and regulations

Legislation and Regulations

Introduction

The *Annual Energy Outlook 2012* (AEO2012) generally represents current Federal and State legislation and final implementation regulations available as of the end of December 2011. The AEO2012 Reference case assumes that current laws and regulations affecting the energy sector are largely unchanged throughout the projection period (including the implication that laws that include sunset dates do, in fact, become ineffective at the time of those sunset dates) [5]. The potential impacts of proposed legislation, regulations, or standards—or of sections of legislation that have been enacted but require funds or implementing regulations that have not been provided or specified—are not reflected in the AEO2012 Reference case, but some are considered in alternative cases. This section summarizes Federal and State legislation and regulations newly incorporated or updated in AEO2012 since the completion of the *Annual Energy Outlook 2011*.

Examples of recently enacted Federal and State legislation and regulations incorporated in the AEO2012 Reference case include:

- New greenhouse gas (GHG) emissions and fuel consumption standards for medium- and heavy-duty engines and vehicles, published by the U.S. Environmental Protection Agency (EPA) and the National Highway Transportation Safety Administration (NHTSA) in September 2011 [6]
- The Cross-State Air Pollution Rule (CSAPR), as finalized by the EPA in July 2011 [7]
- Mercury and Air Toxics Standards (MATS) rule, issued by the EPA in December 2011 [8].

There are many other pieces of legislation and regulation that appear to have some probability of being enacted in the not-too-distant future, and some laws include sunset provisions that may be extended. However, it is difficult to discern the exact forms that the final provisions of pending legislation or regulations will take, and sunset provisions may or may not be extended. Even in situations where existing legislation contains provisions to allow revision of implementing regulations, those provisions may not be exercised consistently. Many pending provisions are examined in alternative cases included in AEO2012 or in other analyses completed by the U.S. Energy Information Administration (EIA). In addition, at the request of the Administration and Congress, EIA has regularly examined the potential implications of proposed legislation in Service Reports. Those reports can be found on the EIA website at www.eia.doe.gov/coal/service_reports.html.

1. Greenhouse gas emissions and fuel consumption standards for heavy-duty vehicles, model years 2014 through 2018

On September 15, 2011, the EPA and NHTSA jointly announced a final rule, called the HD National Program [9], which for the first time established GHG emissions and fuel consumption standards for on-road heavy-duty trucks with a gross vehicle weight rating (GVWR) above 8,500 pounds (Classes 2b through 8) [10] and their engines. The AEO2012 Reference case incorporates the new standards for heavy-duty vehicles (HDVs).

Due to the tremendous diversity of HDV uses, designs, and power requirements, the HD National Program separates GHG and fuel consumption standards into discrete vehicle categories within combination tractors, vocational vehicles, and heavy-duty pickups and vans (Table 1). Further, the rule recognizes that reducing GHG emissions and fuel consumption will require changes to both the engine and the body of a vehicle (to reduce the amount of work demanded by an engine). The final rule sets separate standards for the different engines used in combination tractors and vocational vehicles. AEO2012 represents standard compliance among HDV regulatory classifications that represent the discrete vehicle categories set forth in the rule.

The HD National Program standards begin for model year (MY) 2014 vehicles and engines and are fully phased in by MY 2018. The EPA, under authority granted by the Clean Air Act, has issued GHG emissions standards that begin with MY 2014 for all engine and body categories. NHTSA, operating under regulatory timelines mandated by the Energy Independence and Security Act [11], set voluntary fuel consumption standards for MY 2014 and 2015, with the standards becoming mandatory for MY 2016 and beyond, except for diesel engine standards, which become mandatory for MY 2017 and beyond. Standards reach the most stringent levels for combination tractors and vocational vehicles in MY 2017, with subsequent standards then holding constant. Heavy-duty pickup and van standards are required to reach the highest level of stringency in MY 2018. AEO2012 includes the HD

Table 1. HD National Program vehicle regulatory categories

Category	Description	GVWR
Combination tractors	Combination tractors are semi trucks designed to pull trailers. Standards are set separately for tractor cabs and their engines. There are no GHG or fuel consumption standards for trailers.	Class 7 and 8 (26,001 pounds and above)
Vocational vehicles	Vocational vehicles include a wide range of truck configurations, such as delivery, refuse, utility, dump, cement, fire, and tow trucks, school buses, and ambulances. The rulemaking defines vocational vehicles as all heavy-duty trucks that are not combination tractors or heavy-duty pickups or vans. Vocational vehicle standards are set separately for chassis and engines.	Class 2b through 8 (8,501 pounds and above)
Heavy-duty pickups and vans	Pickup trucks and vans are primarily 3/4-ton or 1-ton pickups used on construction sites or 12- to 15-person passenger vans.	Class 2b and 3 (8,501 to 14,000 pounds)

National Program standards beginning in MY 2014 as set by the GHG emissions portion of the rule, with standards represented by vehicle, including both the chassis and engine. AEO2012 assumes that vehicle chassis and engine manufacturers comply with the voluntary portion of the rule covering the fuel consumption standard. AEO2012 does not model the chassis and engine standards separately but allows the use of technologies to meet the HD National Program combined engine and chassis standards.

Although they are not modeled separately in AEO2012, GHG emission and fuel consumption standards for combination tractors are set for the tractor cabs and the engines used in those cabs separately in the HD National Program. Combination tractor cab standards are subdivided by GVWR (Class 7 or 8), cab type (day or sleeper), and roof type (low, mid, or high). Combination tractor engine standards are subdivided into medium heavy-duty diesel (for use in Class 7 tractors) and heavy heavy-duty diesel (for use in Class 8 tractors) (Table 2). Each tractor cab and engine combination is required to meet the GHG and fuel consumption standards for a given model year, unless they are made up by credits or other program flexibilities.

Again, although they are not modeled separately in AEO2012, GHG emission and fuel consumption standards for vocational vehicles are set separately in the HD National Program for the vehicle chassis and the engines used in the chassis. Vocational vehicle chassis standards are subdivided in the rule by GVWR (Classes 2b to 5, Classes 6 and 7, and Class 8). Vocational vehicle engine standards are subdivided into light heavy-duty diesel (for use in Classes 2b through 5), medium heavy-duty diesel (for use in Classes 6 and 7), heavy heavy-duty diesel (for use in Class 8), and spark-ignited (primarily gasoline) engines (for use in all classes) (Table 3). Each vocational vehicle chassis and engine combination is required to meet the GHG and fuel consumption standard for a given model year, unless made up by credits or other program flexibilities.

Standards for heavy-duty pickups and vans are based on the "work factor"—a weighted average of the vehicle's payload and towing capacity, adjusted for four-wheel drive capability. The standards for heavy-duty pickups and vans are different for diesel

Table 2. HD National Program standards for combination tractor greenhouse gas emissions and fuel consumption (assuming fully compliant engine)

Roof type	Day cab		Sleeper cab
	Class 7	Class 8	Class 8
2014 GHG emissions standards (grams CO ₂ per ton-mile)			
Low roof	107	81	68
Mid roof	119	88	76
High roof	124	92	75
2014-2016 voluntary fuel consumption standards (gallons per 1,000 ton-miles)			
Low roof	10.5	8.0	6.7
Mid roof	11.7	8.7	7.4
High roof	12.2	9.0	7.3
2017 GHG emissions standards (grams CO ₂ per ton-mile)			
Low roof	104	80	66
Mid roof	115	86	73
High roof	120	89	72
2017 fuel consumption standards (gallons per 1,000 ton-miles)			
Low roof	10.2	7.8	6.5
Mid roof	11.3	8.4	7.2
High roof	11.8	8.7	7.1

Table 3. HD National Program standards for vocational vehicle greenhouse gas emissions and fuel consumption (assuming fully compliant engine)

Standard	Light heavy-duty (Classes 2b-5)	Medium heavy-duty (Classes 6-7)	Heavy heavy-duty (Class 8)
2014 GHG emissions standard (grams CO ₂ per ton-mile)	388	234	226
2016 fuel consumption standard (gallons per 1,000 ton-miles)	38.1	23.0	22.2
2017 GHG emissions standards (grams CO ₂ per ton-mile)	373	225	222
2017 fuel consumption standard (gallons per 1,000 ton-miles)	36.7	22.1	21.8

Figure 7. HD National Program model year

standards for diesel pickup and van greenhouse gas emissions and fuel consumption, 2014-2018.

and gasoline engines (Figures 7 and 8). They differ from the standards for combination tractors and vocational vehicles in that they apply to the vehicle fleet average for each manufacturer for a given model year, based on a production volume-weighted target for each model, with targets differing by work factor attribute.

The final rulemaking exempts small manufacturers of heavy-duty engines, combination tractor cabs, or vocational vehicle chassis from the GHG emissions and fuel consumption standards. Fuel consumption and GHG emissions for alternative-fuel vehicles, such as compressed natural gas vehicles, will be calculated according to their tailpipe emissions. Finally, the rulemaking contains four provisions designed to give manufacturers flexibility in meeting the GHG and fuel consumption standards. Both the EPA and NHTSA will allow for early compliance credits in MY 2013; manufacturer averaging, banking, and trading; advanced technology credits; and innovative technology credits. Those flexibility provisions are not included in the AEO2012 Reference case.

1. Cross-State Air Pollution Rule

The CSAPR was created to regulate emissions of sulfur dioxide (SO₂) and nitrogen oxides (NO_x) from power plants greater than 25 megawatts that generate electric power from fossil fuels. CSAPR is intended to assist States in achieving their National Ambient Air Quality Standards for fine particulate matter and ground-level ozone. Limits on annual emissions of SO₂ and NO_x are designed to address fine particulate matter. The seasonal NO_x limits address ground-level ozone. Twenty-three States are subject to the annual limits, and 25 States are subject to the seasonal limits [72].

CSAPR replaces the Clean Air Interstate Rule (CAIR). CAIR is an interstate emissions cap-and-trade program for SO₂ and NO_x that would have allowed for unlimited trading among 28 eastern States. It was finalized in 2005, and requirements for emissions reductions were scheduled to begin 2009. In 2008, however, the U.S. Court of Appeals for the D.C. Circuit found that CAIR did not sufficiently meet the Clean Air Act requirements and directed the EPA to fix the flaws that it identified while CAIR remained in effect.

In July 2011, the EPA published CSAPR, with State coverage as shown in Figure 9. CSAPR consists of four individual cap-and-trade programs:

- Group 1 SO₂ covers 16 States.
- Group 2 SO₂ covers 7 States [73].
- Annual NO_x Group consists of an annual cap-and-trade program that covers all Group 1 and Group 2 SO₂ States.
- Seasonal NO_x Group covers a separate set of States, 20 of which are also in the Annual NO_x Group and 5 of which are not.

There are two SO₂ control groups, because the EPA has determined that the States in Group 1 need to meet more stringent emissions reduction requirements.

All cap-and-trade programs specified in CSAPR are included in AEO2012, but because the National Energy Modeling System (NEMS) does not represent electric power markets at the State level, the four group emissions caps and corresponding allowance trading could not be explicitly represented. The cap-and-trade systems for annual SO₂ and NO_x emissions are implemented for the coal demand regions by aggregating the allowance budget for each State within a region.

Figure 7. HD National Program model year standards for diesel pickup and van greenhouse gas emissions and fuel consumption, 2014-2018

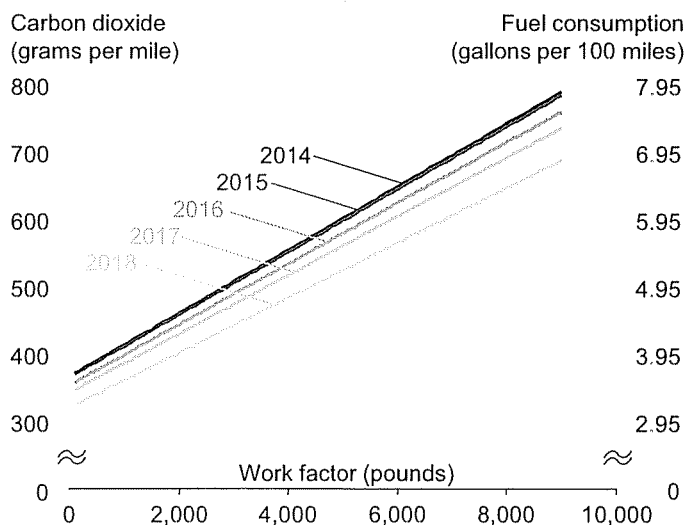
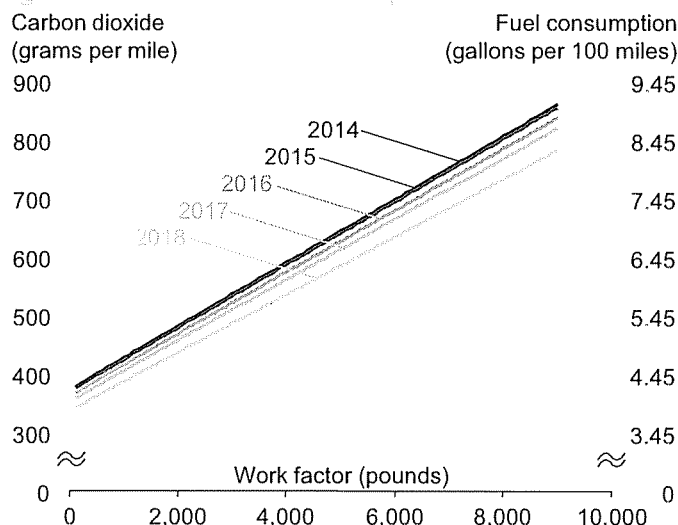


Figure 8. HD National Program model year standards for gasoline pickup and van greenhouse gas emissions and fuel consumption, 2014-2018



The EPA scheduled three annual cap-and-trade programs to commence in January 2012 and the summer season NO_x program to begin in May 2012. For three of the four programs, the initial annual cap does not change over time. For the Group 1 SO₂ program, the emissions cap across States is reduced substantially in 2014.

Emissions trading is unrestricted within a group but is not allowed across groups. Therefore, emissions allowances exist for four independent trading programs. Each State is designated an annual emissions budget, with the sum of the budgets making up the overall group emissions cap. Sources can collectively exceed State emissions budgets by close to 20 percent without any penalty. If the sources collectively exceed the State emission budget by more than the 20 percent, the sources responsible must “pay a penalty” in addition to submitting the additional allowances. The EPA set the penalties with the goal of ensuring that emissions produced by upwind States would not exceed assurance levels and contribute to air quality problems in downwind States. The emissions allowances are allocated to generating units primarily on the basis of historical energy use.





CSAPR was scheduled to begin on January 1, 2012, but the Court of Appeals issued a stay that is delaying implementation while it addresses legal challenges to the rule that have been raised by several power companies and States [74]. CSAPR is included in AEO2012 despite the stay, because the Court of Appeals had not made a final ruling at the time AEO2012 was completed.

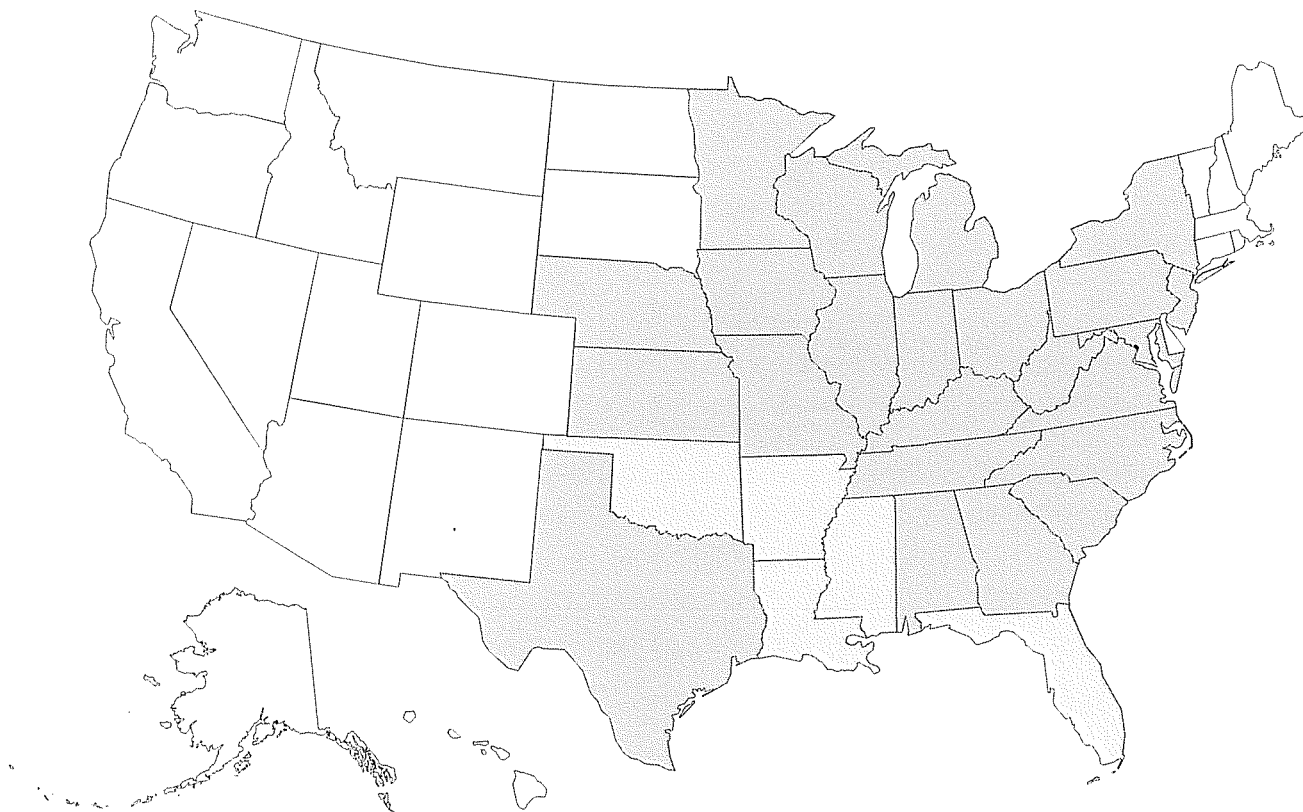
3. Mercury and air toxics standards

The MATS [15] are required by Section 112 of the 1990 Clean Air Act Amendments, which requires that maximum achievable control technology be applied to power plants to control emissions of hazardous air pollutants (HAPs) [16]. The MATS rule, finalized in December 2011, regulates mercury (Hg) and other HAPs from power plants. MATS applies to Hg and hazardous acid gases, metals, and organics from coal- and oil-fired power plants with nameplate capacities greater than 25 megawatts [17]. The standards take effect in 2015.

The AEO2012 Reference case assumes that all coal-fired generating units with capacity greater than 25 megawatts will comply with the MATS rule beginning in 2015. The MATS rule is not applied to oil-fired steam units in AEO2012 because of their small size and limited importance. In order to comply with the MATS rule for coal, the NEMS model requires all coal-fired power plants to

Figure 9. States covered by CSAPR limits on emissions of sulfur dioxide and nitrogen oxides

-  States controlled for both fine particles (annual SO₂ and NO_x) and ozone (ozone season NO_x) (20 States)
-  States controlled for fine particles only (annual SO₂ and NO_x) (3 States)
-  States controlled for ozone only (ozone season NO_x) (5 States)
-  States not covered by the Cross-State Air Pollution Rule



reduce Hg emissions to 90 percent below their uncontrolled emissions levels by using scrubbers and activated carbon injection controls. NEMS does not explicitly model the emissions of acid gases, toxic metals other than Hg, or organic HAPs. Therefore, in order to measure the impact of these rules, specific control technologies—either flue gas desulfurization scrubbers or dry sorbent injection systems—are assumed to be used to achieve compliance. A full fabric filter also is required to meet the limits on emissions of metals other than Hg and to improve the effectiveness of the dry sorbent injection systems. NEMS does not model the best practices associated with reductions in dioxin emissions, which also are covered by the MATS rule.

4. Updated State air emissions regulations

As its first 3-year compliance period came to a close, the Regional Greenhouse Gas Initiative (RGGI) continued to apply to fossil-fuel-fired power plants larger than 25 megawatts capacity in the northeastern United States, despite New Jersey's decision to withdraw from the program at the end of 2011. There are now nine States in the accord, which caps carbon dioxide (CO₂) emissions from covered electricity generating facilities and requires each ton of CO₂ emitted to be offset by an allowance purchased at auction. Because the program is binding, it is included in *AEO2012* as specified in the agreement.

The reduction of CO₂ emissions from the power sector in the RGGI region since 2009 is primarily a result of broader market trends. Since mid-2008, natural gas prices and electricity demand in the Northeast have fallen, while coal prices have increased. Because the RGGI baseline and projected emissions were calculated before the economic recession that began in 2008, the emissions caps are higher than actual emissions have been, leading to an excess of available allowances in recent auctions. In the past seven auctions, allowances have sold at the floor price of \$1.89 per ton [18], indicating that emissions in the region are at or below the program-mandated ceiling.

As a result of the noncompetitive auctions, in which credits have not actually been traded but simply purchased at a floor price, several States have decided to retire their excess allowances permanently [19], which will result in the removal of 67 million tons of CO₂ from the RGGI emissions ceiling. Moreover, the program began a stakeholder hearing process in January 2012 that will last through the summer of 2012. The hearings, which are designed to adjust the program at the end of the first compliance period, may alter the program significantly. Because no changes have been finalized, however, modeling of the provisions in *AEO2012* is the same as in previous *Annual Energy Outlooks*.

The Western Climate Initiative is another program designed to establish a GHG emissions trading program, although the final details of the program remain undecided [20]. At the stakeholders meeting in January 2012, the commitment to emissions trading was reaffirmed. Because of the continued uncertainty over the implementation and design of the final program, it is not included in the *AEO2012* projections.

The California cap-and-trade system for GHG emissions, designed by the California Air Resources Board (CARB) in response to California Assembly Bill 32, the Global Warming Solutions Act of 2006 [21], is discussed in the following section.

5. California Assembly Bill 32: The Global Warming Solutions Act of 2006

California Assembly Bill 32 (AB 32), the Global Warming Solutions Act of 2006, authorized the CARB to set California's GHG reduction goals for 2020 and establish a comprehensive, multi-year program to reduce GHG emissions in California. As one of the major initiatives for AB 32, CARB designed a cap-and-trade program that started on January 1, 2012, with the enforceable compliance obligations beginning in 2013.

The cap-and-trade program is intended to help California achieve its goal of reducing emissions to 1990 levels by 2020. The program covers several GHGs, with the most significant being CO₂ [22]. In 2007, CARB determined that 427 million metric tons carbon dioxide equivalent (MMTCO₂e) was the total State-wide GHG emissions level in 1990 and, therefore, would be the 2020 emissions target. All electric power plants, large industrial facilities, suppliers of transportation fuel, and suppliers of natural gas in California are required to submit emissions allowances for each ton of CO₂ or CO₂-equivalent emissions they produce, in order to comply with the final rule [23]. Emissions resulting from electricity generated outside California but consumed in the State also are subject to the cap.

The cap-and-trade program applies to multiple economic sectors throughout the State's economy, but for *AEO2012*, due to modeling limitations, it is assumed to be implemented only in the electric power sector. *AEO2012* places limits on emissions from electric power plants and cogeneration facilities in California, as well as power plants in other States that sell power to California. The cap is set to begin in 2013 and to decline linearly to 85 percent of the 2013 value by 2020.

The enforceable cap goes into effect in 2013, and there are three compliance periods—multi-year periods for which the compliance obligation is calculated for covered entities. The first compliance period lasts for 2 years, and the second and third periods last for 3 years each, as follows:

- Compliance Period 1: 2013-2014
- Compliance Period 2: 2015-2017
- Compliance Period 3: 2018-2020.

The electricity and industrial sectors are required to comply with the cap starting in 2013. Suppliers of natural gas and transportation fuels are required to comply starting in 2015, when the second compliance period begins. For the first compliance period, covered entities are required to submit allowances for up to 30 percent of their annual emissions in each year; however, at the end of 2014 they are required to account for all the emissions for which they were responsible during the 2-year period.

Annual GHG allowance budgets for the State (i.e., emissions caps) are set by the final rule [24] as follows: for 2013, 162.8 MMTCO₂e; for 2014, 159.7 MMTCO₂e; for 2015, 394.5 MMTCO₂e; for 2016, 382.4 MMTCO₂e; for 2017, 370.4 MMTCO₂e; for 2018, 358.3 MMTCO₂e, for 2019, 346.3 MMTCO₂e, and for 2020, 334.2 MMTCO₂e.

A majority of the allowances (51 percent) [25] allocated over the initial 8 years of the program will be distributed through auctions, which will be held quarterly when the program commences. Auctions are set to begin in 2012, and the program caps will take effect in 2013. Revenue gained from the auctions is intended to be used for purposes related to AB 32, as determined by the Governor and the State Legislature.

Twenty-five percent of the allowances are allocated directly to electric utilities that sell electricity to consumers in the State. The utilities are then required to put their allowances up for auction and use the revenue generated from the auction to credit ratepayers. An exception is made for public power agencies, which will be able to keep allowances for compliance.

Seventeen percent of the allowances are allocated directly to industrial facilities covered by the rule, in order to mitigate the economic impact of the cap on the industrial sector. Over the 2013-2020 period, the number of allowances allocated annually to the industrial sector declines linearly, by a total of 50 percent.

The remaining 7 percent of the allowances issued in a given year go into a cost containment reserve and forward reserve auction. The cost containment reserve is intended to be called on only if allowance prices rise above a set amount. Each entity can also use offsets to meet up to 8 percent of its compliance obligation. Offsets used as part of the program must be approved by the CARB.

7. State renewable energy requirements and goals: Update (through 2011)

To the extent possible, AEO2012 incorporates the impacts of State laws requiring the addition of renewable generation or capacity by utilities doing business in the States. Currently, 30 States and the District of Columbia have an enforceable renewable portfolio standard (RPS) or similar laws (Table 4). Under such standards, each State determines its own levels of renewable generation, eligible technologies [26], and noncompliance penalties. AEO2012 includes the impacts of all laws in effect at the end of 2011 (with the exception of Alaska and Hawaii, because NEMS provides electricity market projections for the contiguous lower 48 States only). However, the projections do not include policies with either voluntary goals or targets that can be substantially satisfied with nonrenewable resources. In addition, the model is not able to treat fuel-specific provisions—such as those for solar and offshore wind energy—as distinct targets. Where applicable, these distinct targets (sometimes referred to as “tiers,” “set-asides,” or “carve-outs”) may be subsumed into the broader targets, or are not modeled because they may be met with existing capacity and/or projected growth based on modeled economic and policy factors.

In the AEO2012 Reference case, States generally are assumed to meet their ultimate RPS targets. The RPS compliance constraint in most regions is approximated, because NEMS is not a State-level model, and each State generally represents only a portion of one of the NEMS electricity regions. Compliance costs in each region are tracked, and the projection for total renewable generation is checked for consistency with any State-level cost-control provisions, such as caps on renewable credit prices,

limits on State compliance funding, or impacts on consumer electricity prices. In general, EIA has confirmed the States’ requirements through original documentation, although the Database of State Incentives for Renewables & Efficiency was also used to support those efforts [27].

No new RPS programs were enacted over the past year; however, some States with existing RPS programs made modifications in 2011. The aggregate RPS requirement for the various State programs, as modeled in AEO2012, is shown in Figure 10. By 2025, these targets account for about 10 percent of U.S. sales. The requirement is derived from the legal targets and projected sales, and does not account for any discretionary or nondiscretionary waivers or limits on compliance found in most State RPS programs. State RPS policies are not the only driver of growth in renewable generation, and a more complete discussion of those factors can be found in “Market trends.” The following sections detail the significant changes made by the States. In addition, Table 4 provides a summary of all State RPS laws.

Figure 10. Total combined requirement for State renewable portfolio standards, 2015-2035 (billion kilowatt-hours)

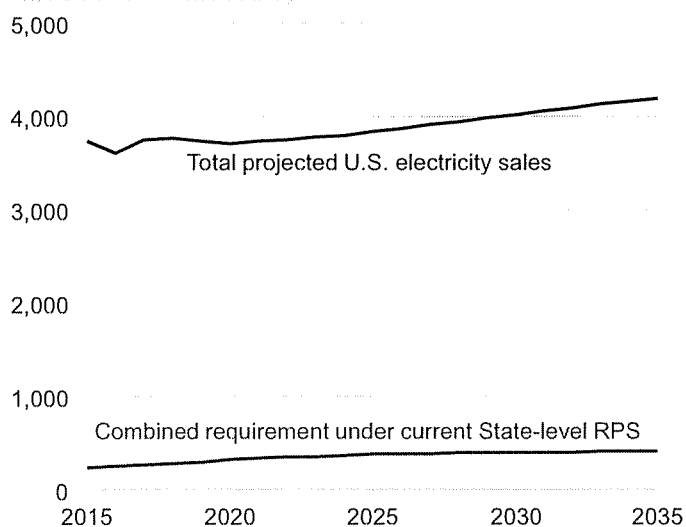


Table 1 Renewable portfolio standards in the 10 States with current mandates

State	Program mandate
AZ	Arizona Corporate Commission Decision No. 69127 requires 15 percent of electricity sales to be renewable by 2025, with interim goals increasing annually. A specific percentage of the target must be from distributed generation. Multiple credits may be provided to solar generation and systems manufactured in-State.
CA	SBX1-2, enacted in 2011, requires that 33 percent of electricity sales be met by renewable sources by 2020. The legislation codifies the 33 percent requirement in Executive Order S-21-09, which served as a continuation of California's first RPS, in which investor-owned utilities (IOUs) were required to deliver 20 percent of sales from renewable sources. Under SBX1-2, both IOUs and publicly owned municipal utilities are subject to the RPS
CO	Enacted in March of 2010, House Bill (HB) 1001 strengthens the State's existing RPS program by requiring that 20 percent of electricity generated by IOUs in 2015 be renewable, increasing to 30 percent in 2020. There is also a distributed generation requirement. In-State generation receives a 25-percent credit premium
CT	Public Act 07-242 mandates a 27-percent renewable sales requirement by 2020, including a 4-percent mandate for higher efficiency or combined heat and power systems. Of the overall total, 3 percent may be met by waste-to-energy and conventional biomass facilities
DE	Senate Substitute 1 amended Senate Bill (SB) 119 to extend the increasing RPS targets to 2025; 25 percent of generation is now required to come from renewable sources in 2025. There is a separate requirement for solar generation (3.5 percent of the total in 2025), and there are penalty payments for compliance failure. Offshore wind generation receives 3.5 times the credit amount, and solar technologies receive 3 times the credit amount.
HI	HB 1464 sets the renewable mandate at 40 percent by 2030. All existing renewable facilities are eligible to meet the target, which has two interim milestones. (Not included in NEMS)
IL	Public Act 095-0481 created an agency responsible for overseeing the mandate of 25-percent renewable sales by 2025, with escalating annual targets. In addition, 75 percent of the required sales must be generated from wind, 6 percent from solar, and 1 percent from distributed generation. The plan also includes a cap on the incremental costs resulting from the penetration of renewable generation. In 2009, the rule was modified to cover sales outside a utility's home territory.
IA	In 1983, a capacity mandate of 105 megawatts of renewable energy capacity was adopted. By the end of 2010, Iowa had well over 3,000 megawatts of wind-powered capacity alone.
KS	In 2009, HB 2369 established a requirement that 20 percent of installed capacity must use renewable resources by 2020.
ME	In 2007, Public Law 403 was added to the State's RPS requirements. The law requires that 10 percent of sales come from new renewable capacity by 2017, and that level must be maintained in subsequent years. The years leading up to 2017 also have new generation milestones. Generation from eligible community-owned facilities receives a 10-percent credit premium.
MD	In April 2008, HB 375 revised the preceding RPS to contain a 20-percent target by 2022, including a 2-percent solar target. HB 375 also raised penalty payments for "Tier 1" compliance shortfalls to 4 cents per kilowatthour. SB 277, while preserving the 2-percent by 2022 solar target, made the interim solar requirements and penalty payments slightly less stringent. In 2011, SB 717 extended the eligibility of the solar target to include solar water heating systems.
MA	The State RPS has a goal of a 15-percent renewable share of total sales by 2020 and includes necessary payments for compliance shortfalls. Eligible biomass is restricted to low-carbon life cycle emission sources. A Solar Carve-Out Program was also added, which seeks to establish 400 megawatts of solar generating capacity.
MI	Public Act 295, enacted in 2008, established an RPS that will require 10 percent of all electricity sales to be generated from renewable sources by 2015. Double credits are given to solar energy. In addition, the State's large utilities are required to procure an additional combined total of 1,100 megawatts of renewable capacity by 2015, although generation from those facilities may be counted toward the generation-based RPS.
MN	SF 4 created a 30-percent renewable requirement by 2020 for Xcel, the State's largest supplier, and a 25-percent requirement by 2025 for other suppliers. The 30-percent requirement for Xcel consists of 24 percent that must be from wind, 1 percent that can be from wind or solar, and 5 percent that can be from other resources.
MO	In November 2008, Missouri voters approved Proposition C, which mandates a 2-percent renewable energy requirement in 2011, increasing incrementally to 15 percent of generation in 2021. Bonus credits are given to renewable generation within the State.
MT	HB 681, approved in April 2007, expanded the State RPS provisions to all suppliers. Initially the law covered only regulated utilities. A 15-percent share of sales must be renewable by 2015. The State operates a renewable energy credit market.
NV	The State has an escalating renewable target, established in 1997 and most recently revised in 2009 by SB 358, which mandates a 25-percent renewable generation share of sales by 2025. Up to one-quarter of the 25-percent share may be met through efficiency measures. There is also a minimum requirement for photovoltaic systems, which receive bonus credits.

(continued on next page)

Table 4. Renewable portfolio standards in the 50 States with current mandates (continued)

State	Program mandate
NH	HB 873, passed in May 2007, legislated that 23.8 percent of electricity sales must be met by renewables in 2025. Compliance penalties vary by generation type.
NJ	In 2006, the New Jersey Board of Public Utilities revised the State RPS to increase the renewable generation target to 22.5 percent of sales by 2021, with interim targets. Assembly Bill (AB) 3520, enacted in 2010, further refines the mandate to include 5,300 gigawatthours of solar generation by 2026, with the percentage-based RPS component to reach 20.38 percent by 2021, not including the required solar generation. SB 2036 has a specific provision for offshore wind, with a goal to develop 1,100 megawatts of capacity.
NM	SB 418, passed in March 2007, directs investor-owned utilities to derive 20 percent of their sales from renewable generation by 2020. The renewable portfolio must consist of diversified technologies, with wind and solar each accounting for 20 percent of the target. There is a separate standard of 10 percent by 2020 for cooperatives.
NY	The Public Service Commission issued updated RPS rules in January 2010 that expand the program to a 30-percent requirement by 2015. There is also a separate end-use standard. The program is administered and funded by the State.
NC	In 2007, SB 3 created an RPS of 12.5 percent by 2021 for investor-owned utilities. There is also a 10-percent requirement by 2018 for cooperatives and municipals. Through 2018, 25 percent of the target may be met through efficiency standards, increasing to 40 percent in later years. Verifiable electricity demand reduction can also satisfy the RPS, with no upper limit.
OH	SB 221, passed in May 2008, requires 25 percent of electricity sales to be produced from alternative energy resources by 2025, including low-carbon and renewable technologies. One-half of the target must come from renewable sources. Municipals and cooperatives are exempt.
OR	SB 838, signed into law in June 2007, requires that renewable generation account for 25 percent of sales by 2025 for large utilities, and 5 to 10 percent of sales by 2025 for smaller utilities. Renewable electricity on line after 1995 is considered eligible.
PA	The Alternative Energy Portfolio Standard, signed into law in November 2004, has an 18-percent requirement by 2020. Most of the qualifying generation must be renewable, but there is also a provision that allows waste coal resources to receive credits.
RI	The Renewable Energy Standard was signed into law in 2004. The program requires that 16 percent of total sales be renewable by 2019. The interim program targets escalate more rapidly in later years. If the target is not met, a generator must pay an alternative compliance penalty. State utilities also must procure 90 megawatts of new renewable capacity, including 3 megawatts of solar, by 2014.
TX	SB 20, passed in August 2005, strengthened the State RPS by mandating 5,880 megawatts of renewable capacity by 2015. There is also a target of 500 megawatts of renewable capacity other than wind.
WA	In November 2006, Washington voters approved Initiative 937, which specifies that 15 percent of sales from the State's largest generators must come from renewable sources by 2020. There is an administrative penalty of 5 cents per kilowatthour for noncompliance. Generation from any otherwise qualified facility that came on line after 1999 is eligible.
WV	HB 103, passed in June 2009, established a requirement that 25 percent of electricity sales must come from alternative energy resources by 2025. Alternative energy was defined to include various renewables, along with several different fossil energy technologies.
WI	SB 459, passed in March 2006, strengthened the State RPS with a requirement that, by 2015, 10 percent of electricity sales must be generated from renewable resources, and that the renewable share of total generation must be at least 6 percentage points above the average renewable share from 2001 to 2003.

California

The State codified its RPS of 33 percent by 2020 through the passage of SBX1-2, the California Renewable Energy Resources Act [28]. The California Public Utilities Commission and California Energy Commission are the primary implementing authorities for SBX1-2, which builds on California's prior RPS mandate for 20 percent of electricity sales by 2010 [29]. SBX1-2 extends the application of the RPS to local publicly owned utilities, which had greater flexibility under the State's previous RPS mandate. SBX1-2 supersedes the 2009 Executive Order that charged the CARB with implementing the 33-percent RPS; however, CARB does retain an enforcement role over publicly owned local utilities. Because implementing regulations were not available at the time the AEO2012 projections were being developed, the 2009 Executive Order was modeled. Although the targets specified in the two programs are similar, enforcement mechanisms may differ significantly.

Connecticut

Public Act 11-80 adds a solar-specific component to the existing RPS target, which requires that renewables should account for 27 percent of sales by 2020 [30]. The State's Clean Energy Finance and Investment Authority is tasked with creating an investment program that will result in the procurement of 30 megawatts of residential solar installations that can be counted toward the general RPS requirement.

7. State renewable energy legislation

Delaware

Delaware enacted SB 124, which extends the list of sources eligible to meet the State's RPS to include fuel cells under certain conditions [37]. Fuel cell projects that can be fueled by renewable sources and that are owned or operated by qualified providers can apply to earn renewable energy credits and, on a limited basis, solar renewable energy credits.

Illinois

With the enactment of SB 1652, the State augmented its existing RPS to include a distributed generation requirement [32]. SB 1652 requires that 1 percent of the renewable target (25 percent of sales from renewable sources by 2025 for large utilities) be fulfilled by distributed generation by mid-2015, with incremental targets beginning to take effect in 2013.

Maryland

The State enacted two pieces of legislation that allow for additional flexibility in meeting the existing RPS target of 20 percent of sales from renewable generation by 2022. SB 690 extends the designation of waste-to-energy facilities as qualifying to meet the 20-percent target beyond 2022, rather than sunseting [33]. In addition, SB 717 specifies that solar water heating systems may also fulfill the solar set-aside requirement, which requires that solar sources account for 2 percent of electricity sales by 2022 [34].

North Carolina

North Carolina enacted SB 75, which allows reductions in electricity demand to qualify toward meeting the State's existing renewable energy and energy efficiency portfolio standard. The legislation defines electricity demand reduction as a "measureable reduction in the electricity demand of a retail electric customer that is voluntary, under the real-time control of both the electric power supplier and the retail electric customer, and measured in real time, using two-way communications devices that communicate on the basis of standards" [35]. There is no upper limit on the portion of the RPS requirement that can be met by electricity demand reduction.

7. California low carbon fuel standard

The Low Carbon Fuel Standard (LCFS), administered by the CARB [36], was signed into law in January 2010. Regulated parties under the legislation generally are the fuel producers and importers who sell motor gasoline or diesel fuel in California. The LCFS legislation is designed to reduce the carbon intensity (CI) of motor gasoline and diesel fuels sold in California by 10 percent between 2012 and 2020 through the increased sale of alternative "low-carbon" fuels. Each alternative low-carbon fuel has its own CI, based on life-cycle analyses conducted under the guidance of CARB for a number of approved fuel pathways. The CIs are calculated on an energy-equivalent basis, measured in grams of CO₂ equivalent emissions per megajoule.

In December 2011, the U.S. District Court for the Eastern Division of California ruled in favor of several trade groups that claimed the LCFS violated the interstate commerce clause of the U.S. Constitution by seeking to regulate farming and ethanol production practices in other States, and granted an injunction blocking enforcement by CARB [37]. The future of the LCFS program remains uncertain. After the initial ruling, a request for a stay of the injunction was quickly filed by CARB, which would have allowed the LCFS to remain in place during the appeal process; however, that request was denied by the same judge who initially blocked enforcement of the LCFS [38]. A new request for a stay of injunction while CARB appeals the original ruling was filed with the U.S. Ninth District Court of Appeals and was granted as of April 23, 2012 [39]. A decision on the appeal filed by CARB is yet to be made. As a result of the initial ruling's timing, along with EIA's prior completion of modeling efforts, the LCFS is not included in the AEO2012 Reference case [40].

Endnotes for Legislation and Regulations

Links current as of June 2012

5. A complete list of the laws and regulations included in AEO2012 is provided in *Assumptions to the Annual Energy Outlook 2012*, Appendix A, website [www.eia.gov/forecasts/aeo/assumptions/html/0554\(2012\).pdf](http://www.eia.gov/forecasts/aeo/assumptions/html/0554(2012).pdf).
6. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule," *Federal Register*, Vol. 76, No. 179 (Washington, DC: September 15, 2011), pp. 57106-57513, website www.epa.gov/fdsys/pkg/FR-2011-09-15/html/2011-20740.htm.
7. U.S. Environmental Protection Agency, "Cross-State Air Pollution Rule (CSAPR)," website epa.gov/air/transport/.
8. U.S. Environmental Protection Agency, "Mercury and Air Toxics Standards," website www.epa.gov/mats.
9. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule," *Federal Register*, Vol. 76, No. 179 (Washington, DC: September 15, 2011), website www.epa.gov/fdsys/pkg/FR-2011-09-15/html/2011-20740.htm.
10. For purposes of this final rulemaking, heavy-duty trucks are those with a gross vehicle weight rating of at least 8,501 pounds, except those Class 2 b vehicles of 8,501 to 10,000 pounds that are currently covered under light-duty vehicle fuel economy and greenhouse gas emissions standards.
11. Congressional Research Service, *Energy Independence and Security Act of 2007: A Summary of Major Provisions*, Order Code RL34294 (Washington, DC: December 2007), website www.senate.gov/energy/0709/0709_CRS_EISA_Summary_Security_Act_2007.pdf.
12. U.S. Environmental Protection Agency, *Cross-State Air Pollution Rule: Reducing Air Pollution, Protecting Public Health* (Washington, DC: December 15, 2011), website www.epa.gov/air-transport/pdfs/CSAPRPresentation.pdf.
13. U.S. Environmental Protection Agency, *Cross-State Air Pollution Rule: Reducing Air Pollution, Protecting Public Health* (Washington, DC: December 15, 2011), Slide 3, website www.epa.gov/air-transport/pdfs/CSAPRPresentation.pdf.
14. T. Schoenberg, B. Wingfield, and J. Johnsson, "EPA Cross-State Emissions Rule Put on Hold by Court," *Bloomberg Businessweek* (January 4, 2012), website www.businessweek.com/news/2012-01-04/epa-cross-state-emissions-rule-put-on-hold-by-court.html.
15. The AEO2012 Early Release Reference case was prepared before the final MATS rule was issued and, therefore, did not include MATS.
16. U.S. Environmental Protection Agency, "National Emission Standards for Hazardous Air Pollutants From Coal- and Oil-Fired Electric Utility Steam Generating Units and Standards of Performance for Fossil-Fuel-Fired Electric Utility, Industrial-Commercial-Institutional, and Small Industrial-Commercial-Institutional Steam Generating Units," *Federal Register*, Vol. 77, No. 32 (Washington, DC: February 16, 2012), pp. 9304-9513, website www.gpo.gov/fdsys/pkg/FR-2012-02-16/pdf/2012-806.pdf.
17. The Clean Air Act, Section 112(a)(8), defines an electric generating unit.
18. Regional Greenhouse Gas Initiative, "CO₂ Auctions, Tracking & Offsets," website www.rggi.org/market.
19. M. Navarro, "Regional Cap-and-Trade Effort Seeks Greater Impact by Cutting Carbon Allowances," *The New York Times* (January 26, 2012), website www.nytimes.com/2012/01/22/nyregion/in-greenhouse-gas-initiative-many-unsold-allowances.html?_r=2.
20. Western Climate Initiative, *WCI Emissions Trading Program Update* (San Francisco, CA: January 12, 2012), website www.westernclimateinitiative.org/document-archives/Partner-Meeting-Materials/Jan-12-Stakeholder-Update-Presentation/%20.
21. California Code of Regulations, Subchapter 10 Climate Change, Article 5, Sections 95800 to 96023, Title 17, "California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms" (Sacramento, CA: July 2011), website www.arb.ca.gov/regact/2010/capandtrade10/candlmodreg.pdf.
22. California Code of Regulations, Subchapter 10 Climate Change, Article 5, Sections 95800 to 96023, Title 17, "California Cap on Greenhouse Gas Emissions and Market-Based Compliance Mechanisms" (Sacramento, CA: July 2011), website www.arb.ca.gov/regact/2010/capandtrade10/candlmodreg.pdf.
23. California Code of Regulations, Subchapter 10 Climate Change, Article 5, Section 95810, "Covered Gases" (Sacramento, CA: July 2011), website www.arb.ca.gov/regact/2010/capandtrade10/candlmodreg.pdf.
24. California Code of Regulations, Subchapter 10 Climate Change, Article 5, Section 95841, "Annual Allowance Budgets for Calendar Years 2013-2020" (Sacramento, CA: July 2011), website www.arb.ca.gov/regact/2010/capandtrade10/candlmodreg.pdf.

Legal Reference List (continued)

25. California Air Resources Board, *Proposed Regulation to Implement the California Cap-and-Trade Program*, Appendix J, "Allowance Allocation" (Sacramento, CA: October 2010), p. 12, website <http://arb.ca.gov/regact/2010/capandtrade/03capandtrade.pdf>.
26. The eligible technology, and even the definition of the technology or fuel category, will vary by State. For example, one State's definition of renewables may include hydroelectric power generation, while another's definition may not. Table 4 provides more detail on how the technology or fuel category is defined by each State.
27. More information about the Database of State Incentives for Renewables & Efficiency can be found at website <http://www.dsireusa.gov/al.html>.
28. State of California, Senate Bill 2, "California Renewable Energy Resources Act" (Sacramento, CA: April 2011), website www.leginfo.ca.gov/pub/11-12/bill/sen/sb_0001-0050/sb_1_2_bill_20110414_chaptered.html.
29. State of California, Public Utilities Code, Sections 399.11 to 399.31, website http://www.leginfo.ca.gov/cgi-bin/displaycode?section=puc&group=00001_01000&file=399.11_399.31.
30. State of Connecticut, Public Act 11-80, "An Act Concerning the Establishment of the Department of Energy and Environmental Protection and Planning for Connecticut's Energy Future" (Hartford, CT: July 1, 2011), website <http://www.cga.ct.gov/2011/ACT/PAZ/2011PA-00080-R000SB-01243-PA.html>.
31. State of Delaware, Senate Bill 124, "An Act To Amend Title 26 Of The Delaware Code Relating To Delaware's Renewable Energy Portfolio Standards And Delaware-Manufactured Fuel Cells" (Dover, DE: July 7, 2011), website www.legis.delaware.gov/LIS/lls146.nsf/vw/legislation/SB0124?file=legis.html?open.
32. State of Illinois, Senate Bill 1652, "An Act Concerning Public Utilities" (Springfield, IL: October 26, 2011), website www.ilga.gov/legislation/97/SB/FBI/097005E16521.pdf.
33. State of Maryland, Senate Bill 690, "An Act Concerning Renewable Energy Portfolio – Waste-to-Energy and Refuse-Derived Fuel" (Annapolis, MD: May 29, 2011), website mls.state.md.us/2011rs/bills/sb/sb0690a.pdf.
34. State of Maryland, Senate Bill 717, "An Act Concerning Renewable Energy Portfolio Standard – Renewable Energy Credits – Solar Water Heating Systems" (Annapolis, MD: May 29, 2011), website mls.state.md.us/2011rs/bills/sb/sb0717a.pdf.
35. General Assembly of North Carolina, Senate Bill 75, "An Act to Promote the Use of Electricity Demand Reduction to Satisfy Renewable Energy Portfolio Standards" (Raleigh, NC: April 28, 2011), website www.ncleg.net/Sessions/2011/Bills/Senate/PDF/S75v4.pdf.
36. California Code of Regulations, Subchapter 10 Climate Change, Article 4, Sections 95480 to 95490, Title 17, Subarticle 7, "Low Carbon Fuel Standard," (Sacramento, CA: July 2011), website www.arb.ca.gov/resect/2009/prs09/finalfro.pdf.
37. State of California, "Low Carbon Fuel Standard (LCFS) Supplemental Regulatory Advisory 10-04B" (Sacramento, CA: December 2011), website <http://arb.ca.gov/fuels/lcfs/123111cfst1004b.pdf>.
38. Renewable Fuels Association, "Judge Denies California Attempt to Reimplement LCFS" (January 23, 2012), website www.ethanolrfa.org/news/centric/judge-denies-california-attempt-to-reimplement-lcfs.
39. State of California, "LCFS Enforcement Injunction is Lifted" (Sacramento, CA: April 24, 2012), website www.arb.ca.gov/fuels/lcfs/LCFS_Stay_Granted.pdf.
40. The LCFS was included in the AEO2012 Early Release Reference case, which was completed before the ruling by the Court.

Issues in focus

Issues in focus

Introduction

The “Issues in focus” section of the *Annual Energy Outlook (AEO)* provides an in-depth discussion on topics of special interest, including significant changes in assumptions and recent developments in technologies for energy production and consumption. Detailed quantitative results are available in Appendix D. The first topic updates a discussion included in the *Annual Energy Outlook 2011 (AEO2011)* that compared the results of two cases with different assumptions about the future course of existing energy policies. One case assumes the elimination of sunset provisions in existing energy policies; that is, the policies are assumed not to sunset as they would under current law. The other case assumes the extension or expansion of a selected group of existing policies—corporate average fuel economy (CAFE) standards, appliance standards, and production tax credits (PTCs)—in addition to the elimination of sunset provisions.

Other topics discussed in this section as identified by subsection number include (2) oil price and production trends in the *Annual Energy Outlook 2012 (AEO2012)*; (3) potential efficiency improvements and their impacts on end-use energy demand; (4) energy impacts of proposed CAFE standards for light-duty vehicles (LDVs), model years (MYs) 2017 to 2025; (5) impacts of a breakthrough in battery vehicle technology; (6) heavy-duty (HD) natural gas vehicles (NGVs); (7) changing structure of the refining industry; (8) changing environment for fuel use in electricity generation; (9) nuclear power in *AEO2012*; (10) potential impact of minimum pipeline throughput constraints on Alaska North Slope oil production; (11) U.S. crude oil and natural gas resource uncertainty; and (12) evolving Marcellus shale gas resource estimates.

The topics explored in this section represent current and emerging issues in energy markets; but many of the topics discussed in *AEOs* published in recent years also remain relevant today. Table 5 provides a list of titles from the 2011, 2010, and 2009 *AEOs* that are likely to be of interest to today’s readers—excluding topics that are updated in *AEO2012*. The articles listed in Table 5 can be found on the U.S. Energy Information Administration (EIA) website at www.eia.gov/analysis/ncerts.cfm?l=12?.

1. No Sunset and Extended Policies cases

Background

The *AEO2012* Reference case is best described as a “current laws and regulations” case, because it generally assumes that existing laws and regulations will remain unchanged throughout the projection period, unless the legislation establishing them sets a sunset date or specifies how they will change. The Reference case often serves as a starting point for the analysis of proposed legislative or regulatory changes. While the definition of the Reference case is relatively straightforward, there may be considerable interest in a variety of alternative cases that reflect the updating or extension of current laws and regulations. In that regard, areas of particular interest include:

- Laws or regulations that have a history of being extended beyond their legislated sunset dates. Examples include the various tax credits for renewable fuels and technologies, which have been extended with or without modifications several times since their initial implementation.

Table 5. Key analyses from “Issues in focus” in recent *AEOs*

<i>AEO2011</i>	<i>AEO2010</i>	<i>AEO2009</i>
Increasing light-duty vehicle greenhouse gas and fuel economy standards for model years 2017 to 2025	Energy intensity trends in <i>AEO2010</i>	Economics of plug-in hybrid electric vehicles
Fuel consumption and greenhouse gas emissions standards for heavy-duty vehicles	Natural gas as a fuel for heavy trucks: Issues and incentives	Impact of limitations on access to oil and natural gas resources in the Federal Outer Continental Shelf
Potential efficiency improvements in alternative cases for appliance standards and building codes	Factors affecting the relationship between crude oil and natural gas prices	Expectations for oil shale production
Potential of offshore crude oil and natural gas resources	Importance of low permeability natural gas reservoirs	Bringing Alaska North Slope natural gas to market
Prospects for shale gas	U.S. nuclear power plants: Continued life or replacement after 60?	Natural gas and crude oil prices in <i>AEO2009</i>
Cost uncertainties for new electric power plants	Accounting for carbon dioxide emissions from biomass energy combustion	Greenhouse gas concerns and power sector planning
Carbon capture and storage: Economics and issues		Tax credits and renewable generation
Power sector environmental regulations on the horizon		

- Laws or regulations that call for the periodic updating of initial specifications. Examples include appliance efficiency standards issued by the U.S. Department of Energy (DOE), and CAFE and greenhouse gas (GHG) emissions standards for vehicles issued by the National Highway Traffic Safety Administration (NHTSA) and the U.S. Environmental Protection Agency (EPA).
- Laws or regulations that allow or require the appropriate regulatory agency to issue new or revised regulations under certain conditions. Examples include the numerous provisions of the Clean Air Act that require the EPA to issue or revise regulations if it finds that an environmental quality target is not being met.

To provide some insight into the sensitivity of results to scenarios in which existing tax credits do not sunset, two alternative cases are discussed in this section. No attempt is made to cover the full range of possible uncertainties in these areas, and readers should not view the cases discussed as EIA projections of how laws or regulations might or should be changed.

Analysis cases

The two cases prepared—the No Sunset and Extended Policies cases—incorporate all the assumptions from the *AEO2012* Reference case, except as identified below. Changes from the Reference case assumptions in these cases include the following.

No Sunset case

- Extension through 2035 of the PTC for cellulosic biofuels of up to \$1.01 per gallon (set to expire at the end of 2012)
- Extension of tax credits for renewable energy sources in the utility, industrial, and buildings sectors or for energy-efficient equipment in the buildings sector, including:
 - The PTC of 2.2 cents per kilowatthour or the 30-percent investment tax credit (ITC) available for wind, geothermal, biomass, hydroelectric, and landfill gas resources, currently set to expire at the end of 2012 for wind and 2013 for the other eligible resources, are assumed to be extended indefinitely.
 - For solar power investment, a 30-percent ITC that is scheduled to revert to a 10-percent credit in 2016 is, instead, assumed to be extended indefinitely at 30 percent.
 - In the buildings sector, tax credits for the purchase of energy-efficient equipment, including photovoltaics (PV) in new houses, are assumed to be extended indefinitely, as opposed to ending in 2011 or 2016 as prescribed by current law. The business ITCs for commercial-sector generation technologies and geothermal heat pumps are assumed to be extended indefinitely, as opposed to expiring in 2016; and the business ITC for solar systems is assumed to remain at 30 percent instead of reverting to 10 percent.
 - In the industrial sector, the ITC for combined heat and power (CHP) that ends in 2016 in the *AEO2012* Reference case is assumed to be preserved through 2035, the end of the projection period.

Extended Policies case

The Extended Policies case includes additional updates in Federal equipment efficiency standards that were not considered in the Reference case or No Sunset case. Residential end-use technologies subject to updated standards are not eligible for tax credits in addition to the standards. Also, the PTC for cellulosic biofuels beyond 2012 is not included because the renewable fuel standard (RFS) program that is already included in the *AEO2012* Reference case tends to be the binding driver of cellulosic biofuels use. Other than these exceptions, the Extended Policies case adopts the same assumptions as the No Sunset case, plus the following:

- Federal equipment efficiency standards are updated at periodic intervals, consistent with the provisions in the existing law, with the levels based on ENERGY STAR specifications, or Federal Energy Management Program (FEMP) purchasing guidelines for Federal agencies. Standards are also introduced for products that are not currently subject to Federal efficiency standards.
- Updated Federal residential and commercial building energy codes reach 30-percent improvement in 2020 relative to the 2006 International Energy Conservation Code in the residential sector and the American Society of Heating, Refrigerating and Air-Conditioning Engineers Building Energy Code 90.1-2004 in the commercial sector. Two subsequent rounds in 2023 and 2026 each add an assumed 5-percent incremental improvement to building energy codes.

The equipment standards and building codes assumed for the Extended Policies case are meant to illustrate the potential effects of these policies on energy consumption for buildings. No cost-benefit analysis or evaluation of impacts on consumer welfare was completed in developing the assumptions. Likewise, no technical feasibility analysis was conducted, although standards were not allowed to exceed “maximum technologically feasible” levels described in DOE’s technical support documents.

- The *AEO2012* Reference, No Sunset, and Extended Policies cases include both the attribute-based CAFE standards for LDVs for MY 2011 and the joint attribute-based CAFE and vehicle GHG emissions standards for MY 2012 to MY 2016. However, the Reference and No Sunset cases assume that LDV CAFE standards increase to 35 miles per gallon (mpg) by MY 2020, as called for in the Energy Independence and Security Act of 2007 (EISA2007), and that the CAFE standards are then held constant in subsequent model years, although the fuel economy of new LDVs continues to rise modestly over time.

The Extended Policies case modifies the assumption in the Reference and No Sunset cases by assuming the incorporation of the proposed CAFE standards recently announced by the EPA and NHTSA for MY 2017 through MY 2025, which call for an

Figure 11

annual average increase in fuel economy for new LDVs of 3.9 percent. After 2025, CAFE standards are assumed to increase at an average annual rate of 1.5 percent through 2035.

- In the industrial sector, the ITC for CHP is extended to cover all system sizes (limited to only capacities between 25 and 50 megawatts in the Reference case), which may include multiple units. Also, the ITC is modified to increase the eligible CHP unit cap from 15 megawatts to 25 megawatts. These extensions are consistent with previously proposed or pending legislation.

Analysis results

The changes made to Reference case assumptions in the No Sunset and Extended Policies cases generally lead to lower estimates for overall energy consumption, increased use of renewable fuels, particularly for electricity generation, and reduced energy-related emissions of carbon dioxide (CO₂). Because the Extended Policies case includes most of the assumptions in the No Sunset case but adds others, the impacts in the Extended Policies case tend to be greater than those in the No Sunset case. Although these cases show lower energy prices—because the tax credits and end-use efficiency standards lead to lower energy demand and reduce the cost of renewable fuels—consumers spend more on appliances that are more efficient in order to comply with the tighter appliance standards, and the Government receives lower tax revenues as consumers and businesses take advantage of the tax credits.

Energy consumption

Total energy consumption in the No Sunset case is close to the level in the Reference case (Figure 11). Improvements in energy efficiency lead to reduced consumption in this case, but somewhat lower energy prices lead to higher relative consumption, offsetting some of the impact of the improved efficiency.

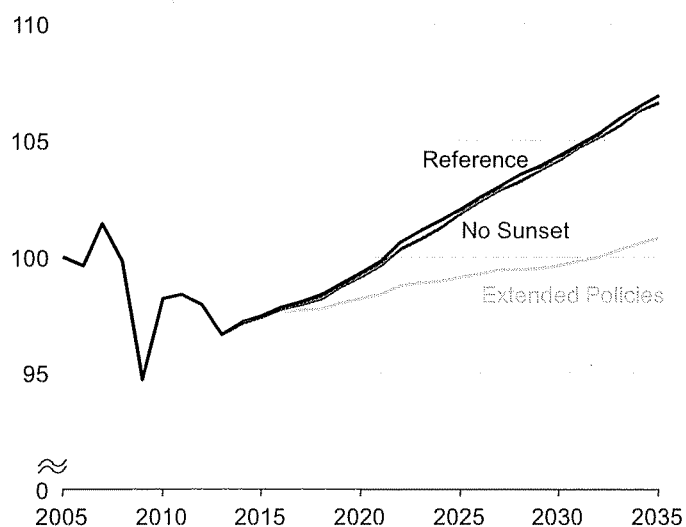
Total energy consumption growth in the Extended Policies case is markedly below the Reference case projection. In 2035, total energy consumption in the Extended Policies case is nearly 6 percent below its projected level in the Reference case.

Buildings energy consumption

The No Sunset case extends tax credits for residential and commercial renewable energy systems and for the purchase of energy-efficient residential equipment. The Extended Policies case builds on the No Sunset case by assuming updated Federal equipment efficiency standards and new standards for some products that are not currently subject to standards. For residential end-use technologies subject to standards, updated standards are assumed to replace any extension of incentives from the No Sunset case. Federal residential and commercial building energy codes are also improved as described above. Renewable distributed generation (DG) technologies (PV systems and wind turbines) provide much of the buildings-related energy savings in the No Sunset case. Extended tax credits in the No Sunset case spur increased adoption of renewable DG systems, leading to 110 billion kilowatthours of onsite electricity generation in 2035—more than four times the amount of onsite electricity generated in 2035 in the Reference case. Similar adoption of renewable DG takes place in the Extended Policies case. With the additional efficiency gains from assumed future standards and more stringent building codes, delivered energy consumption for buildings in 2035 is 6.8 percent (1.5 quadrillion Btu) lower in the Extended Policies case than in the Reference case, a reduction nearly five times as large as the 1.4-percent (0.3 quadrillion Btu) reduction in the No Sunset case.

Electricity use shows the largest reduction relative to the Reference case, with buildings electricity consumption 2.4 percent and 8.2 percent lower, respectively, in the No Sunset and Extended Policies cases in 2035. Space heating and cooling are affected

Figure 11. Total energy consumption in three cases, 2005-2035 (quadrillion Btu)



by both assumed standards and building codes, leading to significant savings in energy consumption for heating and cooling in the Extended Policies case. In 2035, energy use for space heating in buildings is 6.9 percent lower, and energy use for space cooling is 17.3 percent lower, in the Extended Policies case than in the Reference case. In addition to improved standards and codes, extended tax credits for PV prompt increased adoption, offsetting some of the purchased electricity for cooling. New standards for televisions and for personal computers (PCs) and related equipment in the Extended Policies case lead to savings of 20.6 percent and 18.2 percent, respectively, in residential electricity use by this equipment in 2035 relative to the Reference case. Residential and commercial natural gas use declines from 8.3 quadrillion Btu in 2010 to 7.9 quadrillion Btu in 2035 in the Extended Policies case, representing a 6.2-percent reduction from the Reference case in 2035.

Industrial energy consumption

The Extended Policies case modifies the Reference case by extending the existing industrial CHP ITC through the end of the projection period, expanding it to include all industrial CHP system sizes, and raising the maximum credit that can be claimed from 15 megawatts of installed capacity to 25 megawatts. These assumptions are based on the current proposals in H.R. 2750 and H.R. 2784 of the 112th Congress. The changes result in 2.7 gigawatts of additional industrial CHP capacity over the Reference case level in 2035. Natural gas consumption in the industrial sector (excluding refining) increases from 7.3 quadrillion Btu in the Reference case to 7.4 quadrillion Btu in the Extended Policies case, a 1.6-percent rise. Electricity purchases are nearly unchanged in the Extended Policies case, as additional demand for electricity relative to the Reference case is fulfilled almost exclusively by increased generation from CHP.

Transportation energy consumption

The Extended Policies case modifies the Reference case and No Sunset case by assuming the incorporation of the CAFE standards recently proposed by the EPA and NHTSA for MY 2017 through 2025, which call for a 3.9-percent annual average increase in fuel economy for new LDVs, with CAFE standards applicable after 2025 assumed to increase at an average annual rate of 1.5 percent through 2035. Sales of vehicles that do not rely solely on a gasoline internal combustion engine for both motive and accessory power (including those that use diesel, alternative fuels, and/or hybrid electric systems) play a substantial role in meeting the higher fuel economy standards, growing to almost 80 percent of new LDV sales in 2035, compared with about 35 percent in the Reference case.

LDV energy consumption declines in the Extended Policies case, from 16.6 quadrillion Btu (8.9 million barrels per day) in 2010 to 12.9 quadrillion Btu (7.3 million barrels per day) in 2035, about a 20-percent reduction from the Reference case in 2035. Petroleum and other liquids fuels consumption in the transportation sector declines in the Extended Policies case, from 13.8 million barrels per day in 2010 to 12.7 million barrels per day in 2035, compared to an increase in the Reference case to 14.4 million barrels per day (Figure 12).

Renewable electricity generation

The extension of tax credits for renewables through 2035 would, over the long run, lead to more rapid growth in renewable generation than in the Reference case. When the renewable tax credits are extended without extending energy efficiency standards, as is assumed in the No Sunset case, there is a significant increase in renewable generation in 2035 relative to the Reference case (Figure 13). Extending both renewable tax credits and energy efficiency standards (Extended Policies case) results in more modest growth in renewable generation, because renewable generation in the near term is a significant source of new generation to meet load growth, and enhanced energy efficiency standards tend to reduce overall electricity consumption and the need for new generation resources.

In the No Sunset and Extended Policies cases, renewable generation more than doubles from 2010 to 2035, as compared with a 77-percent increase in the Reference case. In 2035, the share of total electricity generation accounted for by renewables is between 19 and 20 percent in both the No Sunset and Extended Policies cases, as compared with 15 percent in the Reference case.

In all three cases, the most rapid growth in renewable capacity occurs in the very near term, largely as the result of projects already under construction or planned. After that, the growth slows through 2020 before picking up again. Some of the current surge of renewable capacity additions is occurring in anticipation of the expiration of Federal incentives within the next year (for wind) or two (for other renewable fuels except solar). Results from the No Sunset and Extended Policies cases indicate that, given sufficient

Figure 12. Consumption of petroleum and other liquids for transportation in three cases, 2005-2035 (million barrels per day)

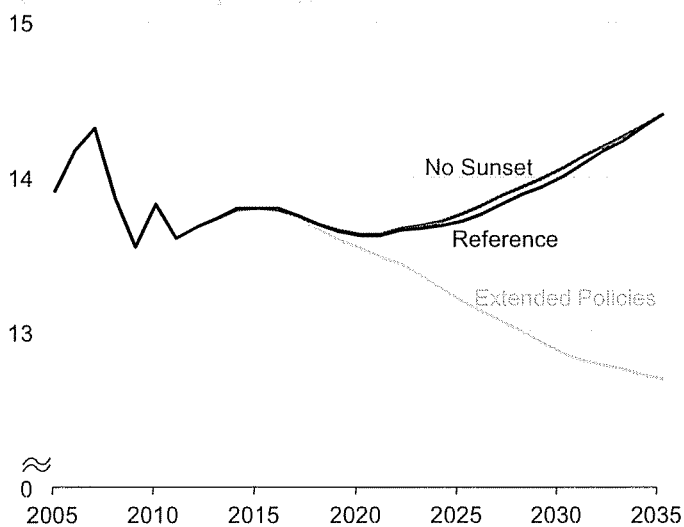


Figure 13. Renewable electricity generation in three cases, 2005-2035 (billion kilowatt-hours)

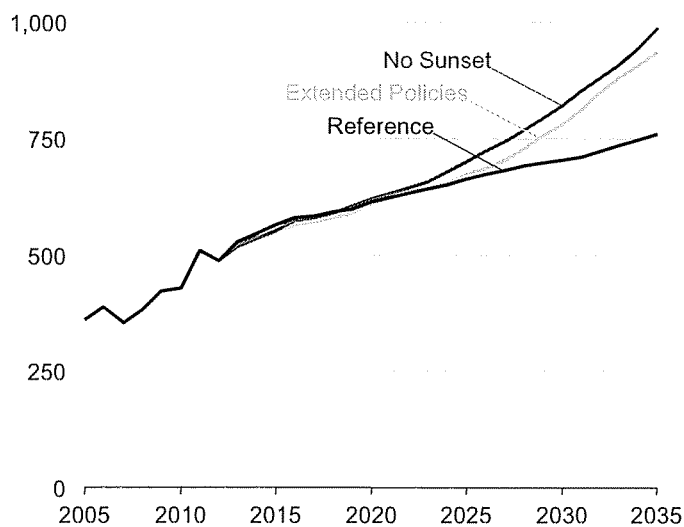


Figure 14. Electricity generation

lead time, a long-term extension of these expiring provisions could result in the postponement of some near-term activity to better match projected patterns of load growth. With slow growth in electricity demand and the addition of capacity stimulated by renewable incentives, little new capacity is needed between 2015 and 2020. In addition, in some regions, attractive low-cost renewable resources already have been developed, leaving only less favorable sites that may require significant investment in transmission as well as other additional infrastructure costs. Starting around 2020, significant new sources of renewable generation also appear on the market as a result of cogeneration at biorefineries built primarily to produce renewable liquid fuels to meet the Federal RFS, where combustion of waste products to produce electricity is an economically attractive option.

Between 2020 and 2025, renewable generation in the No Sunset and Extended Policies cases starts to increase more rapidly than in the Reference case, and, as a result, generation from nuclear and fossil fuels is reduced from the levels in the Reference case. Natural gas represents the largest source of displaced generation. In 2035, electricity generation from natural gas is 11 percent lower in the No Sunset case and 15 percent lower in the Extended Policies case than in the Reference case (Figure 14).

Energy-related CO₂ emissions

In the No Sunset and Extended Policies cases, lower overall energy demand leads to lower levels of energy-related CO₂ emissions than in the Reference case. The Extended Policies case shows much larger emissions reductions than the No Sunset and Reference cases, due in part to the inclusion of tighter LDV fuel economy standards for MY 2017 through MY 2035. From 2010 to 2035, energy-related CO₂ emissions are reduced by a cumulative total of 4.3 billion metric tons (a 3.0-percent reduction over the period) in the Extended Policies case from the Reference case projection, as compared with 0.9 billion metric tons (a 0.6-percent reduction over the period) in the No Sunset case (Figure 15). The increase in fuel economy standards assumed for new LDVs in the Extended Policies case is responsible for more than 40 percent of the total reduction in CO₂ emissions in 2035 in comparison with the Reference case. The balance of the reduction in CO₂ emissions is a result of greater improvement in appliance efficiencies and increased penetration of renewable electricity generation.

The majority of the emissions reductions in the No Sunset case result from increases in renewable electricity generation. Consistent with current EIA conventions and EPA practice, emissions associated with the combustion of biomass for electricity generation are not counted, because they are assumed to be balanced by carbon uptake when the feedstock is grown. A small reduction in transportation sector emissions in the No Sunset case is counterbalanced by an increase in emissions from refineries during the production of synthetic fuels that receive tax credits. Relatively small incremental reductions in emissions are attributable to renewables in the Extended Policies case, mainly because electricity demand is lower than in the Reference case, reducing the consumption of all fuels used for generation, including biomass.

In the residential sector, in both the No Sunset and Extended Policies cases, water heating, space cooling, and space heating together account for most of the emissions reductions from Reference case levels. In the commercial sector, only the Extended Policies case projects substantial reductions of emissions in those categories. In the industrial sector, the Extended Policies case projects reduced emissions as a result of decreases in electricity purchases and petroleum use that are partially offset by increased reliance on natural gas—for example, increased use of natural gas fired industrial CHP.

Energy prices and tax credit payments

With lower levels of overall energy use and more consumption of renewable fuels in the No Sunset and Extended Policies cases, energy prices are lower than in the Reference case. In 2035, natural gas wellhead prices are \$0.44 per thousand cubic feet (6.6

Figure 14. Electricity generation from natural gas in three cases, 2005-2035 (billion kilowatthours)

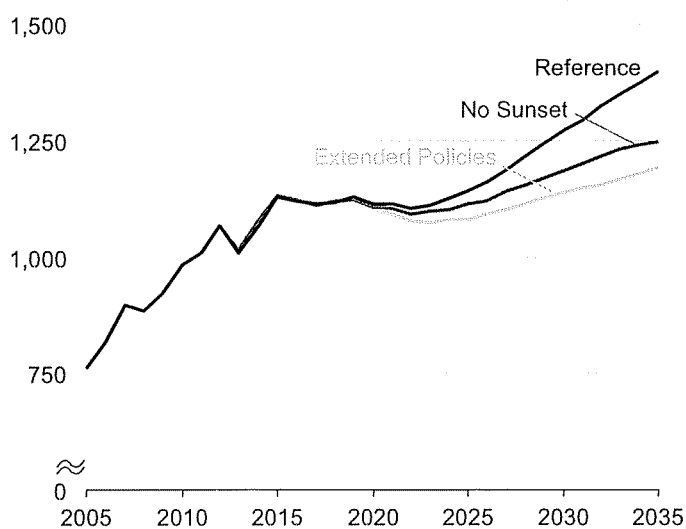
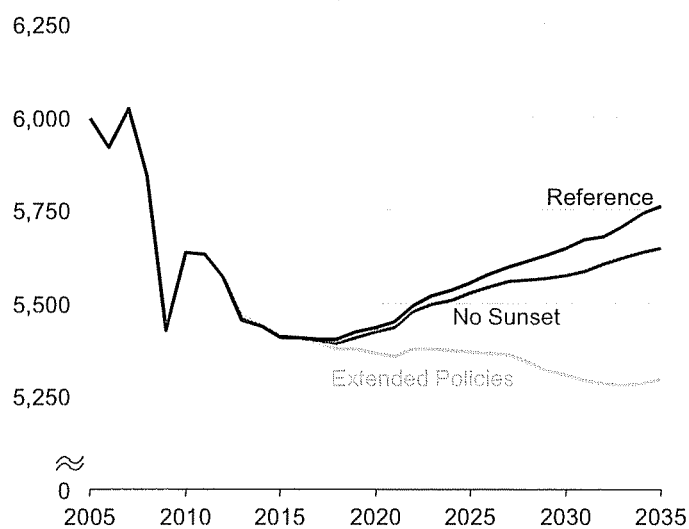


Figure 15. Energy-related carbon dioxide emissions in three cases, 2005-2035 (million metric tons)



percent) and \$0.82 per thousand cubic feet (12.3 percent) lower in the No Sunset and Extended Policies cases, respectively, than in the Reference case (Figure 16), and electricity prices are about 2 percent and 5 percent lower than in the Reference case (Figure 17).

The reductions in energy consumption and CO₂ emissions in the Extended Policies case are accompanied by higher equipment costs for consumers and revenue reductions for the U.S. Government. From 2012 to 2035, residential and commercial consumers spend, on average, an additional \$19 billion per year (in 2010 dollars) for newly purchased end-use equipment, distributed generation systems, and residential building shell improvements in the Extended Policies case as compared with the Reference case. On the other hand, they save an average of \$22 billion per year on energy purchases.

Tax credits paid to consumers in the buildings sector (or, from the Government’s perspective, reduced revenue) in the No Sunset case average \$5 billion (real 2010 dollars) more per year than in the Reference case, which assumes that existing tax credits expire as currently scheduled, mostly by 2016.

The largest response to Federal tax incentives for new renewable generation is seen in the No Sunset case, with extension of the PTC and the 30-percent ITC resulting in annual average reductions in Government tax revenues of approximately \$2.5 billion from 2011 to 2035, as compared with \$520 million per year in the Reference case. Additional reductions in Government tax revenue in the No Sunset case result from extensions of the cellulosic biofuels PTC. These reductions increase rapidly from \$52 million in 2013 to \$7.2 billion (2010 dollars) in 2035 (a cumulative total of \$75.1 billion) in comparison with the Reference case.

2. Oil price and production trends in AEO2012

The oil price in AEO2012 is defined as the average price of light, low-sulfur crude oil delivered in Cushing, Oklahoma, which is similar to the price for light, sweet crude oil, West Texas Intermediate (WTI), traded on the New York Mercantile Exchange. AEO2012 also includes a projection of the U.S. annual average refiners’ acquisition cost of imported crude oil, which is more representative of the average cost of all crude oils used by domestic refiners. Currently there is a price differential between WTI and similar-quality marker crude oils delivered to international ports via tanker (e.g., Brent and Louisiana Light Sweet crudes). The AEO2012 Reference case assumes that the large discrepancy will fade over time, as construction of more adequate pipeline capacity between Cushing and the Gulf of Mexico eases transportation of crude oil supplies to and from U.S. refineries.

Oil prices are influenced by a number of factors, including some that have mainly short-term impacts. Other factors, such as the Organization of the Petroleum Exporting Countries (OPEC) production decisions and expectations about future world demand for petroleum and other liquids, affect prices in the longer term. Supply and demand in the world oil market are balanced through responses to price movements, and the factors underlying supply and demand expectations are both numerous and complex. The key factors determining long-term supply, demand, and prices for petroleum and other liquids can be summarized in four broad categories: the economics of non-OPEC supply, OPEC investment and production decisions, the economics of other liquids supply, and world demand for petroleum and other liquids.

AEO2012 includes projections of future supply and demand for “petroleum and other liquids.” The term “petroleum” refers to crude oil (including tight oil from shale [also referred to as shale oil], chalk, and other low-permeability formations), lease condensate, natural gas plant liquids, and refinery gain. The term “other liquids” refers to biofuels, bitumen (oil sands), coal-to-liquids (CTL), biomass-to-liquids (BTL), gas-to-liquids (GTL), extra-heavy oils (technically petroleum but grouped in “other liquids” in this report), and oil shale [47]

Figure 16. Natural gas wellhead prices in three cases, 2005-2035 (2010 dollars per thousand cubic feet)

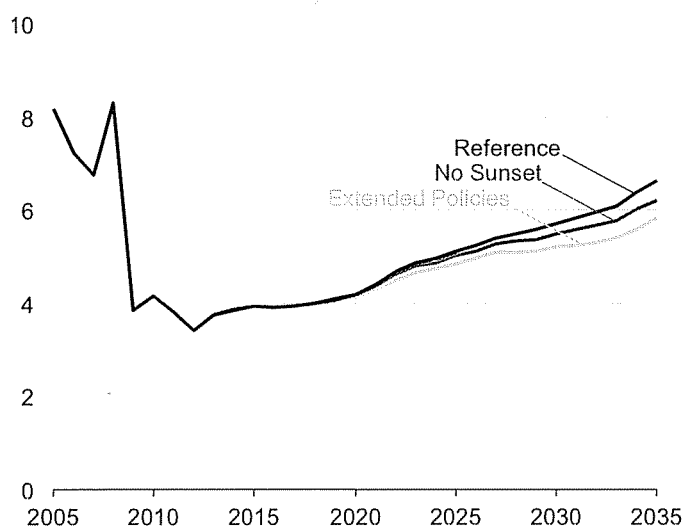
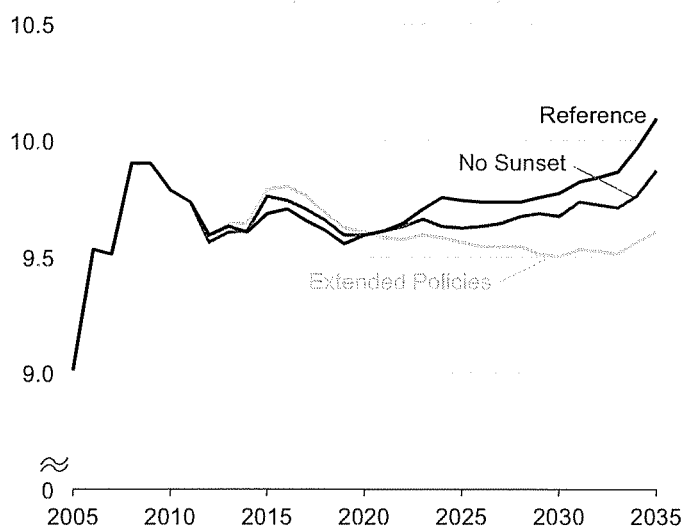


Figure 17. Average electricity prices in three cases, 2005-2035 (2010 cents per kilowatthour)



Reference case

The global oil market projections in the AEO2012 Reference case are based on the assumption that current practices, politics, and levels of access will continue in the near to mid-term. The Reference case assumes that continued robust economic growth in the non-Organization for Economic Cooperative Development (OECD) nations, including China and India, will more than offset slower growth projected for many OECD nations. In the Reference case, non-OECD petroleum and other liquids consumption is about 21 million barrels per day higher in 2035 than it was in 2010, but OECD consumption grows by less than 2 million barrels per day over the same period. Total world consumption of petroleum and other liquids grows to 106 million barrels per day in 2030 and 110 million barrels per day in 2035.

The Reference case also assumes that limitations on access to resources in many areas restrain the growth of non-OPEC petroleum liquids production over the projection period, and that OPEC production maintains a relatively constant share of total world petroleum and other liquids supply—between 40 and 42 percent. With those constraining factors, satisfying the growing world demand for petroleum and other liquids in coming decades requires production from higher-cost resources, particularly for non-OPEC producers with technically challenging supply projects. In the Reference case, the increased cost of non-OPEC supplies, a constant OPEC market share, and easing of Cushing WTI infrastructure constraints combine to support average increases in real oil prices of about 5 percent per year from 2010 to 2020 and about 1 percent per year from 2020 to 2035. In 2035, the average real price of crude oil in the Reference case is \$145 per barrel in 2010 dollars (Figure 18). The rapid increase in the near term is based on the assumption that the WTI price will return to parity with Brent by 2016 as current constraints on pipeline capacity between Cushing and the Gulf of Mexico are eliminated.

Increases in non-OPEC production of petroleum and other liquids in the Reference case come primarily from high-cost petroleum liquids projects in areas with inconsistent or unreliable fiscal or political regimes and from increasingly expensive other liquids projects that are made economical by rising oil prices and advances in production technology (Figure 19). Bitumen production in Canada and biofuels production mostly from the United States and Brazil are the most important components of the world’s incremental supply of other liquids from 2010 to 2035 in the Reference case.

Low Oil Price case

In the Low Oil Price case, non-OECD economic growth is lower than in the Reference case, leading to slower growth in demand for petroleum and other liquids. Lower demand, combined with greater access to and production of petroleum liquids resources, results in sustained lower oil prices. In particular, the Low Oil Price case focuses on demand in non-OECD countries, where uncertainty about future growth is much higher than in the mature economies of the OECD. The Low Oil Price case assumes that oil prices fall steadily after 2011 to about \$58 per barrel in 2017, then rise slowly to \$62 per barrel in 2035. Growth in world demand for petroleum and other liquids is slowed by lower gross domestic product (GDP) growth in the non-OECD countries than is projected in the Reference case. Average annual GDP growth in the non-OECD nations is assumed to be 1.5 percentage points lower than in the Reference case, increasing by only 3.5 percent per year from 2010 to 2035. As a result, non-OECD demand for petroleum and other liquids in 2035 is 7 million barrels per day lower than in the Reference case, and total world consumption in 2035 is 2 million barrels per day lower, at 107 million barrels per day.

In the Low Oil Price case, the market power of OPEC producers is weakened, and they lose the ability to control prices and limit production. As a result, the OPEC market share of world petroleum and other liquids production is 46 percent in 2035, as

Figure 18. Average annual world oil prices in three cases, 1980-2035 (2010 dollars per barrel)

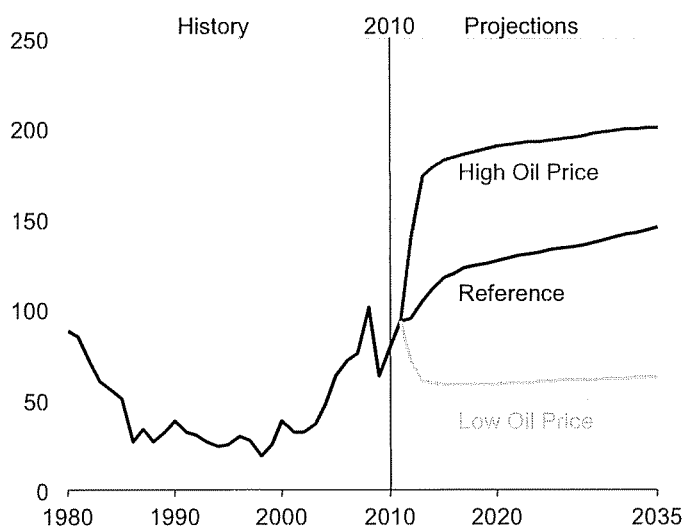
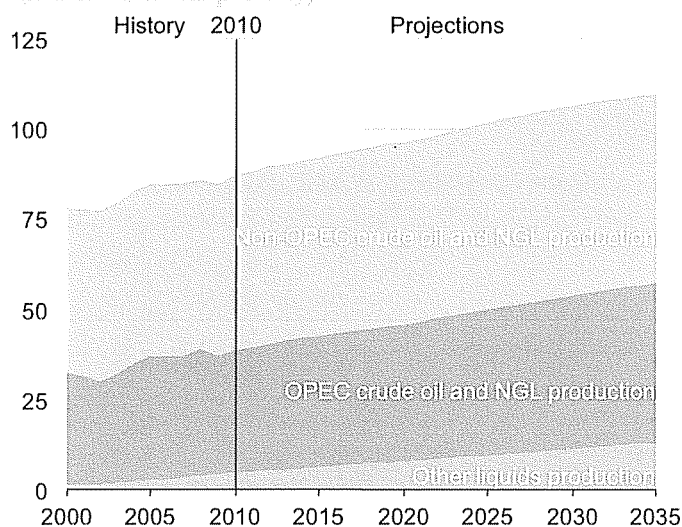


Figure 19. World petroleum and other liquids production in the Reference case, 2000-2035 (million barrels per day)



compared with 40 to 42 percent in the Reference case. Despite lower prices, non-OPEC levels of petroleum liquids production are maintained until about 2020, as projects currently underway or planned are completed and begin production. After 2020, non-OPEC petroleum liquids production declines as existing fields are depleted and not fully replaced by production from new fields and higher cost enhanced recovery technologies.

The Low Oil Price case assumes that technologies for producing biofuels, bitumen, CTL, BTL, GTL and extra-heavy oils achieve much lower costs than in the Reference case. As a result, production of those liquids increases to 16 million barrels per day in 2035 despite significantly lower oil prices.

High Oil Price case

In the High Oil Price case, the assumption of high demand for petroleum and other liquids in the non-OECD nations, combined with more constrained supply availability, results in higher oil prices than in the Reference case. Oil prices ramp up quickly to \$186 per barrel (2010 dollars) in 2017 and continue rising slowly thereafter, to about \$200 per barrel in 2035. The higher prices result from higher demand for petroleum and other liquid fuels in the non-OECD nations, resulting from the assumption of higher economic growth than in the Reference case. Specifically, GDP growth rates for China and India in 2012 are 1.0 percentage point higher than in the Reference case, and 0.3 percentage point higher in 2035. For most other non-OECD regions, GDP growth rates average about 0.5 percentage point above the Reference case in 2012. For the OECD regions, where prices rather than a higher economic growth rate are the main factor affecting demand, consumption of petroleum and other liquids remains fairly flat over the projection.

On the supply side, OPEC countries are assumed to reduce their market share somewhat, to less than 41 percent through 2035. Non-OPEC petroleum liquids resources outside the United States are assumed to be less accessible and/or more costly to produce than in the Reference case, and higher prices make other liquids supply more attractive. In 2035, other liquids production totals 17 million barrels per day in the High Oil Price case, about 4 million barrels per day above the Reference case level, and other liquids account for 15 percent of the total supply of petroleum and other liquids.

3. Potential efficiency improvements and their impacts on end-use energy demand

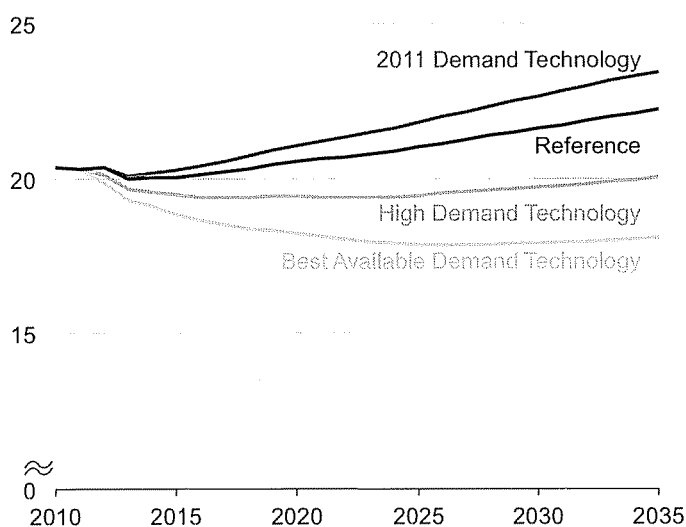
In 2010, the residential and commercial buildings sectors used 20.4 quadrillion Btu of delivered energy, or 28 percent of total U.S. energy consumption. The residential sector accounted for 57 percent of that energy use and the commercial sector 43 percent. In the AEO2012 Reference case, delivered energy for buildings increases by a total of 9 percent, to 22.2 quadrillion Btu in 2035, which is modest relative to the rate of increase in the number of buildings and their occupants. In contrast, the U.S. population increases by 25 percent, commercial floorspace increases by 27 percent, and the number of households increases by 28 percent. Accordingly, energy use in the buildings sector on a per-capita basis declines in the projection. The decline of buildings energy use per capita in past years has been attributable in part to improvements in the efficiencies of appliances and building shells, and efficiency improvements continue to play a key role in projections of buildings energy consumption.

Existing policies, such as Federal appliance standards, along with evolving State policies, and market forces, are drivers of energy efficiency in the United States. A number of recent changes in the broader context of the U.S. energy system that affect energy prices, such as advances in shale gas extraction and the economic slowdown, also have the potential to affect

the dynamics of energy efficiency improvement in the U.S. buildings sector. Although these influences are important, technology improvement remains a critical factor for energy use in the buildings sector. The emphasis for this analysis is on fundamental factors, particularly technology factors, that affect energy efficiency, rather than on potential policy or regulatory options.

Three alternative cases in AEO2012 illustrate the impacts of different assumptions for rates of technology improvement on delivered energy use in the residential and commercial sectors (Figure 20). These cases are in addition to the Extended Policies and No Sunset cases discussed earlier, and they are intended to provide a broader perspective on changes in demand-side technologies. In the High Demand Technology case, high-efficiency technologies are assumed to penetrate end-use markets at lower consumer hurdle rates, with related assumptions in the transportation and industrial sectors. In the Best Available Demand Technology case, new equipment purchases are limited to the most efficient versions of technologies available in the residential and commercial buildings sectors regardless of cost. In the

Figure 20. Residential and commercial delivered energy consumption in four cases, 2010-2035 (quadrillion Btu)



Energy in place

2011 Demand Technology case, future equipment purchases are limited to the options available in 2011 (“frozen technology”), and 2011 building codes remain unchanged through 2035. Like the High Demand and Best Available Demand Technology cases, the 2011 Demand Technology case includes all current Federal standards.

Without the benefits of technology improvement, buildings energy use in the 2011 Demand Technology case grows to 23.4 quadrillion Btu in 2035, as compared with 22.2 quadrillion Btu in the Reference case. In the High Demand Technology case, energy delivered to the buildings sectors only reaches about 20 quadrillion Btu for any year in the projection period, and in the Buildings Best Available Demand Technology case it declines to 17.9 quadrillion Btu in 2026 before rising slightly to 18.1 quadrillion Btu in 2035.

Background

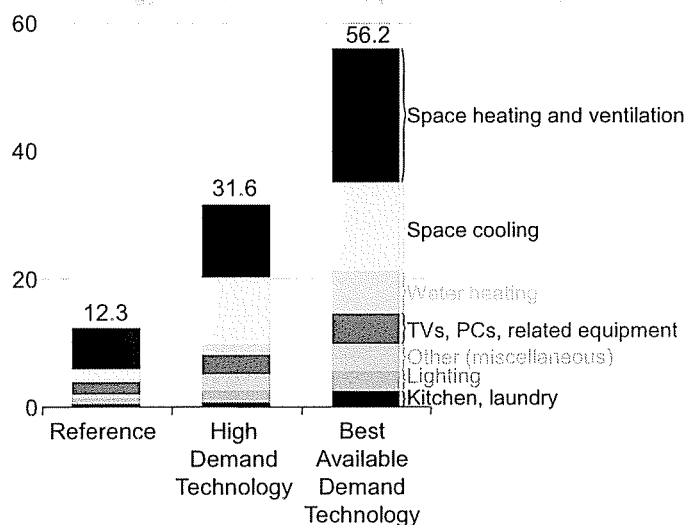
The residential and commercial sectors together are referred to as the “buildings sector.” The cases discussed here are not policy-driven scenarios but rather “what-if” cases used to illustrate the impacts of alternative technology penetration trajectories on buildings sector energy use. In a general sense, this approach can be understood as reflecting uncertainty about technological progress itself, or uncertainty about consumer behavior, in that the market response to a new technology is uncertain. This type of uncertainty is being studied through market research, behavioral economics, and related disciplines that examine how purchasers perceive options, differentiate products, and react to information over time. By varying technology progress across the full range of end uses, the integrated demand cases provide estimates of potential changes in energy savings that, in reality, are likely to be less uniform and more specific to certain end uses, technologies, and consumer groups. Specific assumptions for each of the cases are summarized in Tables 6 and 7.

Results for the residential sector

To emphasize that efficiency is persistent and its effects accumulate over time, energy use is discussed in terms of cumulative reductions (2011-2035) relative to a case with no future advances in technology after 2011. An extensive range of residential equipment is covered by Federal efficiency standards, and the continuing effects of those standards contribute to the cumulative reduction in delivered energy use of 12.3 quadrillion Btu through 2035 in the Reference case relative to the 2011 Demand Technology case. Electricity and natural gas account for more than 85 percent of the difference, each showing a cumulative reduction greater than 5 quadrillion Btu over the period. Energy use for space heating shows the most improvement in the Reference case, affected by improvements in building shells and heating equipment (Figure 21). Televisions and PCs and related equipment use 1.9 quadrillion Btu less energy over the projection period, as devices with energy-saving features continue to penetrate the market, and laptops continue to gain market share over desktop PCs.

Cumulative savings in residential energy use from 2011 to 2035 total 31.6 quadrillion Btu in the High Demand Technology case and 56.2 quadrillion Btu in the Best Available Demand Technology case in comparison with the 2011 Demand Technology case. Electricity accounts for the largest share of the reductions in the High Demand Technology case (49 percent) and the Best Available Demand Technology case (51 percent). In addition to adopting more optimistic assumptions in the High Demand Technology and Best Available Demand Technology cases for end-use equipment, residential PV and wind technologies are assumed to have greater cost declines than in the Reference case, contributing to reductions in purchased electricity. In 2035, residential PV and wind systems produce 23 billion kilowatthours more electricity in the Best Available Demand Technology case than in the 2011 Demand Technology case.

Figure 21. Cumulative reductions to residential energy consumption relative to the 2011 Demand Technology case, 2011-2035 (quadrillion Btu)



In the High Demand Technology and Best Available Demand Technology cases, energy use for residential space heating again shows the most improvement relative to the 2011 Demand Technology case. Large kitchen and laundry appliances claim a small share of the reductions, as Federal standards limit increases in energy consumption for those uses even in the 2011 Demand Technology case. Light-emitting diodes (LED) lighting provide the potential for further savings in the High and Best Available Demand Technology cases beyond the reductions realized as a result of the EISA2007 (Public Law 110-140) lighting standards.

Results for the commercial sector

Like the residential sector, analysis results for the commercial sector are discussed here in terms of cumulative reductions relative to the 2011 Demand Technology case, in order to illustrate the effect of efficiency improvements over the period from 2011 to 2035. Buildings in the commercial sector are less homogeneous than those in the residential sector, in terms of both form and function. Although many commercial products

Table 6. Key assumptions for the residential sector in the 1E/2012 integrated demand technology cases

Assumptions	Integrated 2011 Demand Technology	Integrated High Demand Technology ^a	Integrated Buildings Best Available Demand Technology ^a
End-use equipment	Limited to technology menu available in 2011. Promulgated standards still take effect.	Earlier availability, lower cost, and/or higher efficiencies for advanced equipment.	Purchases limited to highest available efficiency for each technology class, regardless of cost.
Hurdle rates	Same as Reference case distribution; varies by end-use technology.	All energy efficiency investments evaluated at 7-percent real interest rate.	All energy efficiency investments evaluated at 7-percent real interest rate.
Building shells	Fixed at 2011 levels.	New buildings meet ENERGY STAR specifications after 2016. Efficiency improvement for existing buildings is 50 percent greater than in the Reference case.	New buildings meet most efficient specifications. Efficiency improvement for existing buildings is 100 percent greater than in the Reference case.
Distributed and combined heat and power generation	No improvement in technology cost or performance after 2011. Learning rates same as in the Reference case.	PV and wind costs based on Advanced Case in EIA Technology reports. ^b Learning rates adjusted for all technologies.	PV and wind costs reduced by twice the difference between the Reference and High Technology costs. Learning rates adjusted for all technologies.
Personal computers	ENERGY STAR sales and enabling rates; LCD and laptop shares fixed at 2011 values.	ENERGY STAR sales and enabling rates LCD and laptop shares higher than in the Reference case.	ENERGY STAR sales and enabling rates. LCD share approaches 100 percent. Laptop share higher than in the Reference case.
TVs, cable boxes, and satellite systems	Fixed at 2011 values.	Unit energy consumption (UEC) values are average of Reference and Best Available Demand Technology cases.	Per-unit consumption levels reduced to ENERGY STAR specifications.
Miscellaneous electricity end uses	Unit energy consumption (UEC) values fixed at 2011 values.	Most efficient equipment selected after 2014.	Most efficient equipment selected in all years.

^aAll changes from the Reference case start in 2012 unless otherwise stated

^bU.S. Energy Information Administration, *Photovoltaic (PV) Costs and Performance Characteristics for Residential and Commercial Applications, Final Report* (August 2010), and *The Cost and Performance of Distributed Wind Turbines, 2010-2035, Final Report* (August 2010).

Table 7. Key assumptions for the commercial sector in the 1E/2012 integrated demand technology cases

Assumptions	Integrated 2011 Demand Technology	Integrated High Demand Technology ^a	Integrated Buildings Best Available Demand Technology ^a
End-use equipment	Limited to technology menu available in 2011. Promulgated standards still take effect.	Earlier availability, lower cost, and/or higher efficiencies for advanced equipment.	Purchases limited to highest available efficiency for each technology class, regardless of cost.
Hurdle rates	Same as Reference case distribution.	All energy efficiency investments evaluated at 7-percent real interest rate.	All energy efficiency investments evaluated at 7-percent real interest rate.
Building shells	Fixed at 2011 levels.	25 percent more improvement than in the Reference case by 2035.	50 percent more improvement than in the Reference case by 2035.
Distributed and combined heat and power generation	No improvement in technology cost or performance after 2011. Learning rates same as in the Reference case.	PV and wind costs, CHP cost and performance based on Advanced Case in EIA Technology reports. ^b Learning rates adjusted for advanced technologies.	PV and wind costs reduced by twice the difference between the Reference and High Technology costs. CHP based on Advanced Case in EIA Technology reports. ^b Learning rates adjusted for advanced technologies.
PC-related office equipment	ENERGY STAR sales and enabling rates; LCD and laptop shares fixed at 2011 values.	ENERGY STAR sales and enabling rates. LCD and laptop shares higher than in the Reference case.	ENERGY STAR sales and enabling rates. LCD share approaches 100 percent. Laptop share higher than in the Reference case.
Non-PC Office Equipment	Same as Reference case except for elimination of data center efficiency improvements.	Partial adoption of network power management for copiers, etc. Use of higher-efficiency power supplies for servers.	Greater adoption of network power management for copiers, etc. Use of higher-efficiency power supplies and continuous power management for servers.
Miscellaneous electricity	Less efficiency improvement than in the Reference case for uninterruptible power supplies (UPSs), network equipment, elevators, and water services.	Savings from high-efficiency UPSs and network equipment.	Greater savings from high-efficiency UPSs and network equipment.

^aAll changes from the Reference case start in 2012 unless otherwise stated

^bU.S. Energy Information Administration, *Photovoltaic (PV) Costs and Performance Characteristics for Residential and Commercial Applications, Final Report* (August 2010), *The Cost and Performance of Distributed Wind Turbines, 2010-2035, Final Report* (August 2010), and *Commercial and Industrial CHP Technology Costs and Performance Data* (June 2010).

Energy Efficiency

are subject to Federal efficiency standards, FEMP guidelines, and ENERGY STAR specifications, coverage is not as comprehensive as in the residential sector. Still, those initiatives and the ensuing efficiency improvements contribute to a cumulative reduction in commercial delivered energy use of 4.1 quadrillion Btu in the Reference case relative to the 2011 Demand Technology case (Figure 22). Virtually all of the reduction is in purchased electricity. Increased adoption of DG and CHP accounts for 0.4 quadrillion Btu (115 billion kilowatthours) of the cumulative reduction in purchased electricity in the Reference case. Commercial natural gas use is actually slightly higher in the Reference case because of the increased penetration of CHP. Office-related computer equipment sees the most significant end-use energy savings relative to the 2011 Demand Technology case, primarily because laptop computers gain market share from desktop computers

Commercial heating, ventilation and cooling account for almost 50 percent of the 17.1 quadrillion Btu in cumulative energy savings in the High Demand Technology case relative to the 2011 Demand Technology case. The more optimistic assumptions for end-use equipment in the High Demand Technology case offset the additional energy consumed as a result of greater adoption of CHP, resulting in a cumulative reduction in natural gas consumption of 0.9 quadrillion Btu. The increase in distributed and CHP generation contributes 0.8 quadrillion Btu (231 billion kilowatthours) to the cumulative reduction in purchased electricity use.

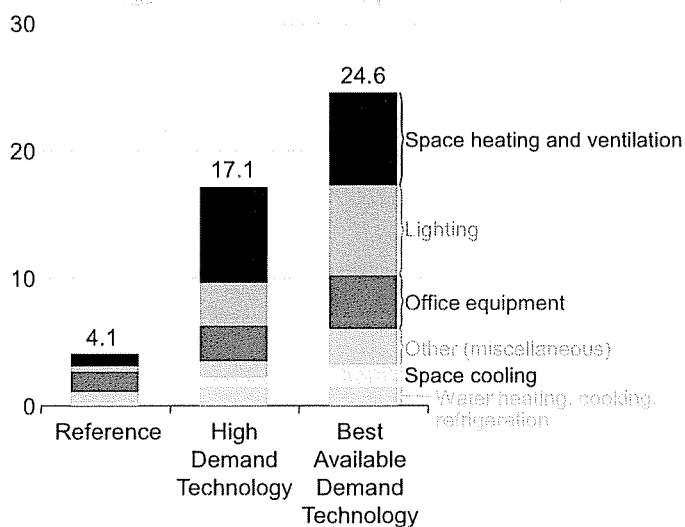
Technologies such as LED lighting result in almost as much improvement as space heating and ventilation in the Best Available Demand Technology case relative to the 2011 Demand Technology case. Significant reductions are seen for all end-use services, with a cumulative reduction in energy consumption of 24.6 quadrillion Btu. Even when consumers choose the most efficient type of each end-use technology, the more optimistic assumptions regarding technology learning for advanced CHP technologies result in more natural gas use in the Best Available Demand Technology case relative to the 2011 Demand Technology case.

In comparison to a case that restricts future equipment to the efficiencies available in 2011, the alternative cases show the potential for reductions in energy consumption from the adoption of more energy-efficient technologies. In the Reference case, technology improvement reduces residential energy consumption by 12.3 quadrillion Btu—equivalent to 4.1 percent of total residential energy use—from 2011 to 2035 in comparison with the 2011 Demand Technology case. In the commercial sector, energy consumption is reduced by 4.1 quadrillion Btu—equivalent to 1.7 percent of total commercial energy use—over the same period. With greater technology improvement in the High Demand Technology case, cumulative energy savings from 2011 to 2035 rise by an additional 6.4 percent and 5.5 percent in the residential and commercial sectors, respectively. In the Best Available Demand Technology case, the cumulative reductions in energy consumption grow by an additional 8.2 percent and 3.1 percent in the residential and commercial sectors, respectively. In the Reference case, a cumulative total of 16.4 quadrillion Btu of energy consumption is avoided over the projection period relative to the 2011 Demand Technology case. That reduction is roughly equivalent to 80 percent of the energy that the buildings sectors consumed in 2010. In the Best Available Demand Technology case, cumulative energy consumption is reduced by an additional 64.3 quadrillion Btu from 2011 to 2035.

4. Energy Impacts of proposed CAFE standards for light-duty vehicles, model years 2017 to 2025

In response to environmental, economic, and energy security concerns, EPA and NHTSA in December 2011 jointly issued a proposed rule covering GHG emissions and CAFE standards for passenger cars and light-duty trucks in MY 2017 through MY 2025 [42]. EPA and NHTSA expect to announce a final rule in the second half of 2012. In this section, EIA uses the National Energy Modeling System (NEMS), which has been updated since last year but, due to the timing of the modeling process, does not incorporate all information from the pending rulemaking process, to assess potential energy impacts of the regulatory proposal.

Figure 22. Cumulative reductions in commercial energy consumption relative to the 2011 Demand Technology case, 2011-2035 (quadrillion Btu)



EPA is proposing GHG emissions standards that will reach a fleetwide LDV average of 163 grams CO₂ per mile (54.5 mpg equivalent) in MY 2025, or 49.6 mpg for the CAFE-only portion (Table 8). Passenger car standards are made more stringent by reducing the average annual CO₂ emissions allowed by 5 percent per year from MY 2016 through MY 2025. Average annual CO₂ emissions from light-duty trucks are reduced by 3.5 percent per year from MY 2016 through MY 2021, with larger average reductions for smaller light-duty trucks and smaller average reductions for larger light-duty trucks. For MY 2021 through MY 2025, light-duty trucks would be required to achieve a 5-percent average annual reduction rate. In this section, EIA assumes that the reductions in GHG emissions required under EPA standards exceed the reductions required under the NHTSA CAFE standards and are achieved through changes other than those that would provide further improvement in fuel economy as tested for compliance with the NHTSA standards.

NHTSA has proposed CAFE standards for LDVs that will reach a fleetwide average of 49.6 mpg in MY 2025, based on the projected inclusion of reductions in GHG emissions that are achieved by means other than improvements in fuel economy. CAFE standards are proposed for MY 2017 through MY 2021, and conditionally for MY 2022 through MY 2025. The proposed standards for passenger cars increase by 4.1 percent per year for MY 2017 through MY 2021 and 4.3 percent for MY 2022 through MY 2025. For light-duty trucks, the CAFE standards would increase by 2.9 percent per year for MY 2017 through MY 2021, with greater improvement required for smaller light-duty trucks and somewhat smaller improvement required for larger light-duty trucks. For MY 2022 through MY 2025, CAFE standards for all light-duty trucks would increase by 4.7 percent per year. Although there are complex dynamics in play among the CAFE standards and other policies, including those related to biofuels [43] and other gasoline alternatives, CAFE standards are the single most powerful regulatory mechanism affecting energy use in the U.S. transportation sector.

AEO2012 includes a CAFE Standards case that incorporates the proposed NHTSA fuel economy standards for MY 2017 through MY 2025. Fuel economy and GHG emissions standards for MY 2011 through MY 2016 have been promulgated already as final rules and are represented in the AEO2012 Reference case. Further, the Reference case assumes that CAFE standards rise slightly to meet the requirement that LDVs reach 35 mpg by 2020 mandated in EISA2007.

As modeled by EIA, compliance with the more stringent fuel economy standards in the CAFE Standards case leads to a change in the vehicle sales mix. Vehicles that use electric power stored in batteries, or use a combination of a liquid fuel (including gasoline) and electric power stored in batteries for motive and/or accessory power—such as hybrid electric vehicles (HEVs) or plug-in hybrid electric vehicles (PHEVs)—or that use liquid fuels other than gasoline, such as diesel or E85, play a larger role than in the Reference case. The CAFE Standards case also projects a significant improvement in the fuel economy of traditional vehicles with gasoline internal combustion engines with and without micro hybrid technologies. In the analysis, vehicles that combine gasoline internal combustion engines with micro hybrid systems are projected to have the largest increase in sales relative to the Reference case (Figure 23 and Table 9).

Gasoline-only vehicles retain the single largest share of new vehicle sales in 2025. In order to meet increased fuel economy requirements, the average fuel economy of gasoline vehicles, including micro hybrids, is raised by the introduction of new fuel-efficient technologies and improved vehicle designs. The fuel economy of gasoline-only passenger cars, including micro hybrids, increases from 32 mpg in 2010 to 51 mpg in 2025 in the CAFE Standards case, compared with 38 mpg in 2025 in the Reference case. The fuel economy of gasoline-powered light-duty trucks, including micro hybrids, rises similarly, from 24 mpg in 2010 to 37 mpg in 2025 in the CAFE Standards case, compared with 31 mpg in 2025 in the Reference case.

As vehicle attributes, such as horsepower and weight, change in response to the more stringent fuel economy standards, some consumers switch from passenger cars to light trucks. Light-duty trucks account for 39 percent of new LDV sales in 2025 in the CAFE Standards case, higher than their 37 percent share in 2025 in the Reference case but still much lower than their 2005 share of more than 50 percent. In 2025, new passenger cars average 56 mpg and light-duty trucks average 40 mpg in the CAFE Standards case, compared with 41 mpg and 31 mpg, respectively, in the Reference case. Although more stringent standards stimulate sales of vehicles with higher fuel economy, it takes time for new vehicles to penetrate the vehicle fleet in numbers that are sufficiently large to affect the average fuel economy of the entire U.S. LDV stock. Currently there are about 230 million LDVs on the road in the United States, projected to increase to 276 million in 2035. As a consequence of the gradual scrapping of older vehicles and the introduction of new, more fuel-efficient models, the average on-road fuel economy of the LDV stock,

Table 8. Estimated^a average fuel economy and greenhouse gas emissions standards proposed for light-duty vehicles, model years 2017-2025

	2016 (base)	2017	2018	2019	2020	2021	2022	2023	2024	2025
Fuel economy only (miles per gallon)										
Passenger cars	37.8	40.0	41.4	43.0	44.7	46.6	48.8	51.0	53.5	56.0
Light-duty trucks	28.8	29.4	30.0	30.6	31.2	33.3	34.9	36.6	38.5	40.3
All light-duty vehicles	34.1	35.3	36.4	37.5	38.8	40.9	42.9	45.0	47.3	49.6
Carbon dioxide emissions (grams per mile)										
Passenger cars	225	213	202	192	182	173	165	158	151	144
Light-duty trucks	298	295	285	277	270	250	237	225	214	203
All light-duty vehicles	250	243	232	223	213	200	190	181	172	163

^aBased on projected mix of LDV sales.

Figure 23 (continued)

representing the fuel economy realized by all vehicles in use, increases from around 20 mpg in 2010 to 22 mpg in 2016, 27.5 mpg in 2025, and 34.5 mpg in 2035, as compared with 28 mpg in 2035 in the Reference case (Figure 24).

More stringent fuel economy standards lead to reductions in total energy consumption. Total cumulative delivered energy consumption by LDVs from 2017 to 2035 is 8 percent lower in the CAFE Standards case than in the Reference case. LDV delivered energy consumption is 6 percent lower in 2025 in the CAFE Standards case than in the Reference case and 17 percent lower in 2035. Total consumption of petroleum and other liquids in the transportation sector is 0.5 million barrels per day lower in 2025 and 1.4 million barrels per day lower in 2035 in the CAFE Standards case than in the Reference case (Figure 25). The existing standards are modestly exceeded in the Reference case. If the standards are just met, the reduction in liquids consumption is 0.5 million barrels per day in 2025 and 1.6 million barrels per day in 2035 in the CAFE Standards case relative to the Reference case. The reductions in total delivered energy use and liquid fuel consumption become more pronounced later in the projection, as more of the total vehicle stock consists of vehicles with higher fuel economy.

The more stringent regulatory standards in the CAFE Standards case change the composition of the vehicle fleet by fuel type and shift the mix of fuels consumed. Nevertheless, motor gasoline, including gasoline blended with up to 15 percent ethanol (used in vehicles manufactured in MY 2001 and after), remains the predominant fuel by far for LDVs in the CAFE Standards case, accounting for 84 percent of LDV delivered energy consumption in 2035—only slightly less than its 86-percent share in 2035 in the Reference case.

Figure 23. Light-duty vehicle market shares by technology type in two cases, model year 2025 (percent of all light-duty vehicle sales)

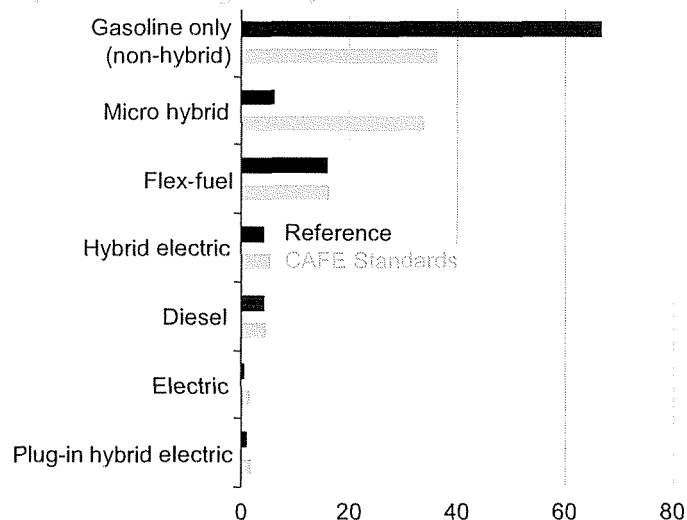


Figure 24. On-road fuel economy of the light-duty vehicle stock in two cases, 2005-2035 (miles per gallon)

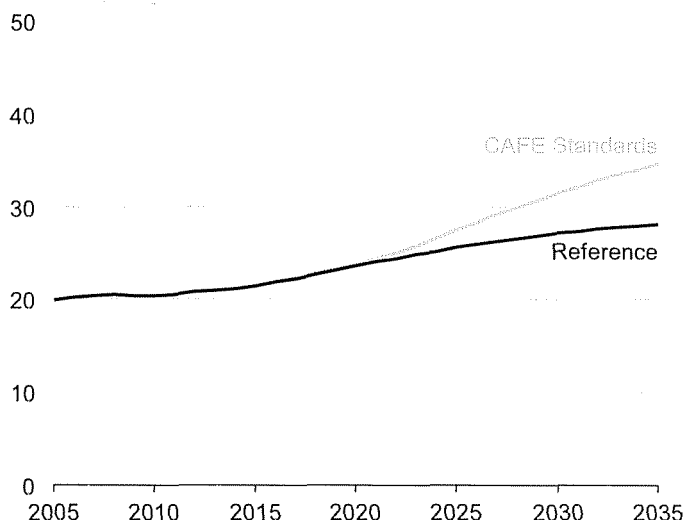


Table 9. Vehicle types that do not rely solely on a gasoline internal combustion engine for motive and accessory power

Vehicle type	Description
Micro hybrid	Vehicles with gasoline engines, larger batteries, and electrically powered auxiliary systems that allow the engine to be turned off when the vehicle is coasting or idling and then quickly restarted. Regenerative braking recharges the batteries but does not provide power to the wheels for traction.
Hybrid electric (gasoline or diesel)	Vehicles that combine internal combustion and electric propulsion engines but have limited all-electric range and batteries that cannot be recharged with grid power.
Diesel	Vehicles that use diesel fuel in a compression-ignition internal combustion engine.
Plug-in hybrid electric	Vehicles that use battery power for driving some distance, until a minimum level of battery power is reached, at which point they operate on a mixture of battery and internal combustion power. Plug-in hybrids also can be engineered to run in a “blended mode,” where an onboard computer determines the most efficient use of battery and internal combustion power. The batteries can be recharged from the grid by plugging a power cord into an electrical outlet.
Electric	Vehicles that operate by electric propulsion from batteries that are recharged exclusively by electricity from the grid or through regenerative braking.
Flex-fuel	Vehicles that can run on gasoline or any gasoline-ethanol blend up to 85 percent ethanol.

Total motor gasoline demand for LDVs is 19 percent lower in the CAFE Standards case in 2035 than in the Reference case, and lower demand for motor gasoline reduces the amount of ethanol used in E10 and E15 gasoline blends. As a consequence, more E85 fuel is sold to meet the RFS. E85 accounts for 10 percent of delivered energy consumption by LDVs in 2035, compared with 8 percent in the Reference case. Diesel fuel accounts for 5 percent of LDV delivered energy consumption in 2035, similar to its share in the Reference case. Electricity use by LDVs grows in the CAFE Standards case but still makes up less than 1 percent of LDV delivered energy demand in 2035.

Reductions in LDV delivered energy consumption reduce GHG emissions from the transportation sector. From 2017 and 2035, cumulative CO₂ emissions from transportation are 357 million metric tons (mmt) lower in the CAFE Standards case compared to the Reference case, a reduction of 5 percent. Transportation GHG emissions decline from 1,876 mmt in 2010 to 1,759 mmt in 2025 and to 1,690 mmt in 2035, reductions of 4 percent and 10 percent from the Reference case, respectively (Figure 26).

5. Impacts of a breakthrough in battery vehicle technology

The transportation sector's dependence on petroleum-based fuels has prompted significant efforts to develop technology and alternative fuel options that address associated economic, environmental, and energy security concerns. Electric drivetrain vehicles, including HEVs, PHEVs, and plug-in electric vehicles (EVs), are particularly well suited to meet those objectives, because they reduce petroleum consumption by improving vehicle fuel economy and, in the case of PHEVs and EVs, substitute electric power for gasoline use (see Table 10 for a descriptive list of electric drivetrain technologies).

AEO2012 includes a High Technology Battery case that examines the potential impacts of significant breakthroughs in battery electric vehicle technology on vehicle sales, energy demand, and CO₂ emissions. Breakthroughs may include a dramatic reduction in the cost of battery and nonbattery systems, success in addressing overheating and life-cycle concerns, as well as the introduction of battery-powered electric vehicles in several additional vehicle size classes. A brief summary of the results of the High Technology Battery case follows a discussion of the current market for battery electric vehicles.

Sales of light-duty HEVs, introduced in the United States more than a decade ago, peaked at about 350,000 new sales in 2007 and have maintained a roughly 3-percent share of total LDV sales through 2011. PHEVs were introduced in the United States at the end of 2010 with the production of the Chevy Volt, a PHEV-40 (PHEV with a 40-mile range). Although manufacturer plans call for increased production of PHEVs, sales in the first full year were under 10,000 units [44]. EVs were first introduced in the early 1900s, and manufacturers again made EVs available in the 1990s but with a focus on niche markets. The Nissan Leaf, an EV-100 (EV with a 100-mile range) introduced around the same time as the Chevy Volt, has sparked interest in the wider commercial prospects for EVs; however, sales in 2011 remained below 10,000 units.

The individual decision to purchase a vehicle is influenced by many factors, including style, performance, comfort, environmental values, expected use, refueling capability, and expectations of future fuel prices. In general, one of the single most important factors consumers consider when deciding to purchase a vehicle is cost. Specifically, they generally are more willing to purchase new vehicle technologies, such as battery electric systems, instead of conventional gasoline internal combustion engines (ICEs) if the economic benefit over a period of ownership is greater than the initial price of the vehicle. Additional costs and benefits—such as refueling time or difficulty of refueling, increased or decreased maintenance, and resale value—also may enter into vehicle choice decisions. Further, consumers may be unwilling to spend more to purchase a vehicle, even if it accrues fuel cost savings beyond the initial cost over a relatively short period, because they are unfamiliar with the new technology or alternative fuel.

Figure 25. Total transportation consumption of petroleum and other liquids in two cases, 2005-2035 (million barrels per day)

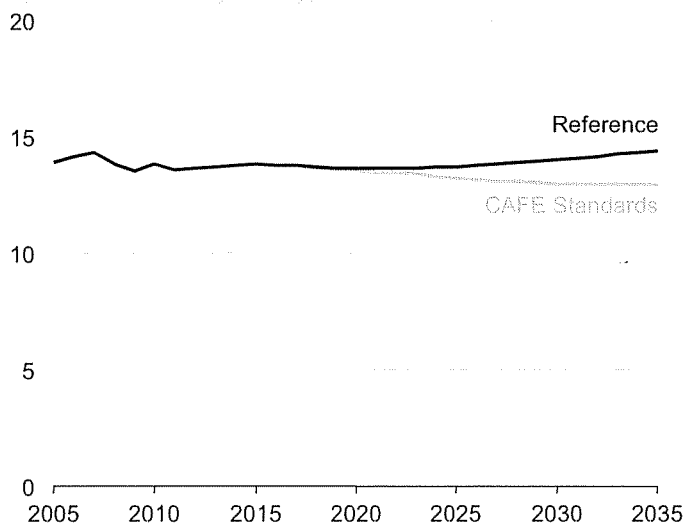
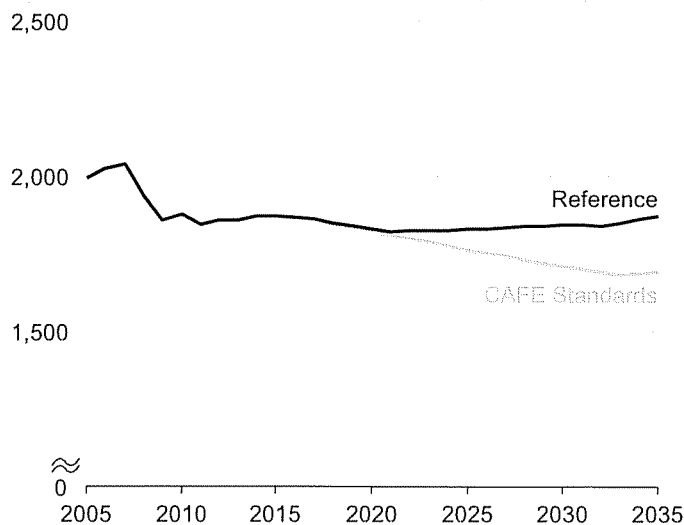


Figure 26. Total carbon dioxide emissions from transportation energy use in two cases, 2005-2035 (million metric tons carbon dioxide equivalent)



Energy Efficiency

Battery electric vehicles offer an economic benefit to consumers over conventional gasoline ICEs in terms of significant fuel cost savings from both increased fuel economy for HEVs and PHEVs and the displacement of gasoline with electricity for PHEVs and EVs. Currently available battery electric vehicles such as the Toyota Prius (HEV), Chevy Volt (PHEV), and Nissan Leaf (EV) achieve much higher fuel economy (mpg) and, with the higher efficiency of electric motors, higher gasoline-equivalent mpg in electric mode, providing consumers with lower fueling costs. The Toyota Prius achieves an EPA-estimated 39 to 53 mpg, depending on trim and driving test cycle. The Chevy Volt achieves 35 to 40 mpg in charge-sustaining mode [45] and 93 to 95 mpg equivalent in charge-depleting mode. The Nissan Leaf achieves 99 mpg equivalent. In comparison, the Toyota Corolla, a passenger car generally similar to the Prius, achieves 26 to 34 mpg; the Chevy Cruze, a passenger car in the compact car size class similar to the Volt, achieves 25 to 42 mpg; and the Nissan Versa, a subcompact passenger car similar to the Leaf [46], achieves 24 to 34 mpg.

The inclusion of advanced battery technology that increases fuel economy and, in the case of PHEVs and EVs, displaces gasoline with electricity increases the initial cost of the vehicle to the consumer. The Toyota Prius has a manufacturer's suggested retail price (MSRP) between \$24,000 and \$29,500 (compared with \$16,130 to \$17,990 for the Toyota Corolla); the Chevy Volt has an MSRP between \$39,145 and \$42,085 (compared with \$16,800 to \$23,190 for the Chevy Cruze); and the Nissan Leaf has an MSRP between \$35,200 and \$37,250 (compared with \$14,480 to \$18,490 for the Nissan Versa) [47]. Based on these MSRPs, the current incremental consumer purchase cost of a battery electric vehicle relative to a comparable conventional gasoline vehicle is around \$7,000 for an HEV and \$20,000 for a PHEV or EV, before accounting for Federal and State tax incentives.

Although consumers may value high-cost battery electric vehicles for a variety of reasons, it is unlikely that they can achieve wide-scale market penetration while their additional purchase costs remain significantly higher than the present value of future fuel savings. Currently, the discounted fuel savings achieved, assuming five years of ownership with future fuel savings discounted at 7 percent, are significantly less than the incremental purchase cost of the vehicles (Table 11). This result is true even if gasoline is \$6.00 per gallon. This calculation does not take into account any difference in maintenance cost or refueling infrastructure.

Recognizing the potential of HEVs, PHEVs, and EVs to reduce U.S. petroleum consumption and save consumers refueling costs, efforts are underway at both the public and private levels to address several of the barriers to wide-scale adoption of battery electric vehicle technology. Paramount among the barriers are reducing the cost of battery electric vehicles by lowering battery and nonbattery system costs and solving battery life-cycle and overheating limitations that will allow battery storage to downsize while maintaining a given driving range. For example, battery and nonbattery systems costs could be reduced by improving the manufacturing process, changing battery chemistry, or improving the electric motor. Solving battery life-cycle and overheating

Table 10. Description of battery-powered electric vehicles

Vehicle type	Description
Micro or "mild" hybrid	Vehicles with ICEs, larger batteries, and electrically powered auxiliary systems that allow the engine to be turned off when the vehicle is coasting or idle and then be quickly restarted. Regenerative braking recharges the batteries but does not provide power to the wheels for traction. Micro and mild hybrids are not connected to the electrical grid for recharging and are not considered as HEVs in this analysis.
Full hybrid electric (HEV)	Vehicles that combine an internal combustion engine with electric propulsion from an electric motor and battery. The vehicle battery is recharged by capturing some of the energy lost during braking. Stored energy is used to eliminate engine operation during idle, operate the vehicle at slow speeds for limited distances, and assist the ICE drivetrain throughout its drive cycle. Full HEV systems are configured in parallel, series, or power split systems, depending on how power is delivered to the drivetrain. HEVs are not connected to the electric grid for recharging.
Plug-in hybrid electric (PHEV)	Vehicles with larger batteries to provide power to drive the vehicle for some distance in charge-depleting mode, until a minimum level of battery power is reached (a "minimum state of charge"), at which point they operate on a mixture of battery and internal combustion power ("charge-sustaining mode"). The minimum state of charge is engineered to about 25 percent of full charge to ensure that the battery's life cycle matches the expected life of the vehicle. PHEVs also can be engineered to run in a "blended mode," using an onboard computer to determine the most efficient use of battery and internal combustion power. The battery can be recharged either from the grid by plugging a power cord into an electrical outlet or by the internal combustion engine. Current PHEV batteries are designed to recharge to about 75 percent of capacity for safety reasons related to battery overheating, leaving a depth of discharge of around 50 percent of total battery capacity. Typically, the distance a fully charged PHEV can travel in charge-depleting mode is indicated by its designation. For example, a PHEV-40 is engineered to travel around 40 miles on battery power alone before switching to charge-sustaining operation.
Plug-in electric (EV)	Vehicles that operate solely on an electric drivetrain with a large battery and electric motor and do not have an ICE to provide motive power. EVs are recharged primarily from the electrical grid by plugging into an electrical outlet, with some additional energy captured through regenerative braking. EV batteries also have a working depth of discharge capacity that is limited to both lower and upper levels due to life-cycle and safety concerns. EVs are designated by the distance a fully charged vehicle can travel in all-electric mode. For example, an EV-100 is designed to travel around 100 miles on battery power. EVs lack the "range extender" capability of PHEVs, which can switch instantly to an ICE when the battery reaches a minimum state of charge.

concerns would allow battery capacity to be downsized, which would improve the depth of discharge and make the battery less expensive. In addition, public and private efforts to address other obstacles to wider adoption of plug-in battery vehicles are underway, including the development of public charging infrastructure.

The AEO2012 High Technology Battery case examines the potential impacts of battery technology breakthroughs by assuming the attainment of program goals established by DOE's Office of Energy Efficiency and Renewable Energy (EERE) for high-energy battery storage cost, maximum depth of discharge, and cost of a nonbattery traction drive system for 2015 and 2030 (Figures 27 and 28) [48]. EERE's program goals represent significant breakthroughs in battery and nonbattery systems, in terms of costs and life-cycle and safety concerns, in comparison with current electric vehicle technologies. Further, with breakthroughs in battery electric vehicle technology, more vehicle size classes are assumed to be available for passenger cars and light-duty trucks.

Reduced costs for battery and nonbattery systems in the High Technology Battery case lead to significantly lower HEV, PHEV, and EV costs to the consumer (Figures 29 and 30). The Reference case already projects a much lower real price to consumers for battery electric vehicles in 2035 relative to 2010 as a result of cost reductions for battery and nonbattery systems. Those declines are furthered in the High Technology Battery case. The prices of HEVs and PHEVs with a 10-mile range decline by an additional \$1,500, or 5 percent, in 2035 in the High Technology Battery case relative to the Reference case. For PHEVs with a 40-mile range the relative decline is \$3,500, or 11 percent, in 2035. For EVs with 100-mile (EV100) and 200-mile (EV200) ranges the relative declines are \$3,600 and \$13,300, or 13 percent and 30 percent, respectively, in 2035 relative to the Reference case.

Figure 27. Cost of electric vehicle battery storage to consumers in two cases, 2012-2035 (2010 dollars per kilowatt-hour)

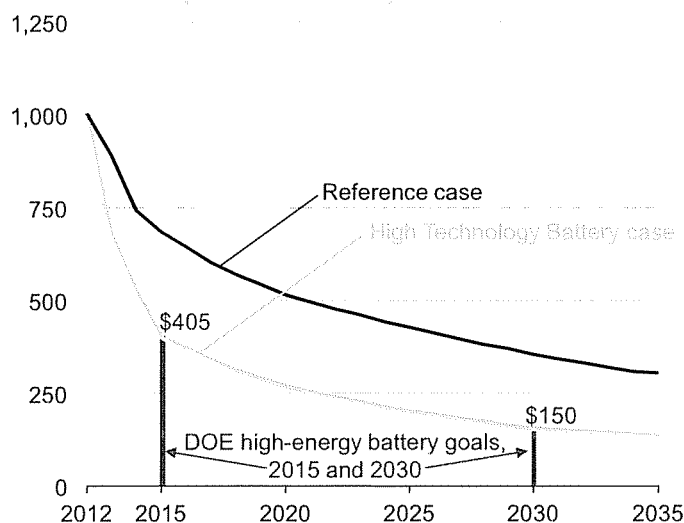


Figure 28. Costs of electric drive/traction nonbattery systems to consumers in two cases, 2012-2035 (2010 dollars)

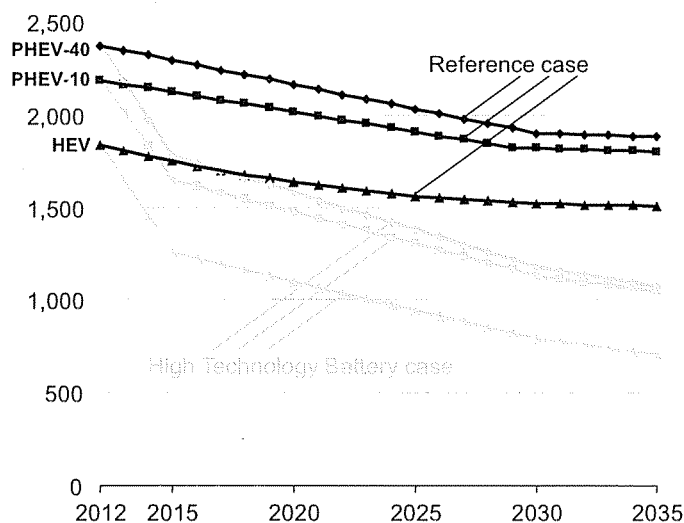


Table 11. Comparison of operating and incremental costs of battery electric vehicles and conventional gasoline vehicles

Characteristics	Hybrid electric vehicle (Prius)	Plug-in hybrid electric vehicle (Volt)	Plug-in electric vehicle (Leaf)
Fuel efficiency (mpg equivalent)	45	38 (charge-sustaining mode) 94 (charge-depleting mode)	99 (charge-depleting mode)
Annual vehicle miles traveled			12,500
Percent vehicle miles traveled electric only	0	58	100
Fuel savings vs. conventional gasoline ICE vehicle (at \$3.50 per gallon) ^a	\$1,169	\$2,036	\$3,314
Fuel savings vs. conventional gasoline ICE vehicle (at \$6.00 per gallon) ^a	\$2,004	\$4,340	\$7,071
Incremental vehicle cost (2010 dollars) relative to cost of 35-mpg conventional gasoline ICE vehicle ^b	\$7,000	\$20,000	\$20,000

^a5-year net present value of fuel savings, assuming 35 mpg for ICE, 7% discount rate, and \$0.10 per kilowatt-hour electricity price

^bDoes not include Federal, State, or local tax credits

Market Penetration

Lower vehicle prices lead to greater penetration of battery electric vehicle sales in the High Technology Battery case than projected in the Reference case. Battery electric vehicles, excluding mild hybrids, grow from 3 percent of new LDV sales in 2013 to 24 percent in 2035, compared with 8 percent in 2035 in the Reference case (Figure 31). Due to the still prohibitive incremental cost, EV200 vehicles do not achieve noticeable market penetration.

Plug-in vehicles, including both PHEVs and EVs, show the largest growth in sales in the High Technology Battery case, resulting from the relatively larger incremental reduction in vehicle costs. Plug-in vehicle sales grow to just over 13 percent of new vehicle sales in 2035, compared with 3 percent in 2035 in the Reference case, with EV sales growing to 8 percent of new LDV sales in 2035, compared with 2 percent in 2035 in the Reference case. Virtually all sales of plug-in vehicles are EVs with a 100-mile range, given the prohibitive cost, even in 2035, of batteries for EVs with a 200-mile range. PHEVs grow to just under 6 percent of total sales, compared with 2 percent in 2035 in the Reference case. Most PHEV sales are vehicles with a 10-mile all-electric range.

Although plug-in vehicle sales increase substantially in the High Technology Battery case, that growth is tempered by the lack of widespread high-speed recharging infrastructure. In the absence of such public infrastructure, consumers must rely almost entirely on recharging at home. According to data from the 2009 Residential Energy Consumption Survey, 49 percent of households that own vehicles park within 20 feet of an electrical outlet [49]. A widespread publicly available infrastructure was not considered as part of the High Technology Battery case, which limits the maximum market potential of PHEVs and EVs.

Figure 29. Total prices to consumers for compact passenger cars in two cases, 2015 and 2035 (thousand 2010 dollars)

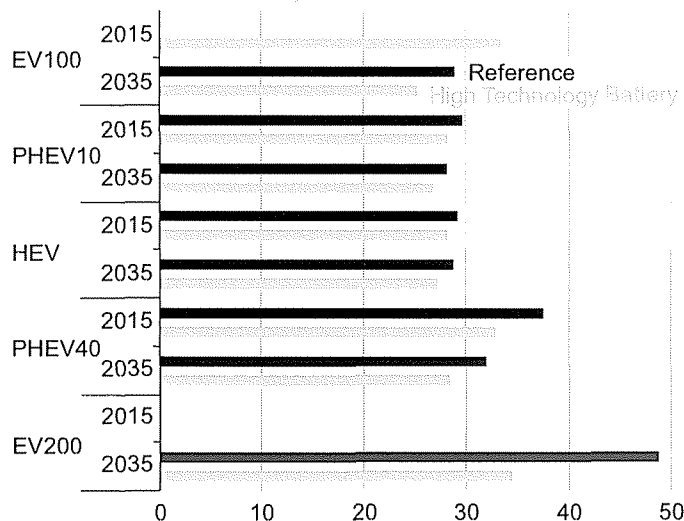
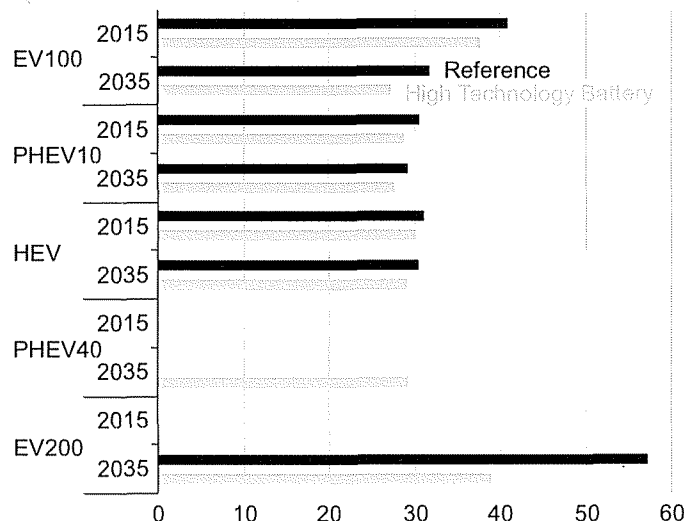


Figure 30. Total prices to consumers for small sport utility vehicles in two cases, 2015 and 2035 (thousand 2010 dollars)

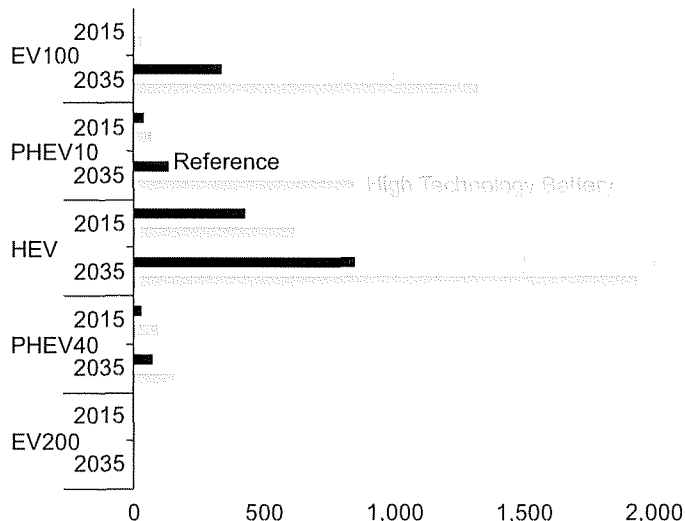


HEV sales, including an ICE powered by either diesel fuel or gasoline, increase in the High Technology Battery case from 3 percent of sales in 2013 to 11 percent in 2035, compared with 5 percent in 2035 in the Reference case. Although the cost declines for HEVs are modest relative to those for other battery electric vehicle types, HEVs benefit from being unconstrained by the lack of recharging infrastructure.

Increased sales of battery electric vehicles in the High Technology Battery case lead to their gradual penetration throughout the LDV fleet. In 2035, HEVs represent 9 percent of the 276 million LDV stock, as compared with 4 percent in the Reference case. EVs and PHEVs each account for about 5 percent of the LDV stock in the High Technology Battery case in 2035, compared with 1 percent each in the Reference case.

The penetration of battery electric vehicles with relatively higher fuel economy and efficient electric motors reduces total energy use by LDVs from 15.6 quadrillion Btu in 2013 to 14.8 quadrillion Btu in 2035 in the High Technology Battery case, compared with 15.5 quadrillion Btu in 2035 in the Reference case (Figure 32). LDV liquid fuel use declines to

Figure 31. Sales of new light-duty vehicles in two cases, 2015 and 2035 (thousand vehicles)



14.6 quadrillion Btu in 2035 in the High Technology Battery case, and their electricity use increases to 0.2 quadrillion Btu—as compared with 15.4 quadrillion Btu of liquid fuel consumption and essentially no electricity consumption in 2035 in the Reference case. The reduction in liquid fuel consumption in the High Technology Battery case lowers U.S. net imports of petroleum from 8.5 million barrels per day in 2013 to 6.9 million barrels per day in 2035, compared with 7.2 million barrels per day in 2035 in the Reference case.

The reduction in total energy consumption by LDVs and displacement of petroleum and other liquid fuels with electricity decreases LDV energy-related CO₂-equivalent emissions from 1,030 million metric tons in 2013 to 935 million metric tons in 2035 in the High Technology Battery case, which represents a 2-percent decrease from 958 million metric tons in 2035 in the Reference case (Figure 33). CO₂ and other GHG emissions from the electric power consumed by PHEVs and EVs is treated as representative of the national electricity grid and not regionalized. Ultimately, the CO₂ and other GHG emissions of plug-in vehicles will depend on the fuel used in generating electricity.

The High Technology Battery case assumes a breakthrough in the costs of batteries and nonbattery systems for battery electric vehicles. Yet, despite the assumed dramatic decline in battery and nonbattery system costs, battery electric vehicles still face obstacles to wide-scale market penetration.

First, prices for battery electric vehicles remain above those for conventional gasoline counterparts, even with the assumption of technology breakthroughs throughout the projection period. The decline in sales prices relative to those for conventional vehicles may be enough to justify purchases by consumers who drive more frequently, consider relatively longer payback periods, or would purchase a more expensive but environmentally cleaner vehicle for a moderate additional cost. However, relatively more expensive battery electric vehicles may not pay back the higher purchase cost over the ownership period for a significant population of consumers.

In addition, EVs face the added constraint of plug-in infrastructure availability. Currently, there are about 8,000 public locations in the United States with at least one outlet for vehicle recharging, about 2,000 of which are in California [50]. In comparison, there are some 150,000 gasoline refueling stations available for public use. Without the construction of a much larger recharging network, consumers will have to rely on residential recharging, which is available for only around 40 percent of U.S. dwellings.

Further, recharging times differ dramatically depending on the voltage of the outlet. Typical 120-volt outlets can take up to 20 hours for a full EV battery to recharge; a 240-volt outlet can reduce the recharging time to about 7 hours [51]. Quick-recharging 480-volt outlets are under consideration for 30-minute “ultra-quick” recharges, but they may raise concerns related to safety and residential or commercial building codes. Even with ultra-quick recharging, EVs still would require substantially longer times for refueling than are required for ICE vehicles using liquid fuels. Given the concerns about availability and duration of recharging, the obstacle of severe range limitation, which does not affect PHEVs or HEVs, may inhibit the adoption of EVs by consumers.

Finally, another obstacle to wide-scale adoption of battery electric vehicles and other types of alternative-fuel vehicles is the increase in fuel economy for conventional gasoline vehicles and other types of AFVs resulting from higher fuel economy standards for LDVs. Final standards for LDV fuel economy currently are in place through MY 2016, and new CAFE standards proposed for MY 2017 through MY 2025 would increase combined LDV fuel economy to 49.6 mpg (56.0 mpg for passenger cars and 40.3 mpg for light-duty trucks) [52]. While the standards themselves may promote the adoption of battery electric vehicles, they also could considerably change the economic payback of electric drivetrain vehicles by decreasing consumer refueling costs for

Figure 32. Consumption of petroleum and other liquids, electricity, and total energy by light-duty vehicles in two cases, 2000-2035 (quadrillion Btu)

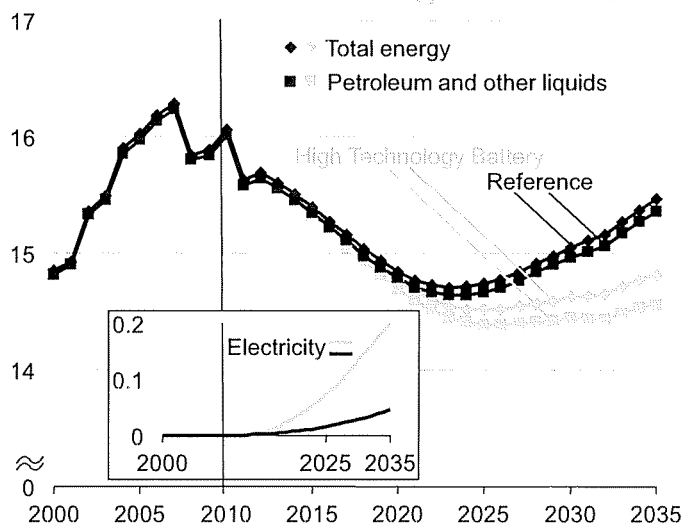
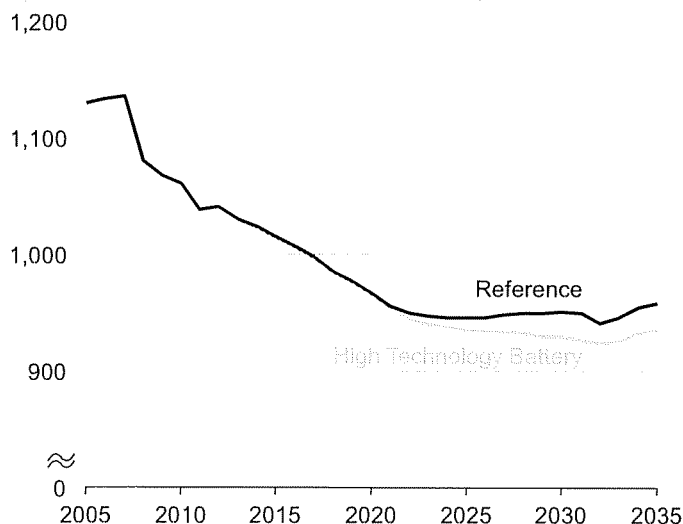


Figure 33. Energy-related carbon dioxide emissions from light-duty vehicles in two cases, 2005-2035 (million metric tons carbon dioxide equivalent)



conventional vehicles.

thus lowering the fuel savings of electric drivetrain vehicles and making the upfront incremental cost more prohibitive. The potential impact of CAFE standards on other vehicle attributes, costs, and fuel savings adds to the complexity of this dynamic.

6. Heavy-duty natural gas vehicles

Environmental and energy security concerns, together with recent optimism about natural gas supply and recent lower natural gas prices, have led to significant interest in the potential for fueling heavy-duty vehicles (HDVs) with natural gas produced domestically. Key market uncertainties with regard to natural gas as a fuel for HDVs include fuel and infrastructure issues (such as the build-out process for refueling stations and whether there will be sufficient demand for refueling to cover the required capital outlays, and retail pricing and taxes for liquefied natural gas [LNG] and compressed natural gas [CNG] fuels); and vehicle issues (including incremental costs for HDVs fueled by natural gas, availability of fueling infrastructure, cost-effectiveness in view of average vehicle usage, vehicle residual value, vehicle weight, and vehicle refueling time).

Current state of the market

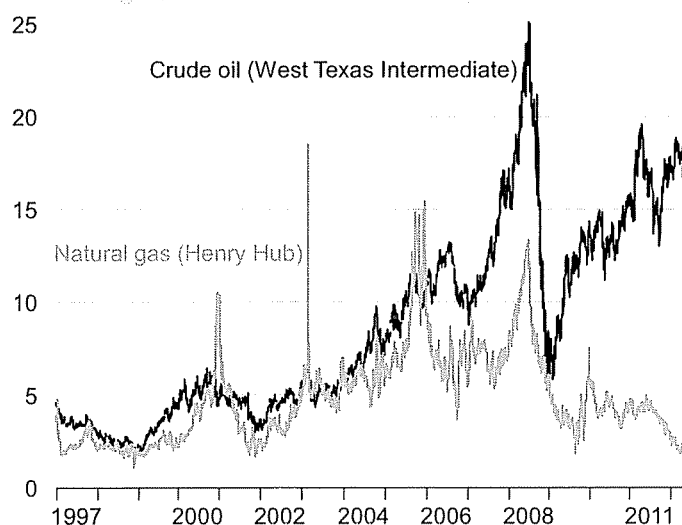
At present, HDVs in the United States are fueled almost exclusively by petroleum-based diesel fuel [53]. In 2010, use of petroleum-based diesel fuel by HDVs accounted for 17 percent (2.2 million barrels per day) of total petroleum consumption in the transportation sector (12.8 million barrels per day) and 12 percent of the U.S. total for all sectors (18.3 million barrels per day). Consumption of petroleum-based diesel fuel by HDVs increases to 2.3 million barrels per day in 2035 in the AEO2012 Reference case, accounting for 19 percent of total petroleum consumption in the transportation sector (12.1 million barrels per day) and 14 percent of the U.S. total for all sectors (17.2 million barrels per day).

Historically, natural gas has played a negligible role as a highway transportation fuel in the United States. In 2010, there were fewer than 40,000 total natural gas HDVs on the road, or 0.4 percent of the total HDV stock of nearly 9 million vehicles. Sales of new HDVs fueled by natural gas peaked at about 8,000 in 2003, and fewer than 1,000 were sold in 2010 out of a total of more than 360,000 HDVs sold. With relatively few vehicles on the road, natural gas accounted for 0.3 percent of total energy used by HDVs in 2010.

As of May 2012, there were 1,047 CNG fueling stations and 53 LNG fueling stations in the United States, with 53 percent of the CNG stations and 57 percent of the LNG stations being privately owned and not open to the public [54]. Further, the stations were not evenly distributed across the United States, with 22 percent (227) of the CNG stations and 68 percent (36) of the LNG stations located in California. In comparison, nationwide, there were more than 157,000 stations selling motor gasoline in 2010 [55].

Developments in natural gas and petroleum markets in recent years have led to significant price disparities between the two fuels and sparked renewed interest in natural gas as a transportation fuel. Led by technological breakthroughs in the production of natural gas from shale formations, domestic production of dry natural gas increased by about 14 percent from 2008 to 2011. In the AEO2012 Reference case, U.S. natural gas production (including supplemental gas) increases from 21.6 trillion cubic feet in 2010 to 28.0 trillion cubic feet in 2035. Further, although the world market for oil and petroleum products is highly integrated, with prices set in the global marketplace, natural gas markets are less integrated, with significant price differences across regions of the world. With the recent growth in U.S. natural gas production, domestic natural gas prices in 2012 are significantly lower than crude oil prices on an energy-equivalent basis (Figure 34).

Figure 34. U.S. spot market prices for crude oil and natural gas, 1997-2012 (2010 dollars per million Btu)



Fuel and infrastructure issues

Even when it appears that an emerging technology can be profitable with significant market penetration, achieving significant penetration can be difficult and, potentially, unattainable. Refueling stations for NGVs are unlikely to be built without some assurance that there will be sufficient numbers of NGVs to be refueled, soon enough to allow for recovery of the capital investment within a reasonable period of time. In terms of estimating the prices that will be charged for NGV fuels beyond the cost of the dry natural gas itself, and the issue of expected utilization rates, there are additional uncertainties related to capital and operating costs, taxes, and the potential of prices being set on the basis of the prices of competing fuels.

Basic fuel issues

Diesel fuel falls into the category of distillate fuels, which have constituted more than 25 percent of U.S. refinery output in recent years. The cost of diesel fuel is linked closely to the

value of crude oil inputs for the refining process. In 2011, the spot price of Gulf Coast ultra-low sulfur diesel fuel averaged \$2.97 per gallon. The wholesale diesel price reflects crude oil costs, as well as the difference between the wholesale price at the refinery gate and the cost of crude oil input, commonly referred to as the “crack spread,” which reflects the costs and profits of refineries. Beyond the wholesale price, the pump price of diesel fuel reflects distribution costs, Federal, State, and local fuel taxes, retailing costs, and profits. For diesel fuel, with an average energy content of 138,690 Btu per gallon, the 2011 national average retail price of \$3.84 per gallon is equivalent to about \$27.80 per million Btu.

Although early models of NGVs sometimes were less fuel-efficient than comparable diesel-fueled vehicles, current technologies allow for natural gas to be used as efficiently as diesel in HDV applications. Therefore, comparisons between natural gas and diesel fueling costs can be based on the price of energy-equivalent volumes of fuel. For this analysis, the cost and price of natural gas fuels are expressed in terms of diesel gallon equivalent (dge). For example, with an energy content of approximately 84,820 Btu per gallon, 1 gallon of LNG is equivalent in energy terms to 0.612 gallons of diesel fuel.

Fuel costs for LNG and CNG vehicles depend on the cost of natural gas used to produce the fuels, the cost of the liquefaction or compression process (including profits), the cost of moving fuel from production to refueling sites (if applicable), taxes, and retailing costs. Costs can vary with the scale of operations, but the significant disparity between current natural gas and crude oil prices suggests that the cost of CNG and LNG fuels in dge terms could be significantly below the price of diesel fuel.

There are different wholesale natural gas prices and capital costs associated with CNG and LNG stations. CNG retail stations, which typically have connections to the pipeline distribution network and thus require compression equipment and special refueling pumps, are likely to pay prices for natural gas that are similar to those paid by commercial facilities. For LNG stations, insulated LNG storage tanks and special refueling pumps are needed. LNG typically would be delivered from a liquefaction facility that, depending on its scale, would pay a natural gas price similar to the prices paid by electric power plants. The costs of liquefying and transporting the fuel to the retail station would ultimately be included in the retail price.

In a competitive market, retail fuel prices should reflect costs, including input, processing, distribution, and retailing costs, normal profit margins for processors, distributors, and retailers, and taxes. For example, the market for diesel fuel, which is produced by a large number of foreign and domestic refiners and is sold through numerous distributors and retail outlets, generally is considered to be a competitive market, in which retail prices follow costs.

CNG and LNG markets, at least in their initial stages, may not be as competitive as diesel fuel markets. For example, at public refueling stations, LNG and CNG currently sell at prices significantly higher than would be suggested by a long-term analysis of cost-based pricing. According to DOE’s April 2012 “Clean Cities Alternative Fuel Price Report,” the average nationwide nominal retail price for LNG was \$3.05 per dge, and the average for CNG was \$2.32 per dge [56].

If the use of LNG and/or CNG to fuel HDVs starts to grow, it is likely to take some time before fuel production and refueling infrastructure become sufficiently widespread for competition among fuel providers alone to assure that fuel prices are more closely linked to cost-based levels. However, even without many fuel providers, operators of an LNG and/or CNG vehicle fleet may be in a position to negotiate cost-based fuel prices with refueling station operators seeking to lock in demand for their initial investments in refueling infrastructure. Such arrangements provide an alternative to reliance on centrally fueled fleets as a means of circumventing the problem of how to introduce NGVs and natural gas refueling infrastructures concurrently.

Build-out process for refueling stations

It is not clear how NGVs and an expanded natural gas refueling infrastructure ultimately will evolve. One view is that a “hub-and-spoke” model for refueling infrastructure will expand sufficiently in multiple areas for a point-to-point system to take hold eventually. The “hubs” in the model would include the local refueling infrastructure, currently in place primarily to support local fleets. The “spokes” would ensure that refueling infrastructure is in place on the main transportation corridors connecting the hubs.

Several regional efforts are in place to encourage such “hub-and-spoke” growth for NGV refueling facilities. They include the Texas Clean Transportation Triangle [57], a strategic plan for CNG and LNG refueling stations between Dallas, San Antonio, and Houston; and the Interstate Clean Transportation Corridor [58], which aims to provide LNG fueling stations between such major western cities as Los Angeles, Las Vegas, Phoenix, Reno, Salt Lake City, and San Francisco. There also is a plan for a Pennsylvania Clean Transportation Corridor [59], which would provide CNG and LNG fueling stations between Pittsburgh, Harrisburg, Scranton, and Philadelphia.

In several corridors, Federal and State incentives are subsidizing both the construction of refueling stations and the production of heavy-duty LNG vehicles [60], in an effort to ensure that both demand and supply will be in place concurrently. A major question is whether gaps between isolated targeted markets can be bridged to provide a nationwide refueling structure that will allow heavy-duty NGVs to travel almost anywhere.

Sufficiency of demand for refueling to cover capital outlay

The cost of providing refueling services for NGVs depends on a number of factors and is distinctly different for CNG and LNG vehicles. Investment decisions are likely to be based on levels of demand. NGV refueling capability can be added at an existing facility or at a separate dedicated facility (which would require an additional investment). The costs depend in part on the number

Types of fuel

of fueling hoses added. LNG stations in particular benefit from higher volumes, but they also require significant additional land to accommodate storage tank(s), and they must satisfy special safety requirements—both of which add costs that can vary significantly from place to place. One added cost in operating an LNG station is the need for safety suits and specialized training for station attendants who dispense the fuel.

LNG typically is delivered to refueling stations via tanker truck from a separate liquefaction facility, the proximity of which is a major factor in the cost and frequency of deliveries. Any significant expansion of LNG refueling capacity also will require expanded liquefaction capacity, which currently is not sufficiently dispersed throughout the country to support a nationwide LNG refueling infrastructure. Although there are several dedicated large-scale natural gas liquefaction facilities in the United States, primarily in the West, there are smaller liquefaction plants and LNG storage tanks currently in use for meeting peak-shaving needs of utilities and pipelines during times of high demand. There are more than 100 such facilities in the United States, with a combined liquefaction capacity of more than 6 billion cubic feet per day. The majority are concentrated in the Northeast and Southeast [61].

Retail prices and taxes for LNG and CNG fuels

Even if the costs are fully known, retail prices for CNG and LNG transportation fuels remain uncertain, given questions about whether dispensers would charge higher prices in order to recover costs more rapidly if the facility were underutilized or would set prices to be competitive with the price of diesel. Prices charged at private stations for fleet vehicles presumably would be based on cost. With the number of refueling stations limited, competition between retailers is likely to be limited, at least initially. However, NGV refueling stations presumably would want to provide sufficient economic incentive in terms of the competitiveness of fuel prices to encourage more purchases of NGVs.

NGV fuel is taxed at State and Federal levels. Currently, on a Federal level, CNG is taxed at the same rate as gasoline on an energy-equivalent basis (\$0.18 per gasoline gallon equivalent, or \$0.21 per dge). However, LNG is taxed at a higher effective rate than diesel fuel, because it is taxed volumetrically at \$0.24 per LNG gallon equivalent (\$0.40 per dge) rather than on the basis of energy content [62]. State taxes vary, averaging \$0.15 per dge for CNG and \$0.24 per dge for LNG.

Vehicle Issues

Incremental vehicle cost

NGVs have significant incremental costs relative to their diesel-powered counterparts because of the need for pressurization and insulation of CNG or LNG tanks and the lower energy content of natural gas as a fuel. Total incremental costs relative to diesel HDVs range from about \$9,750 to \$36,000 for Class 3 trucks (GVWR 10,001 to 14,000 pounds), \$34,150 to \$69,250 for Class 4 to 6 trucks (GVWR 14,001 to 26,000 pounds), and \$49,000 to \$86,125 for Class 7 and 8 trucks (GVWR greater than 26,001 pounds). The incremental costs of heavy-duty NGVs depend in large part on the volume of the vehicle's CNG or LNG storage tank, which can be sized to match its typical daily driving range. Non-storage-tank incremental costs average about \$2,000 for Class 3 vehicles, \$20,000 for Class 4 to 6 vehicles, and \$30,000 for Class 7 to 8 vehicles [63]. Fuel storage costs are about \$350 per gallon diesel equivalent for CNG, with the incremental cost for Class 3 CNG vehicle storage tanks ranging between about \$8,000 and \$30,000; and about \$475 per gallon diesel equivalent for LNG, with the incremental cost for Class 4 to 8 LNG vehicle storage tanks ranging between about \$14,000 and \$52,000. Natural gas fuel storage technology is relatively mature, leaving only modest opportunity for cost reductions.

Availability of fueling infrastructure

The absence of widespread public refueling infrastructure can impose a serious constraint on heavy-duty NGV purchases. Owners who typically refuel vehicles at a private central location do not face an absolute constraint based on infrastructure, however, and heavy-duty NGVs currently in operation have tended to be purchased by fleet operators who refuel consistently at a specific central location or in areas where their vehicles routinely operate on dedicated routes.

Cost-effectiveness with average vehicle usage

In order to take advantage of potential fuel cost savings from switching to NGVs, owners must operate the vehicles enough to pay back the higher incremental cost in a reasonable period of time. The payback period varies with miles driven and is shorter for trucks that are used more intensively. Payback periods for the upfront incremental costs of NGVs are greater than 5 years for Class 3 vehicles unless they are driven at least 20,000 to 40,000 miles per year, and for Class 7 and 8 vehicles unless they are driven at least 60,000 to 80,000 miles per year. Shorter payback periods, 3 years or less, may reflect typical owner expectations more accurately [64], but they require much more intensive use: around 60,000 to 80,000 miles annually for Class 3 vehicles and more than 100,000 miles annually for Class 7 and 8 vehicles. For example, for a Class 7 or 8 compression ignition NGV with average fuel economy of 6 miles per gallon (which has a similar fuel economy compared to a diesel counterpart) and an incremental cost of \$80,000, the payback period would be just over 3 years if the vehicle were driven 100,000 miles per year, assuming a diesel fuel price of \$4.00 per gallon and an LNG fuel price of \$2.50 per gallon. If the same Class 7 or 8 vehicle were driven 40,000 miles per year, the payback period would be about 8 years. Further, without a widely available infrastructure, heavy-duty NGVs tend to be considered by centrally refueled fleets, which may have less mileage-intensive vehicle use.

According to the Department of Transportation’s Vehicle Inventory and Use Survey [65], last completed in 2002, a large segment of the HDV market simply does not drive enough to justify the purchase of an NGV (Figure 35). Around 30 percent of Class 3 vehicles and 75 percent of Class 7 and 8 vehicles are not driven enough to reach the 5-year payback threshold mentioned above. This is a significant portion of the market that would require either more favorable fuel economics or lower vehicle costs before the purchase of an NGV could be justified.

Other market uncertainties

Other factors may also affect market acceptance of heavy-duty NGVs. First, the purchase decision could be affected by the considerable additional weight of CNG or LNG tanks. For owners who typically “weight-out” a vehicle (driving with a full payload), adding heavy CNG or LNG tanks necessitates a reduction in freight payload. The EPA and NHTSA have estimated that about one-third of Class 8 sleeper tractors routinely are “weighted-out” [66].

A diesel tractor with 200 gallons of tank capacity and a fuel economy of 6 miles per gallon can drive 1,200 miles on a single refueling. The same tractor would need up to 110 dge of LNG tank capacity, at a considerable weight penalty and an incremental cost of more than \$80,000, to allow for a range of about 650 miles on a single refueling. Because owner/operators typically stop several times per day, the reduction in unrefueled maximum range would not require additional breaks for vehicles with large CNG or LNG tanks. However, CNG and LNG vehicles that do not opt for large tanks because of either weight or incremental cost considerations might have to refuel more frequently.

Finally, the owner perception of the balance of risk and reward for large capital investment is an uncertainty. Higher upfront capital costs can prove economically prohibitive for some potential owners. Even if the payback period for an investment in natural gas vehicles seemed acceptable, financing constraints or returns available on competing investment options could preclude the purchase. Additionally, the residual value of natural gas HDVs could, in theory, affect market uptake. With little natural gas refueling infrastructure in existence, the potential resale market is constrained to owners of centrally operated fleets. However, lease terms tend to limit the importance of this factor.

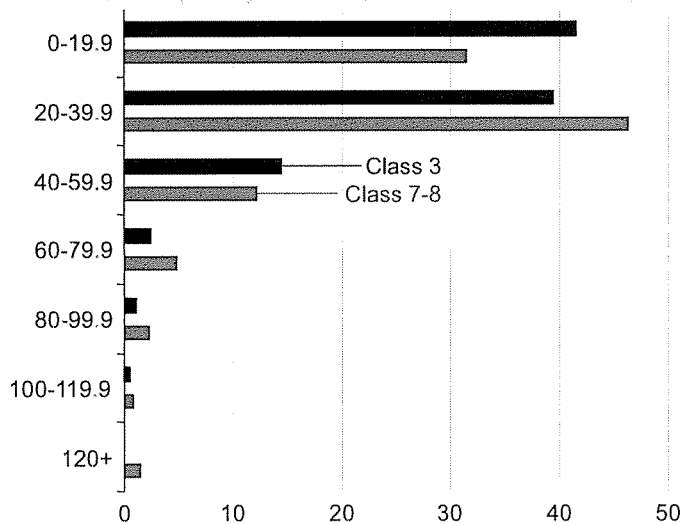
The complex set of factors influencing the potential for natural gas as a fuel for HDVs includes several areas for which policy mechanisms have been discussed. Most policy debates to date have considered the possibility of subsidies to reduce the incremental cost of natural gas vehicles (for example, in Senate and House versions of the New Alternative Transportation to Give Americans Solutions Act [67]) and Federal grant-based or other financial support for fueling station infrastructure. In addition, market hurdles related to consumer acceptance or payback periods might also be addressed through loan guarantees or related financial support policies, both for the vehicles and for the refueling infrastructure.

HD NGV Potential case results

The AEO2012 HD NGV Potential case examines issues associated with expanded use of heavy-duty NGVs, under an assumption that the refueling infrastructure exists to support such an expansion. The HD NGV Potential case differs from an earlier sensitivity case completed as part of the *Annual Energy Outlook 2010*, which focused on possible subsidies to expand the market potential for heavy-duty NGVs and limited its attention to vehicles operating within 200 miles of a central CNG refueling facility.

The AEO2012 HD NGV Potential case permits expansion of the HDV market to allow a gradual increase in the share of HDV owners who would consider purchasing an NGV if justified by the fuel economics over a payback distribution with a weighted

Figure 35. Distribution of annual vehicle-miles traveled by light-medium (Class 3) and heavy (Class 7 and 8) heavy-duty vehicles, 2002 (thousand miles)



average of 3 years. The gradual increase in the maximum natural gas market share reflects the fact that a national natural gas refueling program would require time to build out. The natural gas refueling infrastructure is expanded in the HD NGV Potential case simply by assumption; it is not clear how (or whether) specific barriers to natural gas refueling infrastructure investment can be overcome.

Incremental costs for NGVs in the HD NGV Potential case differ from those in the Reference case. In the HD NGV Potential case, incremental costs are determined by assuming a set cost for CNG or LNG engines plus a CNG or LNG tank cost based on the average amount of daily travel and vehicle size class. The HD NGV Potential case includes separate delivered CNG and LNG fuel prices for fleet and nonfleet operators. Added per-unit charges to recover infrastructure are set and held constant in real terms throughout the projection period, based on the assumptions that refueling stations would be utilized at a sufficiently high rate to warrant the capital investment, and that the prices charged for the fuel would be cost-based (i.e., station operators would not

Issues in Focus

set prices on the basis of prices for competing fuels). Motor fuels taxes are assumed to remain at their current levels in nominal terms, maintaining the higher energy-equivalent tax on LNG relative to diesel fuel

In defining CNG and LNG prices for the HD NGV Potential case, EIA examined current motor fuel taxes and any charges added to the commodity price of dry natural gas sold at private central refueling stations (fleets) and at retail stations where actual data were available. Accordingly, an HDV Reference case was developed from the AEO2012 Reference case, by including the updated fleet and retail CNG and LNG prices, to provide a consistent basis for comparison with the HD NGV Potential case (Figure 36). The HDV Reference case assumes that Class 3 through 6 vehicles use CNG, obtained from either fleet operators (using fleet prices) or nonfleet operators (using retail prices), and that Class 7 and 8 vehicles, both fleet and nonfleet, use LNG.

Sales of heavy-duty NGVs rise dramatically in the HD NGV Potential case, based on the national availability of refueling infrastructure and expanded market potential (Figure 37). Sales of new heavy-duty NGVs increase from 860 in 2010 (0.2 percent of total new HDV sales) to about 275,000 in 2035 (34 percent of total new vehicle sales), as compared with 26,000 in the HDV Reference case (3 percent of total new HDV sales). New heavy-duty NGVs gradually claim a more significant share of the vehicle stock, from 0.4 percent in 2010 to 21.8 percent (2,750,000 vehicles) in 2035, as compared with 2.4 percent (300,000 vehicles) in 2035 in the HDV Reference case.

As a result of the large projected increase in sales of new heavy-duty NGVs, natural gas demand in the HDV sector rises from about 0.01 trillion cubic feet in 2010 to 1.8 trillion cubic feet in 2035 in the HD NGV Potential case, as compared with 0.1 trillion cubic feet in the HDV Reference case (Figure 38). The natural

gas share of total energy use by HDVs grows from 0.2 percent in 2010 to 32 percent in 2035 in the HD NGV Potential case, compared with 1.6 percent in the HDV Reference case.

Roughly speaking, about 1 trillion cubic feet of natural gas consumed per year replaces 0.5 million barrels per day of petroleum and other liquids. Thus, natural gas consumption by HDVs in the HD NGV Potential case displaces about 850,000 barrels per day of petroleum and other liquids consumption in 2035 (Figure 39). Without a major impact on world oil prices, which is not expected to result from the gradual but significant adoption of natural gas as a fuel for U.S. HDVs, nearly all the reduction in petroleum and other liquids use by U.S. HDVs would be reflected by a decline in imports.

In the HD NGV Potential case, projected total U.S. natural gas consumption in 2035 is 1.4 trillion cubic feet (5 percent) higher than in the Reference case, as the increase in natural gas use by vehicles is partially offset by lower consumption in other sectors, in response to higher natural gas prices (Figure 40). The electric power and industrial sectors account for the

Figure 36. Diesel and natural gas transportation fuel prices in the HDV Reference case, 2005-2035 (2010 dollars per diesel gallon equivalent)

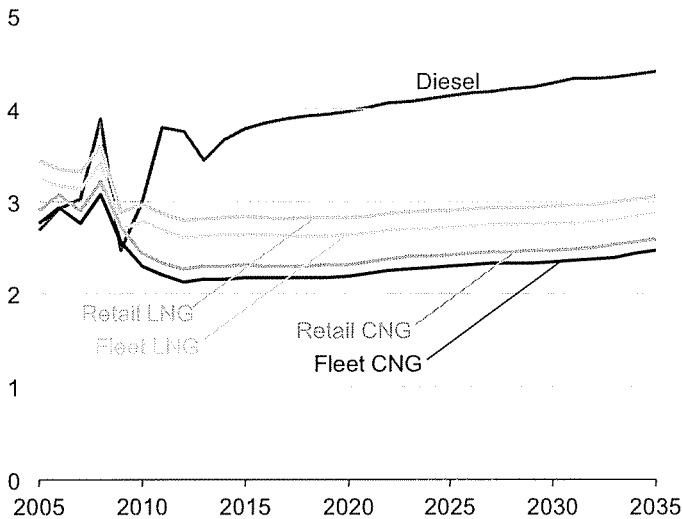


Figure 37. Annual sales of new heavy-duty natural gas vehicles in two cases, 2008-2035 (thousand vehicles)

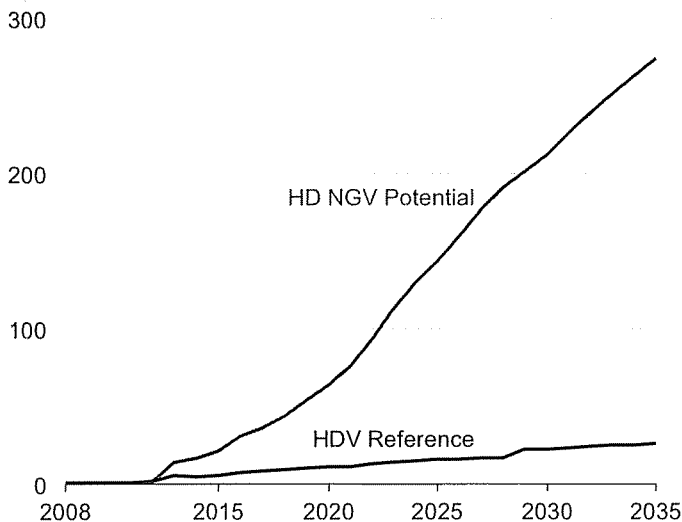
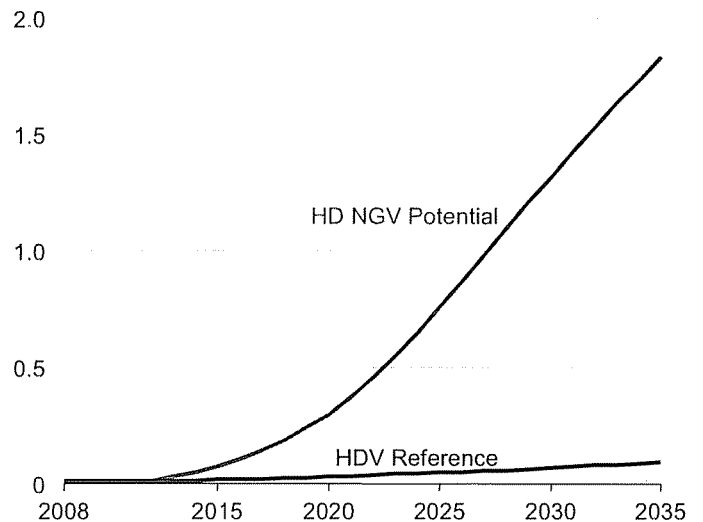


Figure 38. Natural gas fuel use by heavy-duty vehicles in two cases, 2008-2035 (trillion cubic feet)



bulk of the consumption offsets, as their 2035 natural gas use is, respectively, 0.3 trillion cubic feet (3.1 percent) and 0.2 trillion cubic feet (2.7 percent) lower than in the Reference case.

In 2035, U.S. domestic natural gas production in the HD NGV Potential case is 1.1 trillion cubic feet (3.9 percent) higher than in the HDV Reference case. The higher level of natural gas production needed to support the growth in HDV fuel use results in a 10-percent increase in natural gas prices—\$0.76 per million Btu (2010 dollars)—at the Henry Hub in 2035 in comparison with the HDV Reference case. Percentage increases in delivered natural gas prices to other sectors, which include transmission and distribution costs that are not affected by higher prices to producers, are smaller, with delivered natural gas prices increasing by 4.9 percent in the residential sector, 5.9 percent in the commercial sector, 8.9 percent in the industrial sector, and 7.9 percent in the electricity generation sector in comparison with the HDV Reference case in 2035.

7. Changing structure of the refining industry

Petroleum-based liquid fuels represent the largest source of U.S. energy consumption, accounting for about 37 percent of total energy consumption in 2010. The mix and composition of liquids, however, have changed in recent years in response to changes in regulations and other factors, and the structure of the liquid fuels production industry has changed in response [68]. The changes in the industry require that analytical tools used for market analysis of the liquid fuels produced by the industry also be reevaluated.

In recognition of the fundamental changes in the liquid fuels production industry, EIA is developing a new Liquid Fuels Market Module (LFMM), which it intends to use in place of the existing Petroleum Market Module (PMM) to produce the *Annual Energy Outlook 2013*. The LFMM will allow EIA to address more adequately the current and anticipated domestic and international market environments, to analyze the implications of emerging technologies and fuel alternatives, and to evaluate the impact of complex emerging energy-related policy, legislative, and regulatory issues. Some results from an early simulation of the LFMM, the LFMM case, are provided here.

The landscape for both production and consumption of liquid fuels in the United States continues to evolve, leading to changes in the mix of liquid fuel feedstocks, with greater emphasis on renewable fuels. The liquid fuels markets are not homogeneous; regional differences have become more pronounced. Furthermore, U.S. policymakers are paying more attention to evolving markets for liquid fuels and the potential for improving the efficiency of liquid fuels consumption, reducing GHG emissions associated with the production and consumption of liquid fuels, and improving the Nation's energy security by reducing reliance on imports. Major industry changes and their implications are discussed below.

New feedstocks and technologies

Over the past 25 years, the U.S. liquid fuels production industry has changed from being based primarily on domestic petroleum to using a variety of feedstocks and finished products from sources around the world. Regulatory and policy changes have resulted in the use of feedstocks other than crude oil, such as natural gas and renewable biomass, and could lead to the use of other feedstocks (such as coal) in the coming years. These changes have resulted in a transition from a relatively straightforward supply chain relying on crude oil and finished products to an increasingly complex system, which must be reflected in models to produce valid projections.

Figure 39. Reduction in petroleum and other liquid fuels use by heavy-duty vehicles in the HD NGV Potential case compared with the HDV Reference case, 2010-2035 (thousand barrels per day)

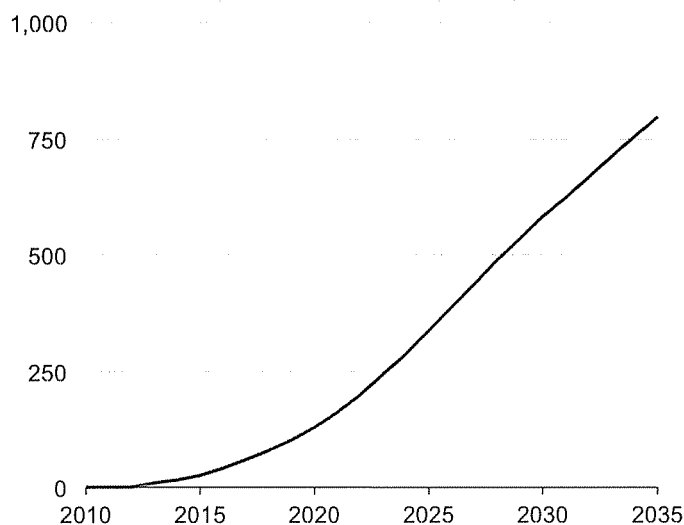
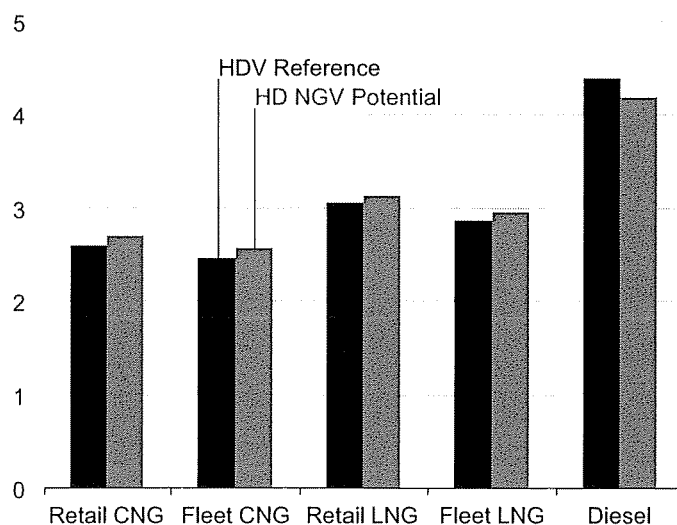


Figure 40. Diesel and natural gas transportation fuel prices in two cases, 2035 (2010 dollars per diesel gallon equivalent)



Energy in focus

The term “liquid fuels production industry” refers to all the participants in the production and delivery of liquid fuels, from production of feedstocks to delivery of both liquid and non-liquid end-use products to customers. It includes participants in the more traditional petroleum refining sector, relying on crude oil as a primary feedstock; in the nonpetroleum fossil fuel sector, using natural gas and coal to produce liquid fuels; and in the biofuel sector, using biomass to produce biofuels such as ethanol and biodiesel. The complexity of the industry supply chain is inadequately described by nomenclature predicated on specific feedstocks (e.g., crude oil), processes (e.g. refinery hydrotreating), or end-use products (e.g., diesel fuel and gasoline), which fail to capture the significant economic implications of non-liquid-fuel products for the industry.

The components of the U.S. liquid fuels production industry—including petroleum, nonpetroleum fossil fuel, and biofuel sectors—are shown in Figure 41, along with examples illustrating processes and products. Figure 41 also highlights the differences between the new expanded “liquid fuels production industry,” which the entire figure represents, and the less extensive “petroleum and other liquids industry,” the components of which are highlighted in red.

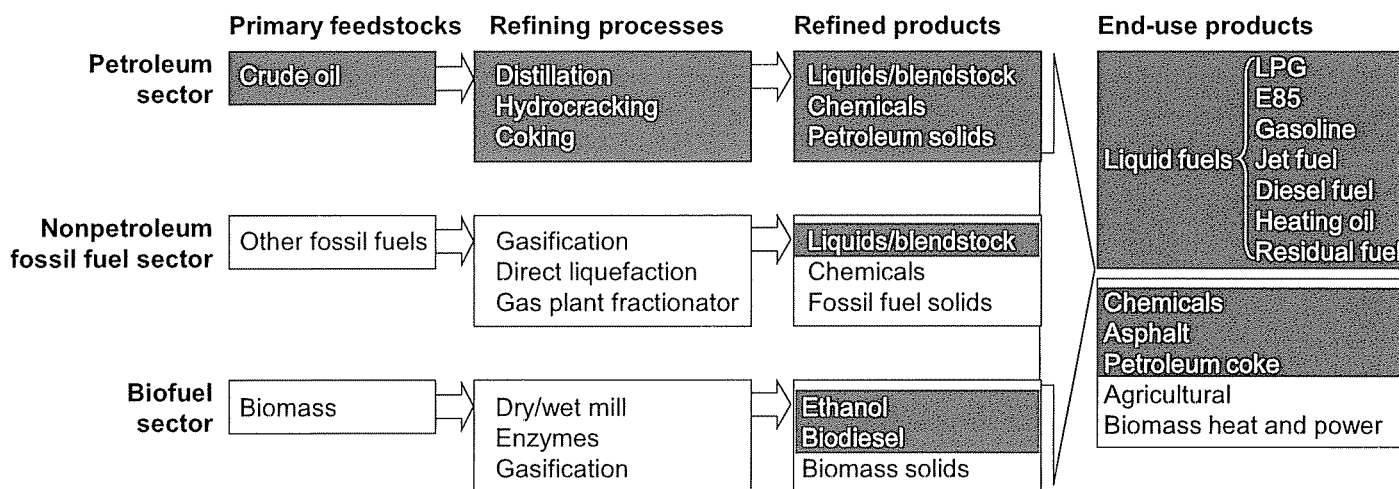
Nonpetroleum feedstocks are used in many new and emerging technologies, such as fermentation, enzymatic conversion, GTL, CTL, biomass-to-liquids, and algae-based biofuels. The new technologies provide valuable non-liquid-fuel co-products—such as chemical feedstocks, distiller’s grains, and vegetable oils—that significantly affect the economics of liquid fuels production. The emergence of renewable biofuels has led to the introduction of midstream components such as ethanol and biodiesel, which are blended with petroleum products such as gasoline and diesel fuel during the final stages of the supply chain at refineries, blending sites, or retail pumps. The increase in biofuel production has led to new distribution channels and infrastructure investments and recognition of new production regions, such as the high concentration of ethanol producers in the Midwest. The new LFMM will include the entire liquid fuels production industry, providing greater flexibility for integrating new technologies and their associated products into the liquid fuels supply chain, better reflecting the industry’s evolution.

In AEO2012, the “petroleum and other liquids” category includes the petroleum sector and those non-petroleum-based liquid products shaded in red in Figure 41, such as ethanol and biodiesel, which are blended with petroleum products to make end-use liquid fuels. Because this approach treats nonpetroleum products as exogenously produced feedstocks, the petroleum and other liquids concept used in AEO2012 does not explicitly link the industrial processes that yield nonpetroleum liquid fuels (nor their feedstocks, nonpetroleum fossil fuels and biomass) with liquids production. The more inclusive definition of the liquid fuels production industry illustrated in Figure 41 is necessary to capture and model the full range of product flows and economic drivers of decisionmaking by firms involved in this complex industry.

Nonpetroleum feedstocks do not exist in traditional liquid form, and they require a different analytical approach for analysis of their conversion to liquid fuels. Traditional volumetric measures, such as process gain, are not applicable to an analysis of the liquids produced from nonpetroleum feedstocks. It is more appropriate to use the fundamental principles of mass and energy balance to evaluate process performance, market penetration, and supply/demand dynamics when the uses of nonpetroleum feedstocks are being examined. This approach allows for comparison among the different sectors of the liquid fuels production industry. Figure 42 provides an overview of the liquid fuels production industry on a mass basis.

The variety and changing dynamics of nonpetroleum feedstocks and the resulting end-use products also are illustrated in Figure 42. In recent history, biomass has taken significant market share from petroleum feedstocks, correlated with shifts in product yields—a trend that is expected to continue in the future, along with further diversification into nonpetroleum fossil feedstocks. In 2000, nearly all liquid fuels were derived from petroleum. Since then, however, the share of petroleum has dropped while the shares of biomass and other fossil fuels have increased. In 2011, the combined biomass and other fossil fuels share of feedstocks was almost 18 percent, measured on a mass basis. In the LFMM case, the biomass share of feedstock consumption increases to

Figure 41. U.S. Liquid Fuels production industry



30 percent in 2035, and the petroleum share falls to about 57 percent. The biomass share of end-use products increases only to 10 percent in 2035, reflecting differences in conversion efficiencies between petroleum and nonpetroleum feedstocks, as highlighted by the growing but still small nonpetroleum content of gasoline and distillates.

Changes in crude oil types

Economic growth in the developing countries over the past decade has increased global demand for crude oil. Over the same period, new technologies for recovering crude oil, changes in the yields of existing crude oil fields, and a global increase in exploration have expanded the number and variety of crude oil types. The United States currently imports more than 100 different types of crude oil from around the world, including a growing number from Canada and Mexico, with a wide range of API gravities (between 10.4 and 64.6) and sulfur content (between 0.02 and 5.5 percent). Consequently, it is difficult to group them according to the categories used in the existing NEMS PMM. A new and more comprehensive representation of the numerous crude types is required, as well as flexibility to add new sources.

The United States increasingly is using crude oil extracted from oil sands and oil shale, as well as other nontraditional petroleum sources that require additional processing. The new sources have led to shifts in crude oil flows and changes in the distribution network. The increased variety and regional availability of certain crude types has created new market dynamics and pricing relationships that are difficult to capture using existing methods, especially considering the rapid emergence of "tight oil" production, which, to date, has been substantially different in quality from the crude oil previously expected to be available to U.S. refineries. For example, light sweet crude oil sourced from the Bakken shale formation in North Dakota has been sold to refiners on the Gulf Coast in recent years at a substantial discount relative to heavier imported crudes, because of limitations in the delivery infrastructure.

Figure 42. Mass-based overview of the U.S. liquid fuels production industry in the LFMM case, 2000, 2011, and 2035 (billion tons per year)

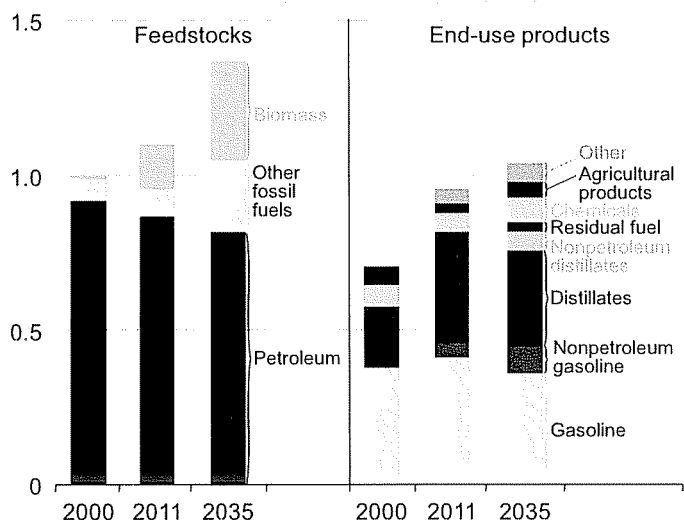
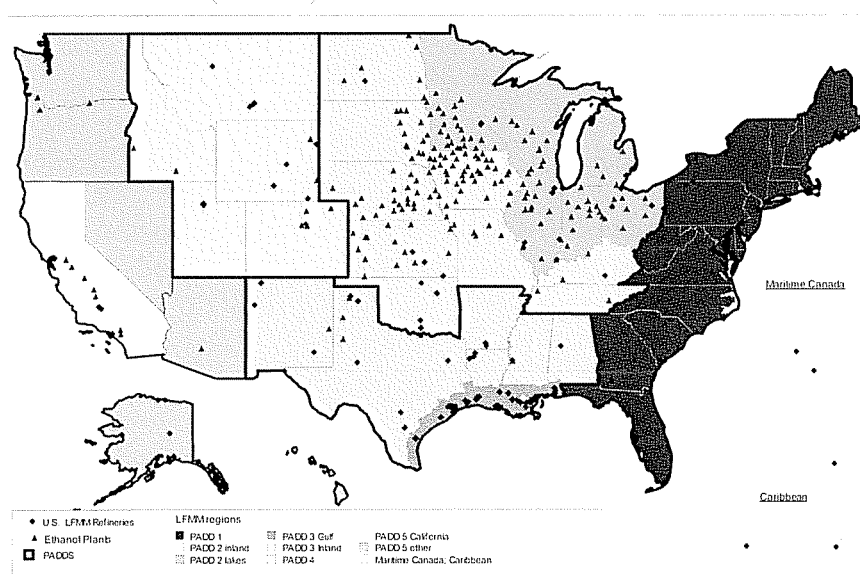


Figure 43. New regional format for EIA's Liquid Fuels Market Module (LFMM)



The growing number of sources, changes in characteristics of crudes, and shifting price relationships in crude oil markets require an updated representation of different crude types in NEMS. The model also needs an updated and more dynamic representation of the crude oil distribution network in order to provide better estimates of changes in crude oil flows and potential new regional sources in the future.

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Regional updates

The Petroleum Administration for Defense Districts (PADD), which were developed by the Department of Defense during World War II, have been traditionally used as the regional framework for analyzing liquid fuels production. Because the topology and configuration of the liquid fuels market

have changed significantly, and new feedstocks have emerged from regions that are subsets of PADDs, the regional definitions for processing liquid fuels need to be redefined. Toward this end, EIA has redefined the refining regions on the basis of market potential and availability of feedstocks. The redefined regions will be further divided as market conditions change. The new regional configuration of the NEMS LFMM will use eight domestic regions and adds a new international region (Figure 43).

Each new refining region has unique characteristics. PADD 1 has been left unchanged in the new configuration, but can be further divided based on recent and possible future refinery closures and shifts in imports from Europe. PADD 2 was subdivided into the Great Lakes and Inland regions due to the concentrated

U.S. Refining

production of biofuels and access to Canadian crudes. PADD 3 was divided into the Gulf Coast and Inland regions due to the inability of the interior refineries to handle heavy sour crude. PADD 4 was left unchanged. California was separated from the rest of PADD 5 due to the State's unique gasoline and diesel specifications and regulatory policies. A new international region was added comprising Maritime Canada and the Caribbean.

The modified regional refinery format will allow EIA's analyses to more accurately capture regional refinery trends and potential regional regulatory policies that affect the liquid fuels market. For example, California often enacts its own regulatory policies earlier than the rest of its PADD region, and its individual actions could not be represented accurately in the PADD framework. As a further example, recent refinery closures and other developments on the East Coast evidence the need for a dynamic and flexible representation of the refinery regions that supply the U.S. market.

Changing product markets

Crude oil is still the most important and valuable feedstock for the liquid fuels production industry. More than 650 refineries, located in more than 116 countries, have the capacity to refine 86 million barrels of crude oil per day. In the past, most of the complex refineries that could transform a wide variety of crudes into numerous different products to meet demand were located in the United States. Now, however, complex refineries are becoming more common in Europe and the developing countries of Asia and Latin America, and the products from export-focused merchant refineries in those countries have the potential to compete with U.S. products. An example is the regular export of surplus gasoline from refiners in Europe to the Northeast United States.

Traditional measures of profitability, such as the 3-2-1 crack spread, require modification in NEMS in view of the changing market for liquid fuels. The calculation of margins requires consideration of multiple feedstocks and multiple products produced in refineries, biorefineries, and production facilities for nonpetroleum fuels. Operators in the liquid fuels production industry are faced with a choice of investing in facilities and modifying their configurations to meet changing market demand, or exchanging domestic feedstocks and products with merchant refineries in a global market. For example, increased U.S. efficiency standards for LDVs have reduced demand for gasoline and increased demand for diesel fuel, which has led to more gasoline exports and more investment to increase diesel output from domestic refineries.

EIA's new LFMM representation of the liquid fuels production industry will need to account for global competition for both crude oil and end-use products. As refineries around the world become larger and more complex, smaller refineries may not be able to compete with imports produced at low margins. Therefore, it is necessary to have a more robust and dynamic representation of the liquid fuel producers, as well as additional flexibility to adjust inputs, refinery configurations, and crude and product demands as the industry evolves.

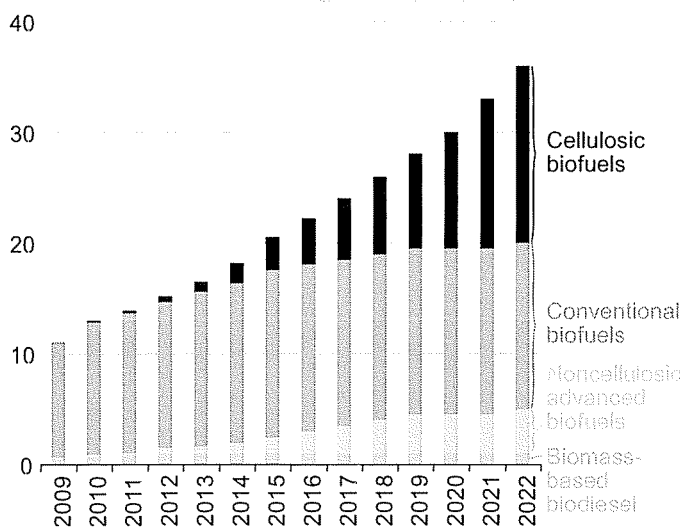
Regulations and policies

It is important for EIA's models to represent existing laws and regulations accurately, in addition to being flexible enough to model proposed laws and regulations. One of the most important regulations currently affecting the U.S. liquid fuels industry is the RFS, which not only has increased production and use of renewable fuels, but also has changed how fuels are distributed and consumed both here and abroad. The RFS mandates the use of biofuels that are consumed primarily as blends with traditional petroleum products, such as gasoline and diesel fuel (Figure 44). Because of their chemical properties, ethanol, biodiesel, and other first-generation biofuels generally require their own distribution networks or investments in new infrastructure. In addition, because they are produced outside traditional petroleum refineries, the new products are added at different points in the supply

chain, either at blending terminals or at retail sites via blender pumps. Modeling those changes requires an update to the traditional PADD regional format used to represent the liquid fuels market, as well as an update to the transportation network that distributes the fuels.

The RFS also requires consideration of many new technologies and increases the complexity of decisionmaking in the liquid fuels production industry. Fuel volumes by product are mandated by the RFS. For each year, regulated parties must make the decision to either buy the available renewable fuels in proportion to their RFS requirements or purchase the necessary credits. For example, the cellulosic biofuel credit price is set as the greater of \$0.25 cents per gallon or \$3.00 per gallon minus the wholesale gasoline price, both based on 2008 real dollars. The RFS also contains a general waiver based on technical, economic, or environmental feasibility that the EPA Administrator has discretionary authority to act on to reduce the mandates for advanced and total biofuels.

Figure 44. RFS mandated consumption of renewable fuels, 2009-2022 (billion gallons per year)



In addition, use of biofuels has broader implications for the global market, in terms of both feedstocks and the fuels themselves. A good example is ethanol. Its primary feedstocks are corn and sugar, both of which are global commodities in high demand as food sources as well as biofuel feedstocks. U.S. ethanol producers compete globally in other countries, such as Brazil, that have their own renewable fuels mandates.

Finally, coproducts from biofuels production have a significant influence on their economics. For example, the value of the dried distillers grains coproduct from corn ethanol production, which can be sold to the agricultural sector, can offset up to one-third of the purchase cost for the corn feedstock. Thus, the economics of biofuels production are complex, and they require a model that accounts for numerous investment decisions, feedstock markets, and global interactions. The RFS adds to the liquids fuels market a number of fuel technologies, midstream products and coproducts, evolving regional production and distribution networks, and complex domestic and global market interactions.

The U.S. liquid fuels market has evolved substantially over the past 20 years in terms of available fuel types, production regions, global market dynamics, and regulations and policies. The transition has resulted in a liquid fuels market that uses both petroleum- and nonpetroleum-based inputs, distributes them around the country by a variety of methods, and makes investment decisions based on both economic and regulatory factors. The changes are significant enough to make the framework and metrics used in traditional refinery models no longer adaptable or robust enough for proper modeling of the transformed liquid fuels market. EIA currently is in the process of updating its framework to allow better representation of the transformed industry.

3. Changing environment for fuel use in electricity generation

Introduction

The AEO2012 Reference case shows considerable change in the mix of generating technologies over the next 25 years. Coal remains the dominant source of electricity generation in the Reference case, with a 38-percent share of total generation in 2035, but that is down from shares of 45 percent in 2010 and nearly 50 percent in 2005. The decrease in coal's share of total generation is offset primarily by increases in the shares of natural gas and renewables. Key factors contributing to the shift away from coal are sustained low natural gas prices, higher coal prices, slow growth in electricity demand, and the implementation of Mercury and Air Toxics Standards (MATS) [69] and Cross-State Air Pollution Rule (CSAPR) [70]. These factors influence how existing plants are used, which plants are retired, and what types of new plants are built.

Fuel prices and dispatch of power plants

The price of fuel is a major component of a power plant's variable operating costs [71]. The fuel-related variable cost of generating electricity is a function of the fuel price and the efficiency of the plant's conversion of the fuel into electricity, also referred to as the heat rate. Although natural gas prices declined dramatically in the second half of 2011 and the first half of 2012, coal-fired power plants have generally had the advantage of lower fuel prices and the disadvantage of higher heat rates in comparison to combined-cycle plants fueled by natural gas.

Power plants are dispatched primarily on the basis of their variable costs of operation. Plants with the lowest operating costs generally operate continuously. Plants with higher variable costs are brought on line sequentially as demand for generation increases. Because fuel prices influence variable costs, changes in fuel prices can affect the choice of plants dispatched. For instance, if the price of natural gas decreases, the variable costs for combined-cycle plants may fall below those for competing coal-fired plants, and, as a result, the combined-cycle plant may be dispatched before the coal-fired plant. Coal and natural gas plants can vary their outputs on the basis of fuel prices, but there are some cases in which plants may cycle off completely until they can be operated economically. In order to examine the overall impacts of changes in projected fuel price trends on the electric power sector, AEO2012 includes alternative cases that assume higher and lower prices for natural gas and coal.

Demand for electricity

Electricity demand determines how much generating capacity is needed. When demand increases, plants with higher operating costs are brought into service, increasing average operating costs and, as a result, average electricity prices. Higher prices, in turn, provide economic incentives for the construction of new capacity. Conversely, when demand declines, plants with higher operating costs are taken off line or run at lower intensities, and the economic incentives for new plant construction are reduced. If a plant is not profitable, the owner may decide to retire it.

Mercury and Air Toxics Standards and Cross-State Air Pollution Rule

Both MATS and CSAPR are included in the AEO2012 Reference case [72]. Both rules have significant implications for the U.S. generating fleet, especially coal-fired power plants. MATS requires all U.S. coal- and oil-fired power plants with capacities greater than 25 megawatts to meet emission limits consistent with the average performance of the top 12 percent of existing units—known as the maximum achievable control technology. MATS applies to three pollutants: mercury, hydrogen chloride (HCl), and fine particulate matter (PM_{2.5}). HCl and PM_{2.5} are intended to serve as surrogate pollutants for acid gases and nonmercury metals, respectively. CSAPR is a cap-and-trade program that sets caps on sulfur dioxide (SO₂) and nitrogen oxide (NO_x) emissions from all fossil-fueled plants greater than 25 megawatts in 28 States in most of the eastern half of the United States. CSAPR is scheduled

to begin in 2012, although implementation was delayed by a court-issued stay at the time this article was completed [73]. See also “Cross-State Air Pollution Rule” in the “Legislation and regulations” section of this report.

Although the two rules differ in their makeup and the pollutants covered, the technologies that can be used to meet their requirements are not mutually exclusive. For instance, in order to meet the MATS acid gas standard, it is assumed that coal-fired plants without appropriate existing controls will need to install either flue-gas desulfurization (FGD) or dry sorbent injection (DSI) systems, which also reduce SO₂ emissions. Therefore, by complying with the MATS standards for acid gases, plants will lower overall SO₂ emissions, facilitating compliance with CSAPR.

AEO2012 assumes that all coal-fired power plants will be required to reduce mercury emissions to 90 percent below their pre-control levels in order to comply with MATS. The *AEO2012* NEMS explicitly models mercury emissions from power plants. Reductions in mercury emissions can be achieved with a combination of FGDs and selective catalytic reduction, which is primarily used to reduce SO₂ and NO_x emissions, or by installing activated carbon injection (ACI) systems. FGD systems may be effective in reducing mercury emissions from bituminous coal (due to its chemical makeup), but ACI systems may be necessary to remove mercury emissions from plants burning subbituminous and lignite coal.

NEMS does not explicitly model emissions of acid gases or toxic metals other than mercury. In order to represent the MATS limits for those emissions, *AEO2012* assumes that plants must install either FGD or DSI systems to meet the acid gas standard and, in the absence of a scrubber, a full fabric filter to meet the MATS standard for nonmercury metals. *AEO2012* assumes that the appropriate control technologies will be installed by 2015 in order to meet the MATS requirements.

DSI and wet and dry FGD systems are technologies that will allow plants to meet the MATS standards for acid gases. As of 2010, 43 percent of U.S. generating capacity already had FGDs installed [74]. For a number of the remaining, uncontrolled plants, operators will need to assess the effectiveness of installing FGD or DSI systems to comply with MATS. There are economic and engineering tradeoffs between the two technologies. FGD systems require significant upfront investment but have relatively low operating costs. DSI systems generally do not require significant capital expenses but may use significant quantities of sorbent to operate effectively, which increases their operating costs. Waste disposal for DSI also may be a significant variable cost, whereas the waste products from FGD systems can be sold as feedstock for industrial processes.

The EPA set an April 2015 compliance deadline for MATS, but the rule allows State environmental permitting agencies to extend the deadline by a year. Beyond 2016, the EPA stated that it will handle noncompliant units that need to operate for reliability purposes on a case-by-case basis [75]. *AEO2012* assumes that all plants will comply with MATS by the beginning of 2015.

Economics of plant retirements

The decision to retire a power plant is an economic one. Plant owners must determine whether a plant’s future operations will be profitable. Environmental regulations, low natural gas prices, higher coal prices, and future demand for electricity all are key factors in the decision. Coal plants without FGD systems and with high heat rates, high delivered coal costs, and strong competition from neighboring natural gas plants in regions with slow growth in electricity demand may be especially prone to retirement.

Greenhouse gas policy in *AEO2012*

Uncertainty about possible future regulation of GHG emissions will continue to influence investment decisions in the power sector. Despite a lack of Congressional action, many utilities include simulations with a future CO₂ emissions price when evaluating long-term investment decisions. A carbon price would increase the cost of generation for all fossil fuel plants, but the largest impact would be on coal-fired plants. Thus, plant owners could be reluctant to retrofit existing coal plants to control for non-GHG pollutants, given the possibility that GHG regulations might be enacted in the near future. This uncertainty may influence the assumptions plant owners make about the economic lives of particular facilities.

In the Reference case, the costs of environmental retrofits are assumed to be recovered over a 20-year period. Two alternative cases assume that the costs would be recovered over 5 years, reflecting concern that future laws or regulations aimed at limiting GHG emissions will have significant negative effects on the economics of investing in existing coal plants.

AEO2012 also includes two alternative cases that assume enactment of an explicit GHG control policy. In each case, a CO₂ price is applied across all sectors starting in 2013 and increased at a 5-percent annual real rate through 2035. The price starts at \$25 per metric ton in the GHG25 case and \$15 per metric ton in the GHG15 case. The CO₂ price is applied across sectors and has a significant impact on the cost of generating electricity from fossil fuels, particularly coal.

Alternative cases

In order to illustrate the impacts of the various influences on the electric power sector, *AEO2012* includes several alternative cases that include varying assumptions about fuel prices, electricity demand, and the cost recovery period for environmental control equipment investments:

- The Reference 05 case assumes that the cost recovery period for investments in new environmental controls is reduced from 20 years to 5 years.

- The Low Estimated Ultimate Recovery (EUR) case assumes that the EUR per tight oil or shale gas well is 50 percent lower than in the Reference case, increasing the per-unit cost of developing the resource and, ultimately, the price of natural gas used at power plants (Figure 45).
- The High EUR case assumes that the EUR per tight oil or shale gas well is 50 percent higher than in the Reference case, decreasing the per-unit cost of developing the resource and the price of natural gas for power plants.
- The Low Gas Price 05 case combines the more optimistic assumptions about future volumes of shale gas production from the High EUR case with a 5-year recovery period for investments in new environmental controls.
- The High Coal Cost case assumes lower mining productivity and higher costs for labor, mine equipment, and coal transportation, which ultimately result in higher coal prices for electric power plants.
- The Low Coal Cost case assumes higher mining productivity and lower costs for labor, mine equipment, and coal transportation, which ultimately result in lower coal prices for electric power plants.
- The Low Economic Growth case assumes lower growth rates for population and labor productivity, higher interest rates, and lower growth in industrial output, which ultimately reduce demand for electricity (Figure 46), which is reflected in electricity sales, relative to the Reference case.
- The High Economic Growth case assumes higher growth rates for population and labor productivity. With higher productivity gains and employment growth, inflation and interest rates are lower than in the Reference case, and, consequently, economic output grows at a higher rate, ultimately increasing demand for electricity, which is reflected in electricity sales, relative to the Reference case.
- In the GHG15 case, the CO₂ price is set at \$15 per metric ton in 2013 and increases at a real annual rate of 5 percent per year over the projection period. Price is set to target the same reduction in CO₂ emissions as in the AEO2011 GHG Price Economywide case.
- In the GHG25 case, the CO₂ price is set at \$25 per metric ton in 2013 and increases at a real annual rate of 5 percent per year over the projection period. Price is set to target the same dollar amount as in the AEO2011 GHG Price Economywide case.

Analysis results

Coal-fired plant retirements

Significant amounts of coal-fired generating capacity are retired in all the alternative cases considered (Figure 47). (For a map of the electricity regions projected, see Appendix F.) In the Reference 05 case, 63 gigawatts of coal-fired capacity is retired through 2035, 28 percent higher than in the Reference case. In the High EUR case, 55 gigawatts of coal-fired capacity is retired, as lower wholesale electricity prices and competition from natural gas combined-cycle units makes the operation of some coal plants uneconomical. In the Low Economic Growth case, 69 gigawatts of coal-fired capacity is retired, because lower demand for electricity reduces the need for new capacity and makes investments in older plants unattractive.

The High Economic Growth case results in fewer retirements, as existing coal-fired capacity is needed to meet growing electricity demand, and higher economic growth pushes up natural gas prices. In the Low Coal Cost case, the lower relative coal prices increase the profit margins for coal-fired power plants, making it more likely that investments in retrofit equipment will be recouped over the life of the plants.

Figure 45. Natural gas delivered prices to the electric power sector in three cases, 2010-2035 (2010 dollars per million Btu)

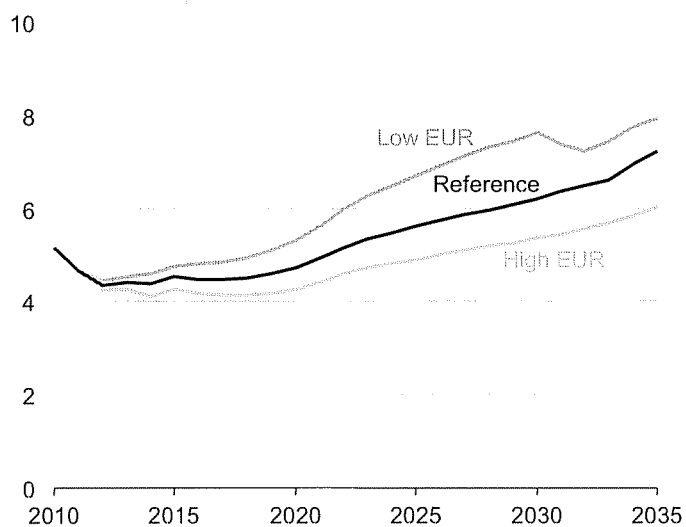
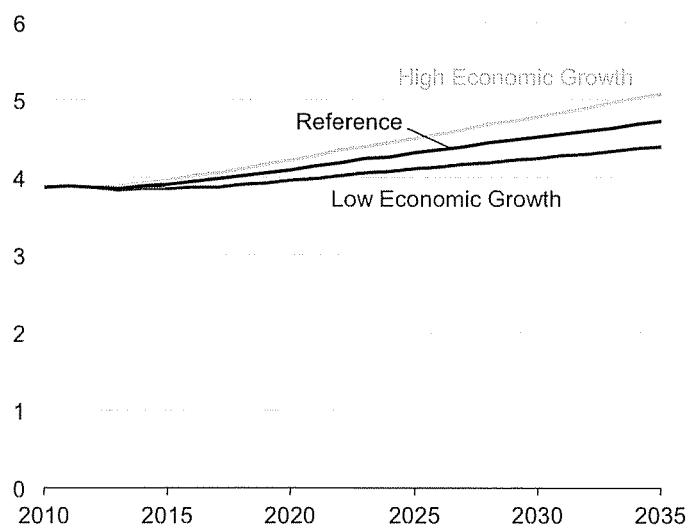


Figure 46. U.S. electricity demand in three cases, 2010-2035 (trillion kilowatt-hours)



Coal-fired capacity retirements are concentrated in two North American Electric Reliability Corporation (NERC) regions: the SERC Reliability Corporation (SERC) region, which covers the Southeast region, and the Reliability First Corporation (RFC), which includes most of the Mid-Atlantic and Ohio Valley region [76]. Many coal-fired plants in those regions are sensitive to the factors that influence retirement decisions, as discussed above. In the SERC and RFC regions, which in 2010 accounted for 65 percent of U.S. coal-fired generating capacity, 43 percent of the coal-fired plants do not have FGD units installed. Coal plants in the RFC and SERC regions are fueled primarily by bituminous coal, generally the coal with the highest cost. Projected demand for electricity in the early years of the Reference case is low nationwide and, especially, in the RFC region, where demand in 2015 is slightly lower than in 2010. In both the GHG15 and GHG25 cases, even larger amounts of coal-fired capacity are retired by 2035 than in the non-GHG policy cases.

Generation by fuel

Coal

In all cases, generation from coal is lower in 2020 than in 2010. Higher coal prices, relatively low natural gas prices, retirements of coal-fired capacity, and slow growth in electricity demand are responsible for the decrease. Generation from coal is lower than in the Reference case in the Reference 05, High EUR, Low Gas Price 05, High Coal Cost, and Low Economic Growth cases as a result of additional retirements of coal-fired capacity, lower natural gas prices, higher coal prices, or lower electricity demand. In cases where the opposite assumptions are incorporated, coal-fired generation is higher.

Generation from coal begins to recover after 2020, as electricity demand and natural gas prices start to rise. The strongest increases in coal-fired electricity generation occur in the Low EUR, Low Coal Cost, and High Economic Growth cases. When lower natural gas prices, lower economic growth, and/or higher coal prices are assumed, coal-fired generation still increases after 2020 but at a slower rate. In all cases, utilization of existing coal-fired power plants increases, because there is no significant growth in new coal-fired capacity. In the most optimistic case, the High Economic Growth case, only 3.3 gigawatts of new coal-fired capacity is added from 2017 to 2035 [77].

Despite a declining share of the generation mix, coal still has the highest share of total electricity generation in 2035 in all non-GHG or High TRR cases. However, it never again reaches the 2010 share of 45 percent, even in the Low EUR case (where it reaches 40 percent in 2035). Conversely, the coal share of total generation in 2035 is 34 percent in the Low Gas Price 05 case. The lower coal share is offset by increased generation from natural gas, which grows significantly in all the cases. The natural gas share of total generation almost equals that of coal in the Low Gas Price 05 case. In the GHG15 and GHG25 cases, coal-fired generation drops to 16 percent and 4 percent, respectively, of the total generation mix in 2035, and in both cases generation from coal declines significantly as the explicit price on CO₂ emissions increases costs. In the GHG15 and GHG25 cases, decreases in coal-fired generation are offset by a mix of natural gas, nuclear, and renewable generation.

Natural gas

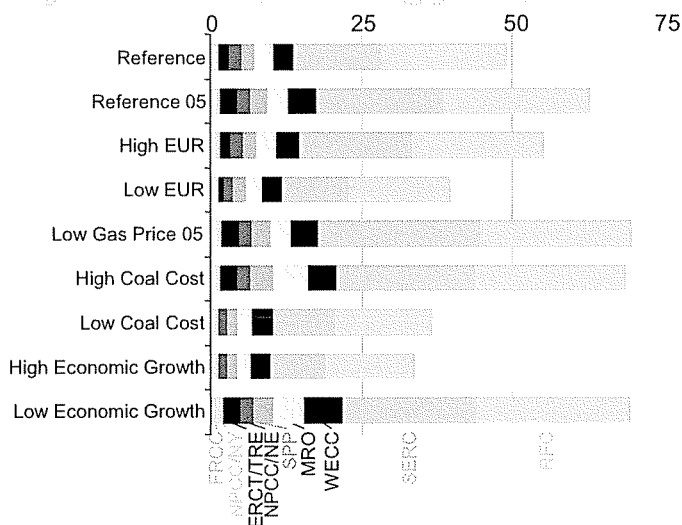
In the AEO2012 Reference case, electricity generation from natural gas in 2020 is 13 percent above the 2010 level, despite an increase of only 5 percent in overall electricity generation. Low natural gas prices result in greater utilization of existing combined-cycle plants as well as the addition of 16 gigawatts of natural gas combined-cycle capacity from 2010 to 2020. The same trends are amplified in cases with lower natural gas prices and more coal-fired capacity retirements and muted in cases with higher

natural gas prices and fewer coal-fired capacity retirements. Generation from combustion turbines does not change significantly across the cases, demonstrating that changes in the relative economics of coal and natural gas affect primarily the dispatch of combined-cycle plants to meet base and intermediate load requirements, not combustion turbines to meet peak load requirements.

In the Reference case, 58 gigawatts of natural gas combined-cycle capacity is added from 2020 to 2035, causing an increase in generation from natural gas during the period (Figures 48 and 49). In the Low EUR and Low Coal Cost cases, growth in natural gas combined-cycle capacity is slower. Although generation from natural gas increases overall with the addition of new capacity, utilization of existing combined-cycle plants drops slightly as higher natural gas prices reduce the frequency at which combined-cycle plants are dispatched.

In the GHG15 and GHG25 cases, electricity generation from natural gas exceeds generation from coal in 2020. Natural gas has one-half the CO₂ emissions of coal, and at relatively low CO₂ prices, natural gas generation is seen as an attractive

Figure 47. Cumulative retirements of coal-fired generating capacity by Electric Market Module region in nine cases, 2011-2035 (gigawatts)



alternative to coal. However, as CO₂ prices rise over the projection period, the increasing cost of generating electricity with natural gas causes the growth in natural gas generation to slow. In the GHG25 case, natural gas combined-cycle plants with CCS play a role in CO₂ mitigation, with 34 gigawatts of natural gas combined-cycle capacity added between 2022 and 2035.

Nuclear

Generation from nuclear power plants does not change significantly from Reference case levels in any of the non-GHG cases, due to the high cost of new nuclear plant construction relative to natural gas and renewables. In the GHG15 and GHG25 cases, nuclear power plants become more competitive with fossil plants, because they do not emit CO₂ and are needed to replace coal-fired capacity that is retired due to the cost of CO₂ emissions. In the GHG15 and GHG25 cases, generation from nuclear power is 57 percent and 121 percent higher, respectively, in 2035 than in 2010.

Renewables

Generation from renewable energy sources grows by 77 percent from 2010 to 2035 in the Reference case. Most of the growth in renewable electricity generation is a result of State RPS requirements, Federal tax credits, and—in the case of biomass—the availability of low-cost feedstocks. The change in renewable generation over the 2010-2035 period varies from a 102-percent increase in the High Economic Growth case to a 62-percent increase in the Low Economic Growth case. The largest growth in renewable generation is projected in the GHG15 and GHG25 cases, where renewable generation increases by about 150 percent from 2010 and 2035 in both cases. A price on CO₂ emissions makes generation from renewables more competitive with fossil plants without CCS.

Figure 48. Electricity generation by fuel in eleven cases, 2010 and 2020 (trillion kilowatt-hours)

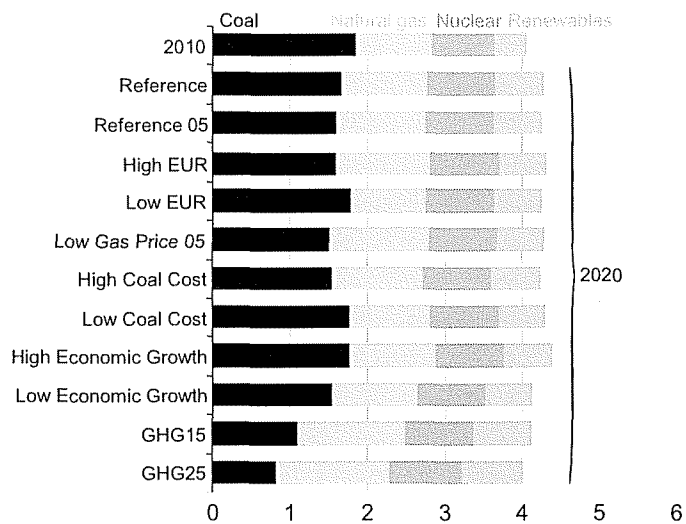
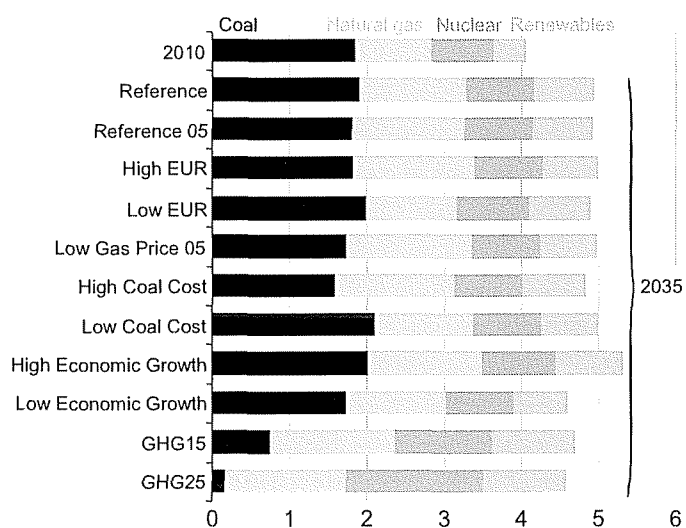


Figure 49. Electricity generation by fuel in eleven cases, 2010 and 2035 (trillion kilowatt-hours)



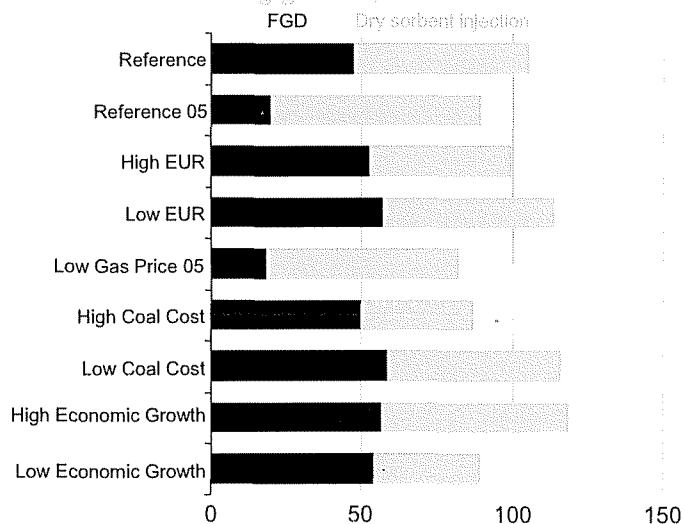
Installations of retrofit equipment

As discussed above, it is assumed that all coal-fired plants must have either FGD or DSI systems installed by 2015 to comply with environmental regulations. Because retirement is the only other option, cases with more retirements have fewer retrofits and vice versa (Figure 50). In the Reference 05 and Low Gas Price 05 cases, the relative cost of FGD units is higher because of the short payback period, making DSI a relatively more attractive option.

Emissions

SO₂ emissions are significantly below 2010 levels in 2015 in all cases, as a result of coal-fired capacity retirements and the installation of pollution control equipment to comply with MATS. AEO2012 assumes that a DSI system, combined with a fabric filter, will remove 70 percent of a coal plant's SO₂ emissions, and an FGD unit 95 percent. As a result of the requirement for FGD or DSI systems, all coal plants larger than 25 megawatts that did not have FGD units installed in 2010 significantly reduce their SO₂ emissions after 2015 by

Figure 50. Cumulative retrofits of generating capacity with FGD and dry sorbent injection for emissions control, 2011-2020 (gigawatts)



SO₂ emissions

installing control equipment. In all cases, coal-fired generation is down overall, which also contributes to the decline in emissions. SO₂ emissions increase after 2020 in all non-GHG cases, as coal-fired generation increases with rising natural gas prices. Because DSI and FGD retrofits do not remove all the SO₂ from coal-fired power plant emissions, increases in coal-fired generation result in higher SO₂ emissions, although they are still much lower than comparable 2010 levels. Also, the level of SO₂ reduction is proportional to the amount of coal-fired generation, and therefore the cases with the highest projected levels of coal-fired generation also project the highest levels of SO₂ emissions.

The projections for mercury emissions are similar. After a sharp drop in 2015, mercury emissions begin to rise slowly as coal-fired generation increases in all non-GHG cases. However, mercury emissions in 2035 still are significantly below 2010 levels, as the requirement for a 90-percent reduction in uncontrolled emissions of mercury remains binding throughout the projection.

NO_x emissions are not directly affected by MATS, but both annual and seasonal cap-and-trade programs are included in CSAPR. Emissions reductions relative to 2010 levels are small throughout the projection period in most cases, mainly because compliance with CSAPR NO_x regulations is required in only 26 States, and 2010 emissions levels already were close to the cap.

CO₂ emissions from the electric power sector fall slightly in cases that project declines in coal use, but the largest reductions occur in the GHG15 and GHG25 cases. In the GHG15 case, CO₂ emissions from the electric power sector are 46 percent below 2010 levels in 2035, and in the GHG25 case they are 76 percent below 2010 levels.

Electricity prices

Real electricity prices in 2035 are 3 percent above the 2010 level in the Reference case. The increase is relatively modest because natural gas prices increase slowly, and several alternatives for complying with the environmental regulations are available. When lower natural gas prices are assumed, real electricity prices decline relative to the Reference case. Both the GHG15 and GHG25 cases assume that costs for CO₂ emission allowances are passed through directly to customers. Therefore, average electricity prices in the GHG15 and GHG25 cases in 2035 are 25 percent and 33 percent higher, respectively, than in the Reference case. The GHG15 and GHG25 cases do not include any of the rebates to electricity consumers included in some other GHG policy proposals, which would reduce the impact on electricity prices.

9. Nuclear power in AEO2012

In the AEO2012 Reference case, electricity generation from nuclear power in 2035 is 10 percent above the 2010 total. The nuclear share of overall generation, however, declines from 20 percent in 2010 to 18 percent in 2035, reflecting increased shares for natural gas and renewables.

In the Reference case, 15.8 gigawatts of new nuclear capacity is added from 2010 through 2035, including both new builds (a total of 8.5 gigawatts) and power uprates at operating nuclear power plants (7.3 gigawatts). A total of 6.1 gigawatts of nuclear capacity is retired in the Reference case, with most of the retirements coming after 2030. However, given the current uncertainty about likely lifetimes of nuclear plants now in operation and the potential for new builds, AEO2012 includes several alternative cases to examine the impacts of different assumptions about future nuclear power plant uprates and operating lifetimes.

Uprates

Power plant uprates involve projects that are intended to increase the licensed capacity of existing nuclear power plants and permit those plants to generate more electricity. The U.S. Nuclear Regulatory Commission (NRC) must approve all uprate projects before they are undertaken and verify that the reactors will be able to operate safely at higher levels of output. Power plant uprates can increase plant capacity by 1 to 20 percent, depending on the size and type of the uprate project. Capital expenditures may be small (e.g., installing a more accurate sensor) or significant (e.g., replacing key plant components, such as turbines).

In developing projections for nuclear power, EIA relies on both reported data and estimates. Reported data come from Form EIA-860 [78], which requires all nuclear power plant owners to report any plans for building new plants or making major modifications to existing plants (such as uprates) over the next 10 years. In 2010, operators reported that they intended to complete uprate projects sometime during the next 10 years, which together would add a total of 0.8 gigawatts of new capacity. In addition to the reported plans for capacity uprates, EIA assumed that additional power uprates over the period from 2011 to 2035 would add another 6.5 gigawatts of capacity, based on interactions with EIA stakeholders with significant experience in implementing power plant uprates.

New builds

Building a new nuclear power plant is a tremendously complex project that can take many years to complete. Specialized high-wage workers, expensive materials and components, and engineering and construction expertise are required, and only a select group of firms worldwide can provide them. In the current economic environment of low natural gas prices and flat demand for electricity, the overall market conditions for new nuclear power plants are challenging.

Nuclear power plants are among the most expensive options for new generating capacity available today [79]. In the AEO2012 Reference case, the overnight capital costs associated with building a nuclear power plant planned in 2012 are assumed to be \$5,335 per kilowatt of capacity, which translates to \$11.7 billion for a dual-unit 2,200-megawatt power plant. The overnight costs

do not include additional costs such as financing, interest carried forward, and peripheral infrastructure updates [80]. Despite the cost, however, deployment of new nuclear capacity supports the long-term resource plans of many utilities, by allowing fuel diversification and providing a hedge in the future against potential GHG emissions regulations or natural gas prices that are higher than expected.

Incentive programs exist to encourage the construction of new reactors in the United States. At the Federal level, the Energy Policy Act of 2005 (EPACT05) established a loan guarantee program for new nuclear plants completed and in operation by 2020 [81]. A total of \$18.5 billion is available, of which \$8.3 billion has been conditionally committed to the construction of Southern Company's Vogtle Units 3 and 4 [82]. EPACT05 also provides a PTC of \$18 per megawatt-hour for electricity produced during the first 8 years of operation for a new nuclear plant [83]. New nuclear plants must be operational by 2021 to be eligible for the PTC, and the credit is limited to the first 6 gigawatts of new nuclear plant capacity. In addition to Federal incentives, several States provide favorable regulatory environments for new nuclear plants by allowing plant owners to recover their investments through retail electricity rates.

Several utilities are moving forward with plans to deploy new nuclear power plants in the United States. The Reference case reflects those plans by including 6.8 gigawatts of new nuclear capacity over the projection period. As reported on Form EIA-860, 5.5 gigawatts of new capacity (Vogtle Units 3 and 4, Summer Units 2 and 3, and Watts Bar Unit 2) are expected to be operational by 2020 [84]. The Reference case also includes 1.3 gigawatts associated with the construction of Bellefonte Unit 1, which the Tennessee Valley Authority reflects in its Integrated Resource Plan [85].

In addition to reported plans for new nuclear power plants, 1.8 gigawatts of unplanned capacity is built in the later years of the Reference case. Higher natural gas prices, recovering demand for electricity, and the need to make up for the loss of a limited amount of nuclear capacity all play a role in the additional builds.

Long-term operation of the existing nuclear power fleet

The NRC has the authority to issue initial operating licenses for commercial nuclear power plants for a period of 40 years. As of December 31, 2011, there were 7 reactors that received their initial full power operating licenses over 40 years ago. Among this set of reactors, Oyster Creek Unit 1 was the first reactor to operate for over 40 years, after receiving its initial full power operating license in August 1969. Oyster Creek Unit 1 was followed by Dresden Units 2 and 3, H.B. Robinson Unit 2, Monticello, Point Beach 1, and R.E. Ginna. The decision to apply for an operating license renewal is made by nuclear power plant owners, typically based on economics and the ability to meet NRC requirements. As of January 2012, the NRC had granted license renewals to 71 of the 104 operating reactors in the United States, allowing them to operate for a total of 60 years [86]. Currently, the NRC is reviewing license renewal applications for 15 reactors and expects to receive applications from another 14 reactors between 2012 and 2016 [87].

NRC regulations do not limit the number of license renewals a nuclear power plant may be granted. The nuclear power industry is preparing applications for license renewals that would allow continued operation beyond 60 years. The first application seeking approval to operate for 80 years is tentatively scheduled to be submitted by 2013. Some aging nuclear plants may, however, pose a variety of issues that could lead to decisions not to apply for a second license renewal, such as high operation and maintenance costs or the need for large capital expenditures to meet NRC requirements. Industry research on long-term reactor operations and aging management is focused on identifying challenges that aging facilities might encounter and formulating potential approaches to meet those challenges [88]. Typical challenges involve materials degradation, safety margins, and assessing the integrity of concrete structures. In the Reference case, 6.1 gigawatts of nuclear power plant capacity is retired by 2035, based on uncertainty related to issues associated with long-term operations and aging management [89].

It should be noted that although the Oyster Creek Generating Station in Lacey Township, New Jersey, received a license renewal and could operate until 2029, the plant's owner has reported to EIA that it will be retired in 2019, after 50 years of operation. The AEO2012 Reference case includes this reported early retirement. Also, given the evolving nature of the NRC's regulatory response to the accident at Japan's Fukushima Daiichi nuclear power plant in March 2011, the Reference case does not include retirements directly related to the accident (for example, retirements prompted by potential new NRC regulatory requirements for safety retrofits).

Sensitivity cases

The AEO2012 Low Nuclear case assumes that only the planned nuclear plant uprates already reported to EIA will be completed. Uprates that are currently under review or expected to be submitted to the NRC are not included. The Low Nuclear case also assumes that all nuclear power plants will be retired after 60 years of operation, resulting in a 30.9-gigawatt reduction in U.S. nuclear power capacity from 2010 to 2035. Figure 51 shows nuclear capacity retirements in the Low Nuclear case by NERC region. It should be noted that after the retirement of Oyster Creek in 2019, the next nuclear plant retirement occurs in 2029 in the Low Nuclear case. No new nuclear plants are built in the Low Nuclear case beyond the 6.8 gigawatts already planned.

In the High Nuclear case, in addition to plants already under construction, plants with active license applications at the NRC are constructed, provided that they have a tentatively scheduled mandatory hearing before the NRC or Atomic Safety and Licensing Board and deploy a currently certified design for the nuclear steam supply system, such as the AP1000. With this assumption, an additional 6.2 gigawatts of new nuclear capacity is added relative to the Reference case. The High Nuclear case also assumes that all existing nuclear power plants will receive their second license renewals and will operate through 2035. Uprates in the

High Nuclear case are consistent with those in the Reference case. The only retirement included in the High Nuclear case is the announced early retirement of Oyster Creek in 2019.

Results

In the Reference case, 8.5 gigawatts of new nuclear power plant capacity is added from 2010 to 2035, including the 6.8 gigawatts reported to EIA (referred to as “planned”) and 1.8 gigawatts built endogenously in NEMS (referred to as “unplanned”). Unplanned capacity is added starting in 2030 in response to rising natural gas prices, which make new nuclear power plants a more competitive option for new electric capacity. In the High Nuclear case, planned capacity additions are almost double those in the Reference case, but unplanned additions are lower. The price of natural gas delivered to the power sector in the High Nuclear case is lower than in the Reference case, making the economics of nuclear power plants slightly less attractive. The additional planned capacity in the High Nuclear case also reduces the need for new unplanned capacity. No unplanned capacity is added in the Low Nuclear case

Nuclear power generation in 2035 reflects the differences in capacity that occur in the nuclear cases. In the High Nuclear case, nuclear generation in 2035 is 10 percent higher than in the Reference case, and the nuclear share of total generation is 20 percent, as compared with 18 percent in the Reference case. The increase in nuclear capacity in the High Nuclear case contributes to an increase in total electricity generation, in spite of lower levels of generation from natural gas (4 percent lower than in the Reference case in 2035) and coal and renewables (less than 1 percent lower for each fuel).

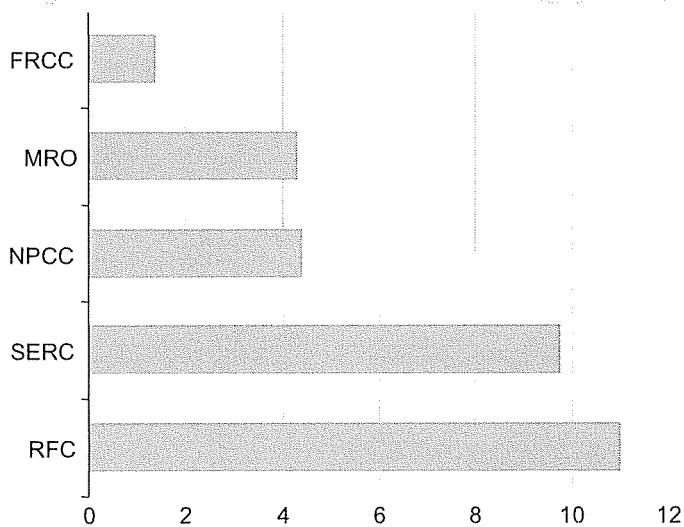
In the Low Nuclear case, generation from nuclear power in 2035 is 30 percent lower than in the Reference case, due to the loss of 30.9 gigawatts of nuclear capacity that is retired after 60 years of operation. As a result, the nuclear share of total generation is reduced to 13 percent. The loss of generation is made up primarily by increased generation from natural gas (12 percent higher than in the Reference case in 2035), coal (1 percent higher), and renewables (3 percent higher).

Real average electricity prices in 2035 are 1 percent lower in the High Nuclear case than in the Reference case, as slightly less natural gas capacity is dispatched, lowering the marginal price of electricity. In the Low Nuclear case, average electricity prices in 2035 are 5 percent higher than in the Reference case as a result of the retirement of a significant amount of nuclear capacity, which has relatively low operating costs, and its replacement with natural gas capacity, which has higher fuel costs that are passed through to consumers in retail electricity prices. With all nuclear power plants being retired after 60 years of operation in the Low Nuclear case, an additional 12 gigawatts of nuclear capacity would be shut down between 2035 and 2040.

The impacts of nuclear plant retirements on retail electricity prices in the Low Nuclear case are more apparent in regions with relatively large amounts of nuclear capacity. For example, electricity prices in the Low Nuclear case are 7 percent higher than in the Reference case for the NERC MRO Region, and 6 percent higher in the Northeast, Mid-Atlantic, and Southeast regions. Even in regions where no nuclear capacity is retired, there are small increases in electricity prices relative to the Reference case, because higher demand for natural gas in regions with nuclear plant retirements affect prices nationwide.

The Reference case projections for CO₂ emissions also are affected by changes in assumptions about nuclear plant lifetimes. In the Low Nuclear case, CO₂ emissions from the electric power sector in 2035 are 3 percent higher than in the Reference case as a result of switching from nuclear generation to natural gas and coal, both which produce more CO₂ emissions. In the High Nuclear case, CO₂ emissions from the power sector are slightly (1 percent) lower than in the Reference case. Table 12 summarizes key results from the AEO2012 Reference, High Nuclear, and Low Nuclear cases.

Figure 51. Nuclear power plant retirements by NERC region in the Low Nuclear case, 2010-2035 (gigawatts)



10. Potential impact of minimum pipeline throughput constraints on Alaska North Slope oil production

Introduction

Alaska’s North Slope oil production has been declining since 1988, when average annual production peaked at 2.0 million barrels per day. In 2010, about 600,000 barrels per day of oil was produced on the North Slope. Although new North Slope oil fields have started production since 1988, the decline of North Slope production has resulted largely from depletion of the North Slope’s two largest fields, Prudhoe Bay and Kuparuk River. Recently, Alyeska Pipeline Service Company (Alyeska), the operator of the Trans-Alaska Pipeline System (TAPS), stated that oil pipeline transportation problems could begin when throughput falls below 550,000 barrels per day and become increasingly severe with further declines [90].

Alyeska estimates that TAPS operational problems could become considerable when throughput falls below 350,000 barrels per day. The decline of both North Slope oil production

and TAPS throughput raises the possibility that North Slope oil production might be shut down, with the existing oil fields plugged and abandoned sometime before 2035. That possibility is discussed here, as well as alternatives that could prolong the life of North Slope oil fields and TAPS beyond 2035.

Background

Declining TAPS throughput

TAPS is an 800-mile crude oil pipeline that transports North Slope oil production south to the Alyeska marine terminal in Valdez, Alaska. The crude oil is then transported by tankers to West Coast refineries. TAPS currently is the only means for transporting North Slope crude oil to refineries and the petroleum consumption markets they serve.

From 2004 through 2006, Alyeska reconfigured and refurbished TAPS, spending about \$400 million to \$500 million [91] both to reduce operating expenses and to permit TAPS to operate at lower flow rates, with a potential minimum mechanical throughput rate thought to be about 200,000 barrels per day at that time [92]. As North Slope oil production has declined, however, concern about TAPS operation under low flow conditions has grown [93]. In August 2008, Alyeska initiated its Low Flow Impact Study, which was released on June 15, 2011 [94].

The Alyeska study identified the following potential problems that might occur as TAPS throughput declines from the current production levels:

- Water dropout from the crude oil, which could cause pipeline corrosion
- Ice formation in the pipe if the oil temperature drops below freezing
- Wax precipitation and deposition
- Soil heaving.

Other potential operational issues at low flow rates include sludge dropout, reduced ability to remove wax, reduction in pipeline leak detection efficiency, pipeline shutdown and restart, and the running of pipeline pigs that both clean the pipeline and check its integrity.

Although TAPS low flow problems could begin at volumes around 550,000 barrels per day in the absence of any mitigation, their severity is expected to increase as throughput declines further. As the types and severity of problems multiply, the investment required to mitigate these is expected to increase significantly. Because of the many and diverse operational problems expected to occur at throughput volumes below 350,000 barrels per day, considerable investment could be required to keep the pipeline operational below that threshold. The Alyeska study does not provide any estimates of what it might cost to keep the pipeline operational below either 550,000 or 350,000 barrels per day. Currently, Alyeska is conducting tests and analyses to determine the likely efficacy and costs of different remedies.

Mitigating the decline of North Slope oil production

Although much of the public focus has been on the operational capability of TAPS at low flow rates, the more fundamental issue is declining oil production. The TAPS low flow issue would be alleviated most readily by discovery and production of large new sources of oil on the North Slope. Potential sources of significant North Slope oil production are located offshore in the Chukchi and Beaufort Seas and onshore in shale and heavy oil deposits. The Arctic National Wildlife Refuge (ANWR) is also estimated to hold approximately 10.4 billion barrels of technically recoverable oil resources, but Federal oil and gas leasing in ANWR currently is prohibited [95]. Another potential source of new TAPS volumes would be the conversion of North Slope natural gas resources to either methanol or Fischer-Tropsch petroleum products that could be transported to market via TAPS. Finally, in the absence of new North Slope petroleum supplies, alternative crude oil transportation facilities could be developed, such as a new small-diameter pipeline running parallel to the TAPS route [96] or a new offshore oil terminal for North Slope production.

Table 12. Summary of key results from the Reference, High Nuclear, and Low Nuclear cases, 2010-2035

Projection	Reference	High Nuclear	Low Nuclear
Nuclear plant cumulative retirements (gigawatts)	6.1	0.6	30.9
Generating capacity cumulative additions (gigawatts)			
Coal	16.6	16.1	18.9
Natural gas	141.6	126.2	147.6
Nuclear capacity uprates	7.3	7.3	0.8
Planned nuclear capacity additions	6.8	13.5	6.8
Unplanned nuclear capacity additions	1.8	1.3	--
Renewables	67.4	64.5	73.4
Average delivered electricity price, 2035 (2010 cents per kilowatthour)	10.1	10.0	10.6
Average delivered natural gas price for electric power, 2035 (2010 dollars per million Btu)	7.21	7.00	8.03
CO ₂ emissions from electric power generation, 2035 (million metric tons)	2,330	2,301	2,404

Which of these potential low-flow solutions (or combination thereof) may ultimately come to fruition is impossible to determine at this time. Moreover, each solution comes with its own unique set of costs, risks, and lead times. Not only does each solution entail its own set of risks, there is also a significant risk that production from existing North Slope fields might decline much faster than anticipated and/or that the cost of operating those fields might escalate much faster than expected. Under those circumstances, there is a risk that any solution(s) could be both too little and too late, because the North Slope oil fields would be shut down before a TAPS solution could be implemented.

How quickly TAPS flows will decline, the types of low flow problems that might develop, and the degree of mitigation required depend on the success or failure of current offshore and onshore oil exploration and development programs and the quality of the oil produced. For example, low-viscosity oil is less problematic to TAPS operations than heavy, viscous oil. Because the future success of North Slope oil exploration and development is unknown, it is prudent to consider the circumstances under which North Slope oil production might cease altogether, causing a shutdown of the TAPS pipeline.

Aside from the question of what it might cost to keep TAPS operating at lower flow rates, an additional question is what it might cost to keep the existing North Slope oil fields producing. Even if the continued operation of TAPS were not in question, each North Slope oil field's production will eventually decline to a point at which it is no longer economical to keep the field operating. Oil and gas fields typically are shut down and abandoned when operating and maintenance costs exceed production revenues. At that point, wells are plugged and abandoned, surface equipment is removed, and the land is remediated to meet State and Federal requirements.

Although the cost structure of North Slope field production as production declines is unknown, production generally can be sustained profitably at lower production rates when oil prices are higher. Similarly, the economic feasibility of mitigating the problems arising from TAPS low flow rates improves when oil prices are higher. Consequently, revenues generated by North Slope oil production will play a pivotal role in determining the continued economic viability of existing North Slope oil fields, the development of new oil fields, the continued operation of TAPS at lower flow rates, and the potential development of new transportation facilities.

Several basic strategies have been employed to mitigate declining oil production and revenues from existing oil fields. First, the field operator can drill in-fill wells into those portions of the reservoir where oil cannot flow to existing production wells. Second, the operator can use enhanced oil recovery (EOR) that involves injecting steam or gases (along with water) to reduce viscosity and increase oil volumes as an aid to moving oil to the production wells. Currently, methane and natural gas liquids are being reinjected with water into many North Slope oil fields to achieve this outcome, which is referred to as "miscible hydrocarbon" EOR [97].

Drilling in-fill and EOR injection wells requires investments that are paid for through "maintenance" capital expenditures [98]. Both activities provide diminishing returns over time, as less oil typically is recovered with each new in-fill or EOR well, causing the cost per barrel of oil recovered to rise over time. Table 13 shows the number of in-fill and gas/water injection wells completed in 2010 at the three largest North Slope oil fields.

The diminishing returns from new in-fill and EOR wells is demonstrated in recent remarks by a ConocoPhillips official who noted that approximately \$630 million was to be spent on maintenance capital expenditures in 2011, compared with about \$240 million in 2001 [99]. In 2001 and 2010, ConocoPhillips provided 37.4 percent and 39.1 percent, respectively, of total North Slope oil production [100]. Using those percentages to scale up ConocoPhillips maintenance capital expenditures so that they represent total capital expenditures for North Slope maintenance, then total North Slope maintenance costs can be estimated at about \$640 million in 2001 and \$1.6 billion in 2011—a 150-percent increase over a period in which total North Slope oil production declined from 931,000 barrels per day to 562,000 barrels per day. If maintenance capital expenditures increased at the same rate (150 percent) over the next 10 years, they could be as high as \$4 billion in 2021.

Another method for extending oil production is to produce increasing amounts of water relative to oil [101]. As oil is produced from a reservoir, water typically enters the formation, causing the water-to-oil ratio to increase exponentially over time as oil production volumes decline [102]. Because the cost per barrel for handling and reinjecting reservoir water typically is relatively constant, the operating cost per barrel of oil produced increases exponentially over time.

Shutdown and abandonment assumptions

According to the Alyeska study, a TAPS throughput of about 350,000 barrels per day appears to be the threshold at which significant investment would be required to permit lower TAPS throughput. AEO2012 adopts the 350,000 barrel per day figure as

Table 13. Alaska North Slope wells completed during 2010 in selected oil fields

Production unit	Miscible hydrocarbon EOR	In-fill development wells	Gas/water injection wells	Total wells
Colville River	Yes	8	6	14
Kuparuk River	Yes	25	26	51
Prudhoe Bay	Yes	68	8	76
Subtotal		101	40	141
Total North Slope				168

the threshold for either making significant investments in TAPS or the alternatives, or shutting down and decommissioning TAPS and the North Slope oil fields [103].

In the AEO2012 analysis, the shutdown and decommissioning of TAPS and the North Slope oil fields are also conditional on whether North Slope wellhead oil production revenues fall below a specific level. The appropriate revenue threshold is uncertain, because there is little or no information available to the public on operating and maintenance costs for existing oil fields, how those costs have grown historically as production has declined, or how they might grow in the future. Similarly, there are no public data available on what it might cost to keep TAPS operating as throughput declines [104]. Given the lack of public information, this analysis endeavors to determine both future North Slope production revenues in alternative oil price cases and an order-of-magnitude estimate of wellhead production costs.

AEO2012 assumes that, in order for the North Slope fields to be shut down, plugged, and abandoned, two conditions would need to be met simultaneously: TAPS throughput at or below 350,000 barrels per day and total North Slope oil production revenues at or below \$5 billion per year. It is also assumed that if those two conditions were met, TAPS would be decommissioned and dismantled, and North Slope oil exploration and production activities would cease [105].

The \$5 billion threshold for North Slope oil production revenue used in AEO2012 is not intended to be conclusive regarding the conditions under which the North Slope oil fields and TAPS would remain in operation. As noted earlier, in-fill and EOR well drilling requirements could escalate to about \$4 billion per year by 2021 [106]. Moreover, with the State of Alaska royalty rate currently at about 18.5 percent [107], a \$5 billion revenue level would equate to almost \$1 billion in royalties.

Also, an order of magnitude estimate of operating costs can be made by examining what oil companies report for their annual production expenses. For example, ExxonMobil reported a range of regional production costs per barrel of oil equivalent (excluding taxes) of \$6.17 to \$20.07 per barrel in 2010, with the U.S. average production cost being \$10.67 per barrel [108]. At 350,000 barrels per day, a North Slope operating expense of \$10 to \$20 per barrel would equate to \$1.28 to \$2.56 billion per year in annual operating expenses. Of course, production costs could well exceed \$20 per barrel as North Slope oil production declines.

Although the \$5 billion North Slope revenue figure is not conclusive with regard to the actual annual costs faced by North Slope field operators in the future, it is a reasonable estimate in light of the sum of current maintenance capital expenditures (\$1.6 billion), estimated operating expenses at 350,000 barrels per day (\$1.28 to \$2.56 billion), and a royalty cost of about \$1 billion. As discussed below, the oil production revenue threshold serves to either advance or delay the date when TAPS and North Slope oil production would be shut down.

The final assumption is that a complete shutdown of North Slope oil production would occur in the year in which both the throughput and revenue criteria are satisfied. In reality, the actual shutdown of North Slope oil production might be extended over a number of years and could begin either before or after the year in which the criteria employed by North Slope producers are met.

Projections

A shutdown of North Slope oil production before 2035 is projected only in the Low Oil Price case, which shows both TAPS throughput and North Slope oil revenues falling below the 350,000 barrels per day and \$5 billion per year thresholds, respectively, in 2026 (Figures 52 and 53). In both the Reference and High Oil Price cases, oil prices are sufficiently high both to stimulate the

Figure 52. Alaska North Slope oil production in three cases, 2010-2035 (million barrels per day)

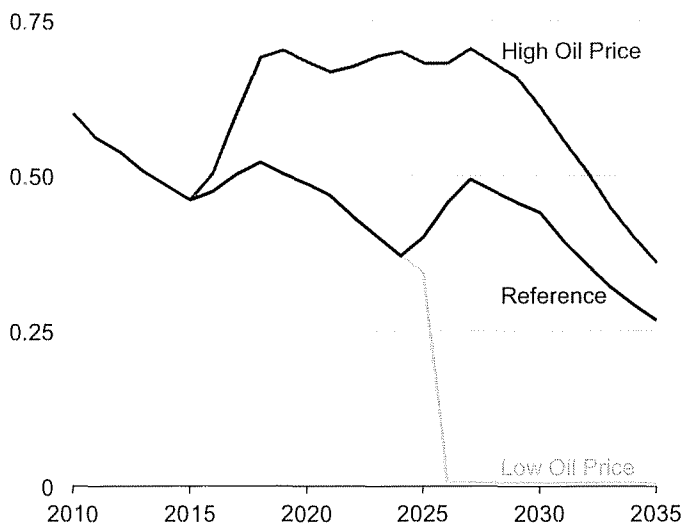
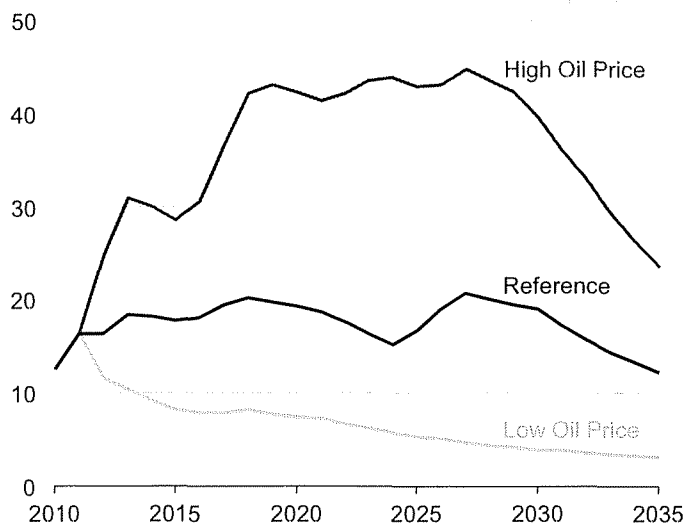


Figure 53. Alaska North Slope wellhead oil revenue in three cases, assuming no minimum revenue requirement, 2010-2035 (million 2010 dollars per year)



development of new North Slope oil fields, especially offshore, and to provide sufficient oil production revenues to keep the North Slope producing oil through 2035.

Figure 53 shows the projected North Slope oil production revenue stream over time in the three price cases, with North Slope oil production continuing even after production volume and revenue requirements are no longer met in the Low Oil Price case. Thus, if the minimum North Slope revenue requirement were \$7.5 billion, a shutdown of North Slope production could occur as soon as 2020, but only in the Low Oil Price case.

There is considerable uncertainty about the long-term viability of North Slope oil production and continued operation of TAPS through 2035. The two most important determinants of their future viability are the wellhead oil price that North Slope producers receive and the availability and cost of developing new North Slope oil resources. Those two factors will determine whether new oil fields are developed, whether existing oil fields remain sufficiently profitable to continue operating, and whether the investments required to keep TAPS operating at flow rates below 350,000 barrels per day are economically feasible.

The AEO2012 Low and High Oil Price cases suggest that North Slope oil production will remain viable across a wide range of oil prices. Only in the Low Oil Price case are North Slope wellhead oil revenues sufficiently low to cause a shutdown of North Slope oil production. If the Low Oil Price case represents a low-probability outer boundary for future oil prices, then the likely future outcome is that North Slope oil production will continue until at least 2035, if not longer.

11.1.5 U.S. crude oil and natural gas resource uncertainty

A common measure of the long-term viability of U.S. domestic crude oil and natural gas as an energy source is the remaining technically recoverable resource (TRR). Estimates of TRR are highly uncertain, however, particularly in emerging plays where few wells have been drilled. Early estimates tend to vary and shift significantly over time as new geological information is gained through additional drilling, as long-term productivity is clarified for existing wells, and as the productivity of new wells increases with technology improvements and better management practices. TRR estimates used by EIA for each AEO are based on the latest available well production data and on information from other Federal and State governmental agencies, industry, and academia.

The remaining TRR consist of “proved reserves” and “unproved resources.” *Proved reserves* of crude oil and natural gas are the estimated volumes expected to be produced, with reasonable certainty, under existing economic and operating conditions [109]. Proved reserves are also company financial assets reported to investors, as determined by U.S. Securities and Exchange Commission regulations. *Unproved resources* are additional volumes estimated to be technically recoverable without consideration of economics or operating conditions, based on the application of current technology [110]. As wells are drilled and field equipment is installed, unproved resources become proved reserves and, ultimately, production.

AEO estimates of TRR for shale gas and tight oil [111] have changed significantly in recent years (Table 14) [112]. In particular, the estimates of shale gas TRRs have changed significantly since the AEO2011 was published, based on new well performance data and United States Geological Survey (USGS) resource assessments. For example, in the past year the USGS has released resource assessments for five basins: Appalachian (Marcellus only), Arkoma, Texas-Louisiana-Mississippi Salt, Western Gulf, and Anadarko [113]. The shale gas and tight oil formations in those five basins were the primary focus of EIA’s resource revisions for AEO2012. In 2002, the USGS estimated Marcellus TRR at 1.9 trillion cubic feet; in 2011, the updated USGS estimate for Marcellus was 84 trillion cubic feet (see the following article for more discussion). For the four other basins, shale gas and tight oil TRR had not been assessed previously. The USGS has not published an assessment of the Utica play in the Appalachian Basin.

The remainder of this discussion describes how estimates of remaining U.S. unproved technically recoverable resources of shale gas and tight oil are developed for AEO, and how uncertainty in those estimates could affect U.S. crude oil and natural gas markets in the future.

Estimating technically recoverable resources of shale gas and tight oil

The remaining unproved TRR for a continuous-type shale gas or tight oil area is the product of (1) land area, (2) well spacing (wells per square mile), (3) percentage of area untested, (4) percentage of area with potential, and (5) EUR per well [114]. The USGS periodically publishes shale gas resource assessments that are used as a guide for selection of key parameters in the calculation of the TRR used in the AEO. The USGS seeks to assess the recoverability of shale gas and tight oil based on the wells drilled and technologies deployed at the time of the assessment.

The AEO TRRs incorporate current drilling, completion, and recovery techniques, requiring adjustments to the USGS estimates, as well as the inclusion of shale gas and tight oil resources not yet assessed by USGS. When USGS assessments and underlying data become publicly available, the USGS assumptions for land area, well spacing, and percentage of area with potential typically are used by EIA to develop the AEO TRR estimates. EIA may revise the well spacing assumptions in future AEOs to reflect evolving drilling practices. If well production data are available, EIA analyzes the decline curve of producing wells to calculate the expected EUR per well from future drilling.

Of the five basins recently assessed by the USGS, underlying details have been published only for the Marcellus shale play in the Appalachian basin. AEO2012 assumptions for the other shale plays are based on geologic surveys provided from State agencies (if

available), analysis of available production data, and analogs from current producing plays with similar geologic properties (Table 15). For AEO2012, only eight plays are included in the tight oil category (Table 16). Additional tight oil resources are expected to be included in the tight oil category in future AEOs as more work is completed in identifying currently producing reservoirs that may be categorized as tight formations, and as new tight oil plays are identified and incorporated.

A key assumption in evaluating the expected profitability of drilling a well is the EUR of the well. EURs vary widely not only across plays but also within a single play. To capture the economics of developing each play, the unproved resources for each play within each basin are divided into subplays—first across States (if applicable), and then into three productivity categories: best, average, and below average. Although the average EUR per well for a play may not change by much from one AEO to the next, the range of well performance encompassed by representative EURs can change substantially (Table 17).

For every AEO, the EUR for each subplay is determined by fitting a hyperbolic decline curve to the latest production history, so that changes in average well performance can be captured. Annual reevaluations are particularly important for shale gas and tight oil formations that have undergone rapid development. For example, because there has been a dramatic change from drilling vertical wells to drilling horizontal wells in most tight oil and shale gas plays since 2003, EURs for those plays based on vertical well performance are less useful for estimating production from future drilling, given that most new wells are expected to be primarily horizontal.

In addition, the shape of the annual well production profiles associated with the EUR varies substantially across the plays (Figure 54). For example, in the Marcellus, Fayetteville, and Woodford shale gas plays, nearly 65 percent of the well EUR is produced in the first 4 years. In contrast, in the Haynesville and Eagle Ford plays, 95 percent and 82 percent, respectively, of the well EUR is produced in the first four years. For a given EUR level, increased “front loading” of the production profile improves well economics, but it also implies an increased need for additional drilling to maintain production levels.

At the beginning of a shale play’s development, high initial well production rates result in significant production growth as drilling activity in the play increases. The length of time over which the rapid growth can be sustained depends on the size of the

Table 14. Unproved technically recoverable resource assumptions by basin

Basin	AEO2006 (as of 1/1/2004)	AEO2007 (as of 1/1/2005)	AEO2008 (as of 1/1/2006)	AEO2009 (as of 1/1/2007)	AEO2010 (as of 1/1/2008)	AEO2011 (as of 1/1/2009)	AEO2012 (as of 1/1/2010)
Shale gas (trillion cubic feet)							
Appalachian	15	15	14	51	59	441	187
Fort Worth	40	39	38	60	60	20	19
Michigan	11	11	11	10	10	21	18
San Juan	10	10	10	10	10	12	10
Illinois	3	3	3	4	4	11	11
Williston	4	4	4	4	4	7	3
Arkoma	--	42	42	49	45	54	27
Anadarko	--	3	3	7	6	3	13
TX-LA-MS Salt	--	--	--	72	72	80	66
Western Gulf	--	--	--	--	18	21	59
Columbia	--	--	--	--	51	41	12
Uinta	--	--	--	--	7	21	11
Permian	--	--	--	--	--	67	27
Greater Green River	--	--	--	--	--	18	13
Black Warrior	--	--	--	--	--	4	5
Shale gas total	83	126	125	267	347	827	482
Tight oil (billion barrels)							
Williston	--	3.7	3.7	3.7	3.6	3.6	5.4
San Joaquin/Los Angeles	--	--	--	--	15.4	15.4	13.7
Rocky Mountain basins	--	--	--	--	5.1	5.1	6.5
Western Gulf	--	--	--	--	5.6	5.6	5.7
Permian	--	--	--	--	--	1.6	1.6
Anadarko	--	--	--	--	--	0.2	0.3
Tight oil total	--	3.7	3.7	3.7	29.7	31.5	33.2

Shale Gas Plays

technically recoverable resource in each play, the rate at which drilling activity increases, and the extent of the play's "sweet spot" area [115]. In the longer term, production growth tapers off as high initial production rates of new wells in "sweet spots" are offset by declining rates of existing wells, and as drilling activity moves into less-productive areas. As a result, in the later stages of a play's resource development, maintaining a stable production rate requires a significant increase in drilling.

Table 15. Attributes of unproved technically recoverable resources for selected shale gas plays as of January 1, 2010

Basin/Play	Area (square miles)	Average well spacing (wells per square mile)	Percent of area untested	Percent of area with potential	Average EUR (billion cubic feet per well)	Number of potential wells	TRR (billion cubic feet)
Appalachian							
Marcellus	104,067	5	99	18	1.56	90,216	140,565
Utica	16,590	4	100	21	1.13	13,936	15,712
Arkoma							
Woodford	3,000	8	98	23	1.97	5,428	10,678
Fayetteville	5,853	8	93	23	1.30	10,181	13,240
Chattanooga	696	8	100	29	0.99	1,633	1,617
Caney	2,890	4	100	29	0.34	3,369	1,135
TX-LA-MS Salt							
Haynesville/Bossier	9,320	8	98	34	2.67	24,627	65,860
Western Gulf							
Eagle Ford	7,600	6	99	47	2.36	21,285	50,219
Pearsall	1,420	6	100	85	1.22	7,242	8,817
Anadarko							
Woodford	3,350	4	99	29	2.89	3,796	10,981
Total, selected shale gas plays						181,714	318,825
Total, all U.S. shale gas plays						410,722	481,783

Table 16. Attributes of unproved technically recoverable tight oil resources as of January 1, 2010

Basin/Play	Area (square miles)	Average well spacing (wells per square mile)	Percent of area untested	Percent of area with potential	Average EUR (million barrels per well)	Number of potential wells	TRR (million barrels)
Western Gulf							
Austin Chalk	16,078	3	72	61	0.13	21,165	2,688
Eagle Ford	3,200	5	100	54	0.28	8,665	2,461
Anadarko							
Woodford	3,120	6	100	88	0.02	16,375	393
Permian							
Avalon/Bone Springs	1,313	4	100	78	0.39	4,085	1,593
Spraberry	1,085	6	99	72	0.11	4,636	510
Rocky Mountain basins							
Niobrara	20,385	8	97	80	0.05	127,451	6,500
Williston Bakken ^a	6,522	2	77	97	0.55	9,767	5,372
San Joaquin/Los Angeles							
Monterey/Santos	2,520	12	98	93	0.50	27,584	13,709
Total tight oil						219,729	33,226

^aIncludes Sanish-Three Forks formation

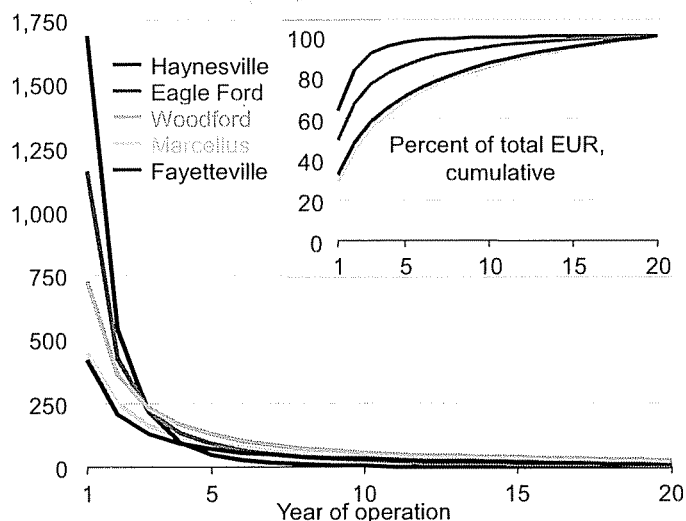
The amount of drilling that occurs each year depends on company budgets and finances and the economics of drilling, completing, and operating a well—determined largely by wellhead prices for oil and natural gas in the area. For example, current high crude oil prices and low natural gas prices are directing drilling toward those plays or portions of plays with a high concentration of liquids (crude oil, condensates, and natural gas plant liquids). Clearly, not all the wells that would be needed to develop each play fully can be drilled in one year—for example, more than 630,000 new wells would be needed to bring total U.S. shale gas and tight oil resources into production. In 2010, roughly 37,500 total oil and natural gas wells were drilled in the United States. It takes time and money to evaluate, develop, and produce hydrocarbon resources.

Although changes in the overall TRR estimates are important, the economics of developing the TRR and the timing of the development determine the projections for production of domestic crude oil and natural gas. TRR adjustments that affect resources which are not economical to develop during the projection period do not affect the AEO projections. Thus, significant variation in the overall TRR does not always result in significant changes in projected production.

EUR sensitivity cases and results

Estimated ultimate recovery per well is a key component in estimates of both technically recoverable resources and economically recoverable resources of tight oil and shale gas. The EUR for future wells is highly uncertain, depending on the application of new

Figure 54. Average production profiles for shale gas wells in major U.S. shale plays by years of operation (million cubic feet per year)



and/or improved technologies as well as the geology of the formation where the wells will be drilled. EUR assumptions typically have more impact on projected production than do any of the other parameters used to develop TRR estimates. For AEO2012, two cases were created to examine the impacts of higher and lower TRR for tight oil and shale gas by varying the assumed EUR per well.

These High and Low EUR cases are not intended to represent a confidence interval for the resource base, but rather to illustrate how different EUR assumptions can affect projections of domestic production, prices, and consumption. To emphasize this point, an additional case was developed that combines a change in the assumed well spacing for all shale gas and tight oil plays with the EUR assumptions in the High EUR case. Well spacing is also highly uncertain, depending on the application of new and/or improved technologies as well as the geology of the formation where the well is being drilled. In the AEO2012 Reference case, the well spacing for shale gas and tight oil drilling ranges from 2 to 12 wells per square mile.

Table 17. Estimated ultimate recovery for selected shale gas plays in three AEOs (billion cubic feet per well)

Basin/Play	AEO2010		AEO2011		AEO2012	
	Range	Average	Range	Average	Range	Average
Appalachian						
Marcellus	0.25–0.74	0.49	0.86–4.66	1.62	0.02–7.80	1.56
Utica	--	--	--	--	0.10–2.75	1.13
Arkoma						
Woodford	1.43–4.28	2.85	3.00–5.32	4.06	0.40–4.22	1.97
Fayetteville	0.91–2.73	1.82	0.86–2.99	2.03	0.19–3.22	1.30
Chattanooga	--	--	--	--	0.14–1.94	0.99
Caney	--	--	--	--	0.05–0.66	0.34
TX-LA-MS Salt						
Haynesville/Boosier	2.30–6.89	4.59	1.13–8.65	3.58	0.08–5.76	2.67
Western Gulf						
Eagle Ford	1.10–3.29	2.19	1.73–7.32	2.63	0.41–4.93	2.36
Pearsall	--	--	--	--	0.12–2.91	1.22
Anadarko						
Woodford	--	--	2.65–4.54	3.42	0.68–5.37	2.89

Figure 18 (continued)

Low EUR case. In the Low EUR case, the EUR per tight oil or shale gas well is assumed to be 50 percent lower than in the Reference case, increasing the per-unit cost of developing the resource. The total unproved tight oil TRR is decreased to 17 billion barrels, and the shale gas TRR is decreased to 241 trillion cubic feet, as compared with 33 billion barrels of tight oil and 482 trillion cubic feet of shale gas in the Reference case.

High EUR case. In the HIGH EUR case, the EUR per tight oil or shale gas well is assumed to be 50 percent higher than in the Reference case, decreasing the per-unit cost of developing the resource. The total unproved tight oil TRR is increased to 50 billion barrels and the shale gas TRR is increased to 723 trillion cubic feet.

High TRR case. In the High TRR case, the well spacing for all tight oil and shale gas plays is assumed to be 8 wells per square mile (i.e., each well has an average drainage area of 80 acres), and the EUR per tight oil or shale gas well is assumed to be 50 percent higher than in the Reference case. In addition, the total unproved tight oil TRR is increased to 89 billion barrels and the shale gas TRR is increased to 1,091 trillion cubic feet, more than twice the TRRs for tight oil and shale gas wells in the Reference case.

The effects of the changes in assumptions in the three cases on supply, demand, and prices for oil and for natural gas are significantly different in magnitude, because the domestic oil and natural gas markets are distinctly different markets. Consequently, the following discussion focuses first on how the U.S. oil market is affected in the three sensitivity cases, followed by a separate discussion of how the U.S. natural gas market is affected in the three cases

Crude oil and natural gas liquid impacts

The primary impact of the Low EUR, High EUR, and High TRR cases with respect to oil production is a change in production of tight oil and natural gas plant liquids (NGPL) (Table 18). NGPL production is discussed in conjunction with tight oil production, because significant volumes of NGPL are produced from tight oil and shale gas formations. Thus, changing the EURs directly affects NGPL production. Relative to the Reference case, tight oil production increases more slowly in the Low EUR case and more rapidly in the High EUR and High TRR cases. On average, tight oil production from 2020 to 2035 is approximately 450,000 barrels per day lower in the Low EUR case, 410,000 barrels per day higher in the High EUR case, and 1.3 million barrels per day higher in the High TRR case than in the Reference case (Figure 55). NGPL production in 2035 is more than 350,000 barrels per day lower in the Low EUR case than in the Reference case, nearly 320,000 barrels per day higher in the High EUR case, and 1.0 million barrels per day higher in the High TRR case.

Tight oil production is highest in the High TRR case, which assumes both higher EUR per well and generally lower drainage area per well than in the Reference case. In the High TRR case, tight oil production increases from roughly 400,000 barrels per day in 2010 to nearly 2.8 million barrels per day in 2035, with the Bakken formation accounting for most of the increase. The TRR estimate for the Bakken is more than 7 times higher in the High TRR case than in the Reference case—39.3 billion barrels compared to 5.4 billion barrels—which supports a continued dramatic production increase through 2015 and a longer plateau at a much higher production level through 2035 than in the Reference case. Bakken crude oil production (excluding NGPLs) increases from roughly 270,000 barrels per day in 2010 to nearly 800,000 barrels per day in 2015 before reaching over 1 million barrels per day in 2021 and remaining at that level through 2035 in the High TRR case, compared with peak tight oil production of roughly 530,000 barrels per day in the Reference case. Cumulative crude oil production from the Bakken from 2010 to 2035 is roughly 8.5 billion barrels in the High TRR case, compared with 4.3 billion barrels in the Reference case.

Table 18. Petroleum supply, consumption, and prices in four cases, 2020 and 2035

Projection	2010	2020				2035			
		Reference	Low EUR	High EUR	High TRR	Reference	Low EUR	High EUR	High TRR
Low-sulfur light crude oil price (2010 dollars per barrel)	79	127	128	125	122	145	147	143	140
Total U.S. production of crude oil and natural gas plant liquids (million barrels per day)	7.5	9.6	8.8	10.3	11.6	9.0	8.1	10.0	11.8
Tight oil	0.4	1.2	0.9	1.5	2.2	1.2	0.7	1.7	2.8
Natural gas plant liquids	2.1	2.9	2.6	3.1	3.6	3.0	2.7	3.3	4.0
Other U.S. crude oil	5.1	5.5	5.3	5.6	5.7	4.8	4.8	4.9	5.0
Tight oil share of total U.S. crude oil and NGPL production (percent)	5	12	10	15	19	14	9	17	23
U.S. net import share of petroleum product supplied (percent)	50	37	41	34	27	36	41	32	24

Every incremental barrel of domestic crude oil production displaces approximately one barrel of imports, because U.S. consumption of liquid fuels varies little across the cases. Consequently, the projected share of net petroleum imports in total U.S. liquid fuel consumption in 2035 varies considerably across the EUR and TRR cases, from 41 percent in the Low EUR case to 24 percent in the High TRR case, as compared with 36 percent in the Reference case. However, additional downstream infrastructure may be required to process the high levels of NGPL production in the High EUR and High TRR cases.

Changes in domestic oil production have only a modest impact on domestic crude oil and petroleum product prices, because any change in domestic oil production is diluted by the much larger world oil market. The United States produced 5.5 million barrels per day, or 7 percent of total world crude oil production of 73.9 million barrels per day in 2010 and is projected generally to maintain that share of world crude oil production through 2035 in the Reference case.

Natural gas impacts

The EUR and TRR cases show more significant impacts on U.S. natural gas supply, consumption, and prices than that projected for crude oil and petroleum products for two reasons (Table 19). First, the U.S. natural gas market constitutes the largest regional submarket within the relatively self-contained North American natural gas market. Second, in the Reference case, shale gas production accounts for 49 percent of total U.S. natural gas production in 2035, while tight oil production accounts for only 14 percent of total U.S. crude oil and NGPL production and 1 percent of world crude oil production. As a result, changes in shale gas production have a commensurately larger impact on North American natural gas prices than tight oil production has on world oil prices.

The projections for domestic shale gas production are highly sensitive to the assumed EUR per well. In 2035, total shale gas production varies from 9.7 trillion cubic feet in the Low EUR case to 16.0 trillion cubic feet in the High EUR case and 20.5 trillion cubic feet in the High TRR case, as compared with 13.6 trillion cubic feet in the Reference case (Figure 56). Because shale gas production accounts for such a large proportion of total natural gas production in 2035, the large changes in shale gas production result in commensurately large swings in total U.S. natural gas production. In 2035, total U.S. natural gas production ranges from 26.1 trillion cubic feet in the Low EUR case to 34.1 trillion cubic feet in the High TRR case, a difference of 8.0 trillion cubic feet production between the two cases.

In comparison with the Reference case, per-unit production costs are nearly double in the Low EUR case and about one-half in the High EUR case. In the Low EUR case, the Henry Hub natural gas price of \$8.26 per million Btu in 2035 (2010 dollars) is \$0.89 per million Btu higher than the Reference case price of \$7.37 per million Btu. In the High EUR case, the 2035 Henry Hub natural gas price of \$5.99 per million Btu is \$1.38 per million Btu lower than the Reference case price. In the High TRR case, the 2035 Henry Hub natural gas price of \$4.25 per million Btu is \$3.12 per million Btu less than the Reference case price.

The natural gas prices projected in the Low EUR case are sufficiently high to enable completion of an Alaska gas pipeline, with operations beginning in 2031. Because an Alaska gas pipeline would make up for some of the reduction in Lower 48 shale gas production, differences between the Reference and Low EUR case projections for natural gas production, prices, and consumption in 2035 are somewhat less than would otherwise be expected.

The 2035 price spread of \$4.01 per million Btu across the cases is reflected in the projected levels of U.S. natural gas consumption. Higher natural gas prices in the Low EUR case reduce total natural gas consumption to 25.0 trillion cubic feet in 2035, compared with 26.6 trillion cubic feet in the Reference case; and lower natural gas prices in the High EUR and High TRR cases increase consumption in 2035 to 28.4 trillion cubic feet and 31.9 trillion cubic feet, respectively.

Figure 55. U.S. production of tight oil in four cases, 2000-2035 (million barrels per day)

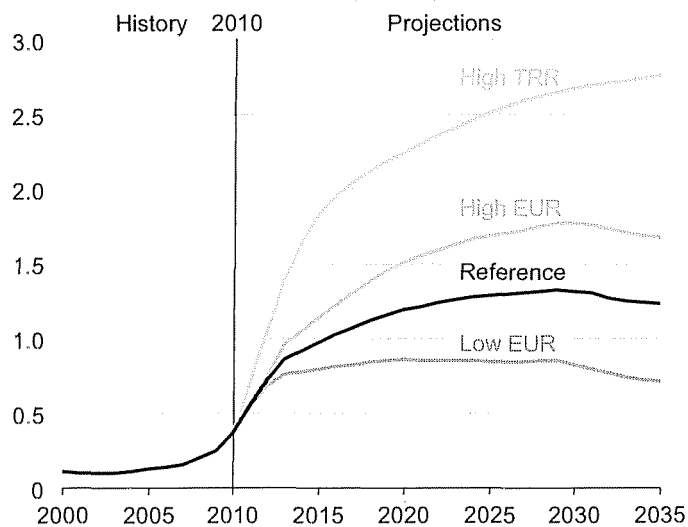
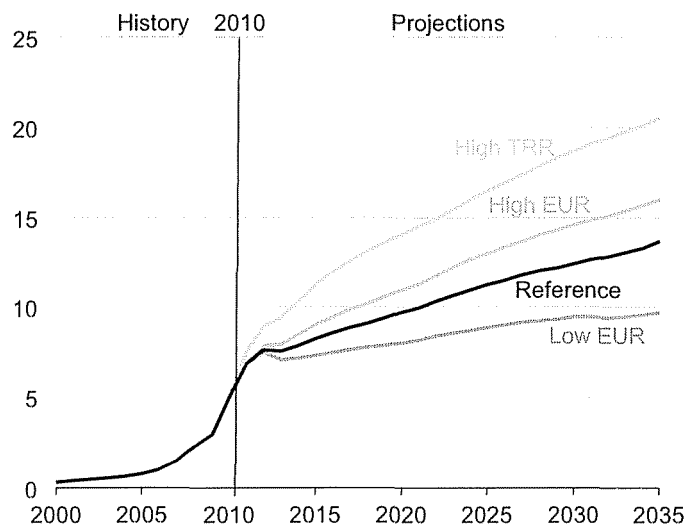


Figure 56. U.S. production of shale gas in four cases, 2000-2035 (trillion cubic feet)



Natural Gas

The variation in total U.S. natural gas consumption between the High EUR and High TRR cases is reflected to some degree in each end-use category. The electric power sector shows the greatest sensitivity to natural gas prices, with natural gas use for electricity generation being more responsive to changes in fuel prices than is consumption in the other sectors, because much of the electric power sector's fuel consumption is determined by the dispatching of existing generation units based on the operating cost of each unit, which in turn is determined largely by the costs of competing fuels—especially coal and natural gas. Natural gas consumption in the electric power sector in 2035 totals 7.7 trillion cubic feet in the Low EUR case, compared with 9.0 trillion cubic feet in the Reference case, 10.1 trillion cubic feet in the High EUR case, and 12.6 trillion cubic feet in the High TRR case.

In the end-use consumption sectors, opportunities to switch fuels generally are limited to when a new facility is built or when a facility's existing equipment is retired and replaced. Collectively, for all the end-use sectors, natural gas consumption in 2035 varies by only about 1.9 trillion cubic feet across the cases, from 17.3 trillion cubic feet in the Low EUR case to 19.2 trillion cubic feet in the High TRR case, as compared with 17.7 trillion cubic feet in the Reference case.

In 2035, the United States is projected to be a net exporter of natural gas in all the cases. The projected volumes of net exports vary, with lower natural gas prices resulting in higher net exports. However, the High TRR, High EUR, and Low EUR cases assume that U.S. gross exports of LNG remain constant at 0.9 trillion cubic feet from 2020 through 2035, because of the inherent complexities and uncertainties of projecting foreign natural gas production, consumption, and trade. It is likely, however, that actual levels of net LNG exports would be affected by changes in U.S. prices, which in turn, would dampen the extent of the price difference across the resource cases.

The variation in levels of net U.S. natural gas exports shown in Table 20 reflects the impact of domestic natural gas prices on natural gas pipeline imports and exports. Generally, lower natural gas prices, as in the High TRR case, result in lower natural gas imports from Canada and higher natural gas exports to Mexico. In 2035, net natural gas exports from the United States vary from 1.2 trillion cubic feet in the Low EUR case to 2.4 trillion cubic feet in the High TRR case, as compared with 1.4 trillion cubic feet in the Reference case.

The sensitivity cases in this discussion are not intended to provide a confidence interval for estimates of recoverable resources of domestic tight oil and shale gas but rather to illustrate the significance of key assumptions underlying the tight oil and shale

Table 19. Natural gas prices, supply, and consumption in four cases, 2020 and 2035

Projection	2010	2020				2035			
		Reference	Low EUR	High EUR	High TRR	Reference	Low EUR	High EUR	High TRR
Henry Hub natural gas spot price (2010 dollars per million Btu)	4.39	4.58	5.31	4.04	3.02	7.37	8.26	5.99	4.25
Total U.S. natural gas production (trillion cubic feet)	21.6	25.1	23.6	26.3	29.1	27.9	26.1	30.1	34.1
Onshore lower 48	18.7	22.5	21.0	23.6	26.6	25.0	21.2	27.2	31.7
Shale gas	5.0	9.7	8.0	10.9	14.0	13.6	9.7	16.0	20.5
Other natural gas	13.7	12.8	12.9	12.7	12.6	11.3	11.4	11.2	11.1
Offshore lower 48	2.6	2.3	2.4	2.3	2.2	2.7	3.1	2.6	2.3
Alaska	0.4	0.3	0.3	0.3	0.3	0.2	1.8	0.2	0.2
Shale gas production as percent of total U.S. natural gas production	23	39	34	42	48	49	37	53	60
Total net U.S. imports of natural gas (trillion cubic feet)	2.6	0.3	0.5	0.2	-0.2	-1.4	-1.2	-1.7	-2.4
Total U.S. consumption of natural gas (trillion cubic feet)	24.1	25.5	24.2	26.5	28.9	26.6	25.0	28.4	31.9
Electric Power	7.4	7.9	6.8	8.7	10.5	9.0	7.7	10.1	12.6
Residential	4.9	4.8	4.8	4.9	4.9	4.6	4.6	4.7	4.8
Commercial	3.2	3.4	3.4	3.5	3.6	3.6	3.5	3.7	4.0
Industrial	6.6	7.1	7.0	7.1	7.4	7.0	6.9	7.2	7.6
Other	2.0	2.3	2.2	2.3	2.5	2.4	2.4	2.6	2.8

gas TRRs used in AEO2012. TRR estimates are highly uncertain and can be expected to change in subsequent AEOs as additional information is gained through continued exploration, development, and production.

12. Evolving Marcellus shale gas resource estimates

As discussed in the preceding article, estimates of crude oil and natural gas TRR are uncertain. Estimates of the Marcellus shale TRR, which have received considerable attention over the past year, are no exception. TRR estimates are likely to continue evolving as drilling continues and more information becomes publicly available. The Marcellus shale gas play covers more than 100,000 square miles in parts of eight States, but most of the drilling to date has been in two areas of northeast Pennsylvania and southwest Pennsylvania/northern West Virginia. Until 2010, the State of Pennsylvania had maintained a 5-year embargo on the release of well-level production data, which severely limited the publicly available information about Marcellus well production. Now Pennsylvania provides well production data on a cumulative basis—annually for the years before 2010 and semi-annually starting in the second half of 2010. Even with more data available, however, it is still a challenge to estimate TRR for the Marcellus play.

In 2002, the USGS estimated that 0.8 trillion cubic feet to 3.7 trillion cubic feet of technically recoverable shale gas resources existed in the Marcellus, with a mean estimate of 1.9 trillion cubic feet [116]. At that time, most of the well production data available were for vertical wells drilled in West Virginia. Since 2003, technological improvements have led to more-productive and less-costly wells. The newer horizontal wells have higher EURs [117] than the older vertical wells. In 2011, the USGS released an updated assessment for the Marcellus resource, with a mean estimate of 84 trillion cubic feet of undiscovered TRR (ranging from 43 trillion cubic feet to 144 trillion cubic feet) [118]. For its 2011 assessment, the USGS evaluated well production data from Pennsylvania and West Virginia that were available in early 2011 and determined that the data were “not sufficient for the construction of individual well Estimated Ultimate Recovery distributions” [119]. Instead, the USGS chose analogs from other U.S. shale gas plays to determine the EUR distributions for its three Marcellus assessment units—Foldbelt, Interior, and Western Margin (Figure 57).

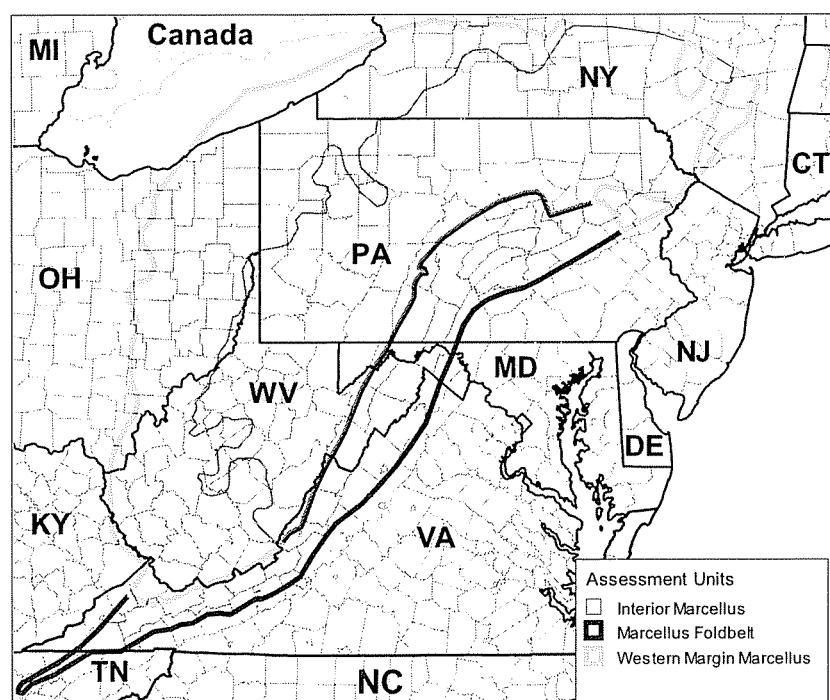
Estimates of the TRR for U.S. shale gas are updated each year for the AEO. For AEO2011, an independent consultant was hired to estimate the Marcellus TRR as the available USGS TRR estimate issued in 2003 was clearly too low, since cumulative production from the Marcellus shale was on a path to exceed it within a year or two. For AEO2012, EIA adopted the 2011 USGS estimates of the Marcellus assessment areas, well spacing, and percent of area with potential. However, EIA examines available well production data each year to estimate shale EURs for use in the AEO (Table 20).

The revised Marcellus EUR for AEO2012 is close to the EUR used in AEO2011 but nearly 70 percent higher than the EUR used in the 2011 USGS assessment. The Interior Assessment Unit EURs developed by EIA reflects the current practice of horizontal drilling and well production data through June 2011 for Pennsylvania and West Virginia [120]. Because there has been very little, if any, drilling in the Western Margin and Foldbelt Assessment Units, the USGS EURs were used for the States in those areas. The resulting

AEO2012 estimate for the Marcellus TRR is 67 percent lower than the AEO2011 estimate, primarily as a result of increased well spacing (132 acres per well vs. 80 acres per well) and a lower percentage of area with potential (18 percent vs. 34 percent) (Table 21).

The estimation of Marcellus shale gas resources is highly uncertain, given both the short production history of current producing wells and the concentration of most producing wells in two small areas, Northeast Pennsylvania and Southwest Pennsylvania/Northern West Virginia. The Marcellus EURs are expected to change as additional data are released and the methodology for developing EURs is refined. Also, as more wells are drilled over a broader area, and as operators optimize well spacing to account for evolving drilling practices, the assumption for average well spacing may be revised. Although the Marcellus shale resource estimate will be updated for every AEO, revisions will not necessarily have a significant impact on projected natural gas production, consumption, and prices.

Figure 57. United States Geological Survey
Marcellus Assessment Units



Assessment of Factors

Table 20. Marcellus approved technically recoverable resources in AEO2012 (as of January 1, 2010)

Assessment Unit/State	Area (square miles)	Well spacing (wells per square mile)	Percent of area untested	Percent of area with potential	EUR (billion cubic feet per well)				TRR (billion cubic feet)
					High	Mid	Low	Average	
Foldbelt	19,063	4	100	5	0.50	0.18	0.03	0.21	757
Maryland	435	4	100	5	0.50	0.18	0.03	0.21	17
Pennsylvania	7,951	4	100	5	0.50	0.18	0.03	0.21	316
Tennessee	353	4	100	5	0.50	0.18	0.03	0.21	14
Virginia	7,492	4	100	5	0.50	0.18	0.03	0.21	298
West Virginia	2,833	4	100	5	0.50	0.18	0.03	0.21	113
Interior	45,161	4	99	37	6.33	1.41	0.06	1.95	137,677
Maryland	763	4	100	37	2.02	0.30	0.02	0.52	629
New York	10,381	4	100	37	7.80	1.79	0.07	2.43	40,124
Ohio	361	4	99	37	2.02	0.30	0.02	0.52	296
Pennsylvania	23,346	4	98	37	7.80	1.79	0.07	2.43	88,182
Virginia	321	4	100	37	2.02	0.30	0.02	0.52	264
West Virginia	9,989	4	99	37	2.02	0.30	0.02	0.52	8,182
Western	39,844	5	100	7	0.35	0.11	0.03	0.13	2,107
Kentucky	207	5	100	7	0.35	0.11	0.03	0.13	11
New York	7,985	5	100	7	0.35	0.11	0.03	0.13	424
Ohio	13,515	5	100	7	0.35	0.11	0.03	0.13	718
Pennsylvania	6,582	5	100	7	0.35	0.11	0.03	0.13	350
Virginia	653	5	100	7	0.35	0.11	0.03	0.13	35
West Virginia	10,901	5	98	7	0.35	0.11	0.03	0.13	569
Total Marcellus	104,067	5	99	18	5.05	1.13	0.05	1.56	140,541

Table 21. Marcellus approved technically recoverable resources: AEO2011, USGS 2011, and AEO2012

Estimate	Area (square miles)	Well spacing		Percent of area untested	Percent of area with potential	Average EUR (billion cubic feet per well)	TRR (billion cubic feet)
		Acres	Wells per square mile				
AEO2011 (as of 1/1/2009)							
Marcellus	94,893	80	8	99%	34%	1.62	410,374
USGS (2011 assessment)							
Marcellus	104,067	132	4.9	99%	18%	0.93	84,198
Foldbelt	19,063	149	4.3	100%	5%	0.21	765
Interior	45,156	149	4.3	99%	37%	1.15	81,374
Western	39,844	117	5.5	99%	7%	0.13	2,059
AEO2012 (as of 1/1/2010)							
Marcellus	104,067	132	4.9	99%	18%	1.56	140,541
Foldbelt	19,063	149	4.3	100%	5%	0.21	757
Interior	45,161	149	4.3	99%	37%	1.95	137,677
Western	39,844	117	5.5	100%	7%	0.13	2,107

Endnotes for Issues in Focus

Links current as of June 2012

41. Oil shale liquids, derived from heating kerogen, are distinct from shale oil and also from tight oil, which is classified by EIA as crude oil. Oil shale is not expected to be produced in significant quantities in the United States before 2035.
42. U.S. Environmental Protection Agency and National Highway Transportation Safety Administration, "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Proposed Rule," Federal Register, Vol. 76, No. 231 (Washington, DC: December 1, 2011), website www.nhtsa.gov/staticfiles/rulemaking/pdf/cale/2017-25_CAFE_NPRM.pdf.
43. The EISA2007 RFS requirement for increasing volumes of biofuels results in a significant number of FFVs in both the Reference case and the CAFE case.
44. S. Bianco, "Chevy Volt Has Best Month Ever, But Nissan Leaf Still Wins 2011 Plug-in Sales Contest," autobloggreen, website www.autoblog.com/2012/01/02/chevy-volt-has-best-month-ever-but-nissan-leaf-still-wins-2011.
45. Battery electric vehicle charge-depleting mode occurs when the vehicle relies on battery power for operation. Charge-sustaining mode occurs when battery electric power is coupled with power provided by the internal combustion engine. Vehicles can be designed to operate on a blended mode that uses both charge-depleting and charge-sustaining modes while in operation, depending on the drive cycle.
46. Toyota, "Toyota Cars, Trucks, SUVs, and Accessories," website www.toyota.com; Nissan USA, "Nissan Cars, Trucks, Crossovers, & SUVs," website www.nissanusa.com; and Chevrolet, "2012 Cars, SUVs, Trucks, Crossovers & Vans," website www.chevy.com. Note: Miles per gallon equivalent, as listed by automotive manufacturers, is derived by the U.S. Environmental Protection Agency, www.fueleconomy.gov.
47. Toyota, "Toyota Cars, Trucks, SUVs, and Accessories," website www.toyota.com; Nissan USA, "Nissan Cars, Trucks, Crossovers, & SUVs," website www.nissanusa.com; and Chevrolet, "2012 Cars, SUVs, Trucks, Crossovers & Vans," website www.chevy.com. Note: Miles per gallon equivalent, as listed by automotive manufacturers, is derived by the U.S. Environmental Protection Agency, www.fueleconomy.gov.
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51. Indiana University, School of Public and Environmental Affairs, "Plug-in Electric Vehicles: A Practical Plan for Progress," website www.indiana.edu/~sopa2/pubs/14PE_combined.pdf.
52. U.S. Environmental Protection Agency and National Highway Transportation Safety Administration, "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Proposed Rule," Federal Register, Vol. 76, No. 231 (Washington, DC: December 1, 2011), website www.nhtsa.gov/staticfiles/rulemaking/pdf/cale/2017-25_CAFE_NPRM.pdf.
53. For this analysis, heavy-duty vehicles include trucks with a Gross Vehicle Weight Rating of 10,001 pounds and higher, corresponding to Gross Vehicle Weight Rating classes 3 through 8 vehicles.
54. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, "Alternative Fueling Station Database Custom Query" (Washington, DC: June 3, 2010), website www.afdc.energy.gov/afdc/fuels/stations_query.html. Accessed June 30, 2012.
55. National Petroleum News, Market Facts 2011.
56. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Clean Cities Alternative Fuel Price Report* (Washington, DC: April, 2012), website www.afdc.energy.gov/afdc/odfs/afor_apr_12.pdf.
57. The Texas Clean Transportation Triangle is supported by Texas State Senate Bill 20, which provides vehicle rebates and fueling grants. See West, Williams, House Research Organization, "Bill Analysis: SB 20" (Austin, TX: May 21, 2011), website www.hro.house.state.tx.us/pdi/ba82r/sb0020.pdf.
58. The Interstate Clean Transportation Corridor was developed in 1996. The corridor is now partially established with LNG truck refueling infrastructure in California and to Reno, Las Vegas, and Phoenix. See Gladstein, Neandross & Associates, "Interstate Clean Transportation Corridor" (Santa Monica, CA: February 2, 2012), website icct.gladstein.org.

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59. The Pennsylvania Clean Transportation Corridor was proposed in a report, "A Road Map to a Natural Gas Vehicle Future" (Canonsburg, PA: April 5, 2011), sponsored by the Marcellus Shale Coalition, website marcelluscoalition.org/wp-content/uploads/2011/04/MSC_NGV_Study.pdf.
60. The American Recovery and Reinvestment Act has provided more than \$300 million toward cost-sharing projects related to alternative fuels. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, "American Recovery and Reinvestment Act Project Awards" (Washington, DC: September 7, 2011) website www.eere.energy.gov/cleancities/awards.cfm.
61. For a map of U.S. LNG peak shaving, see U.S. Energy Information Administration, "U.S. LNG Peaking Shaving and Import Facilities, 2008" (Washington, DC: December, 2008), website www.eia.gov/pub/oil_gas/natural_gas/analysis_publications/magazines/importshaving_map.html.
62. The LNG Excise Tax Equalization Act of 2012, proposed in the U.S. House of Representatives, would require the tax treatment of LNG and diesel fuel to be equivalent on the basis of heat content. See Civic Impulse, LLC, "H.R. 3832: LNG Excise Tax Equalization Act of 2012" (Washington, DC: May 29, 2012), website legacy.govtrack.us/congress/bill.xpd?bill=H12-3832.
63. Developed from e-mail correspondence with Graham Williams, 4/11/12.
64. U.S. Environmental Protection Agency and National Highway Transportation Safety Administration, "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles," Federal Register Vol. 76, No. 179 (Washington, DC: September 15, 2011), website www.federalregister.gov/articles/2011/09/15/2011-20740/greenhouse-gas-emissions-standards-and-fuel-efficiency-standards-for-medium-and-heavy-duty-engines.
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66. U.S. Environmental Protection Agency and National Highway Transportation Safety Administration, "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles," Federal Register Vol. 76, No. 179 (Washington, DC: September 15, 2011), website www.federalregister.gov/articles/2011/09/15/2011-20740/greenhouse-gas-emissions-standards-and-fuel-efficiency-standards-for-medium-and-heavy-duty-engines#p3.
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68. The liquid fuels production industry includes all participants involved in the production of liquid fuels: producers of feedstocks, petroleum- and nonpetroleum-based refined products and blendstocks, and liquid and non-liquid end-use products.
69. U.S. Environmental Protection Agency, "Mercury and Air Toxics Standards" (Washington, DC: March 27, 2012), website www.epa.gov/mats.
70. U.S. Environmental Protection Agency, "Cross-State Air Pollution Rule (CSAPR)" (May 25, 2012), website www.epa.gov/airtransport.
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72. The AEO2012 Early Release Reference case was prepared before the final MATS rule was issued and, therefore, did not include MATS.
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74. U.S. Energy Information Administration, *Electric Power Annual 2010* (Washington, DC, November 2011), Table 3.10, "Number and Capacity of Existing Fossil-Fuel Steam-Electric Generators with Environmental Equipment, 1991 through 2010," website www.eia.gov/press/annual/html/table3.10.cfm.
75. U.S. Environmental Protection Agency, Office of Enforcement and Compliance Assurance, "The Environmental Protection Agency's Enforcement Response Policy for Use of Clean Air Act Section 113(a) Administrative Orders in Relation to Electric Reliability and the Mercury and Air Toxics Standard" (Washington, DC: December 16, 2011), website www.epa.gov/compliance/resources/policies/civil/enp/mats-erp.pdf.
76. See Appendix F for a map of the EMM regions.
77. The EPA is proposing that new fossil-fuel-fired power plants begin meeting an output-based standard of 1,000 pounds CO₂ per megawatt-hour. See U.S. Environmental Protection Agency, "Carbon Pollution Standard for New Power Plants" (Washington, DC: May 23, 2012), website www.epa.gov/carbonpollutionstandard/actions.html. Existing coal plants without CCS will not be able to meet that standard, and the proposed rule does not apply to plants already under construction. The EPA proposal is not included in AEO2012.

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79. U.S. Energy Information Administration, "Levelized Cost of New Generation Resources in the Annual Energy Outlook 2012" (Washington, DC: March 2012), website www.eia.gov/forecasts/aeo/levelized_cost_of_new_generation.cfm.
80. U.S. Energy Information Administration, "Assumptions to AEO2012" (Washington, DC: June 2012), website www.eia.gov/forecasts/aeo/assumptions.
81. U.S. Government Printing Office, "Energy Policy Act of 2005, Public Law 109-58, Title XVII—Incentives for Innovative Technologies" (Washington, DC: August 8, 2005), website www.gpo.gov/fdsys/pkg/PLAW-109/publ58/html/PLAW-109publ58.htm.
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85. Tennessee Valley Authority, "Integrated Resource Plan" (Knoxville, TN: March 2011), website www.tva.com/enr/irp/irpmain/irp-reports/irp/index.htm.
86. U.S. Nuclear Regulatory Commission, "Status of License Renewal Applications and Industry Activities: Completed Applications" (Washington, DC: May 22, 2012), website www.nrc.gov/reactors/operating/licensing/renewal/applications.html#completed.
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91. Tim Bradner, "Alyeska Invests in New Methods to Extend Pipeline Life," *Alaska Journal of Commerce* (June 1, 2009), website www.alaskajournal.com/Alaska-Journal-of-Commerce/June-2009/Alyeska-invests-in-new-methods-to-extend-pipeline-life/.
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93. Alan Bailey, "TAPS transitioning to a low flow future," *Petroleum News*, Vol. 14, No. 29 (Anchorage, AK: July 19, 2009), website www.petroleumnews.com/content/view/full/5496274.shtml (subscription site).
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95. U.S. Department of the Interior, U.S. Geological Survey, *The Oil and Gas Resource Potential of the Arctic National Wildlife Refuge 1002 Area, Alaska*, Open File Report 98-34 (Washington, DC: May 1998), website pubs.usgs.gov/of/1998/ofr-98-0034/ANWR1002.pdf; U.S. Geological Survey, *Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis*, USGS Fact Sheet FS-028-01 (Washington, DC: April 2001), website pubs.usgs.gov/fs/fs-0028-01/fs-0028-01.pdf; and David W. Houseknecht and Kenneth J. Bird, *Oil and Gas Resources of the Arctic Alaska Petroleum Province*, U.S. Geological Survey Professional Paper 1732-A (Washington, DC: October 31, 2006), website pubs.usgs.gov/pp/pp1732/pp1732a/pp1732a.pdf.
96. In 2004, BP commissioned a study that examined the possibility of building a 20-inch pipeline to Fairbanks and using the Alaska railroad to transport the oil to Valdez, at an estimated cost of about \$3 billion. Source: Alan Bailey, "A TAPS bottom line," *Petroleum News*, Volume 17, Number 3 (Anchorage, AK: January 15, 2012), website www.petroleumnews.com/content/view/full/22501971.shtml.

Issues in dispute:

97. The most common miscible gas EOR technique is to alternate the injection of gas and water, referred to as water-alternating-gas or WAG. Source: Oil and Gas Journal, Special Report: EOR/Heavy Oil Survey: 2010 worldwide EOR survey, Volume 108, Issue 14, published April 19, 2010.
98. Capital expenditures can be split into two categories—maintenance and development—with development expenditures allocated to the development of new fields that have not yet reached peak production.
99. Source for 2011 CP capital expenditures—*Petroleum News*, “Eagle Ford Could Nudge Alaska for COP” (May 8, 2011); source for 2001 CP capital expenditures—*Petroleum News*, “Sunrise or Sunset for ConocoPhillips in Alaska?” (October 27, 2002); source for 2001 and 2011 CP split in capital expenditures—*Petroleum News*, “Johansen: Urgency Lacking on Throughput” (October 16, 2011).
100. These figures were derived from the CP ownership shares of the Colville River, Kuparuk River, and Prudhoe Bay field units and from the oil production reports of the Alaska Department of Natural Resources—Oil and Gas Division.
101. The volume of water produced relative to the volume of oil produced is referred to as the “water cut.”
102. U.S. Geological Survey, *Economics of Undiscovered Oil in Federal Lands on the National Petroleum Reserve—Alaska*, by Emil Attanasi, Open-File Report 03-44 (January 2003), Figures A-2 (Alpine Field) and A-3 (Kuparuk Field).
103. In fact, these decisions would have to be made some time before the 350,000-barrel-per-day threshold is reached so they would be ready for implementation either prior to reaching the threshold or when that threshold is reached.
104. The owners of TAPS and operators of the North Slope fields might not know either at this junction what these future costs might be for both operating TAPS and the North Slope fields as volumes decline; at best they have estimates that might or might not turn out to be true.
105. The assumption that all North Slope exploration activity would cease with the decommissioning of TAPS might not be entirely realistic because some offshore oil fields might be economic to develop using floating production, storage, and offloading facilities (FPSO). This would be especially true in the Chukchi Sea, which has much less of an ice pack problem during the winter than the Beaufort Sea.
106. Maintenance capital expenditures could also decline if the field operators determined that drilling more wells was unprofitable.
107. *Petroleum News*, “Who Produces Crude Oil in Alaska?” Vol. 16, No. 43 (October 23, 2011).
108. ExxonMobil, 2010 Financial & Operating Review, Table entitled: “Oil and Gas Exploration and Production Earnings,” p. 70.
109. See also EIA, “U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves,” November 30, 2010, website www.eia.gov/oil_gas/natural_gas/data_publications/crude_oil_natural_gas_reserves/cr.html.
110. The further delineation of unproved resources into inferred reserves and undiscovered resources is not applicable to continuous resources since the extent of the formation is geologically known. For continuous resources, the USGS undiscovered technically recoverable resources are comparable to the EIA unproved resources. The USGS methodology for assessing continuous petroleum resources is at pubs.usgs.gov/of/2011/1298/downloads/D7547.pdf.
111. “Tight oil” refers to crude oil and condensates produced from low-permeability sandstone, carbonate, and shale formations.
112. See shale gas map at www.eia.gov/oil_gas/natural_gas/shale_gas.pdf for basin locations.
113. Appalachian: pubs.usgs.gov/of/2011/1298/; Arkoma: pubs.usgs.gov/fs/2010/3043/; TX-LA-MS Salt and Western Gulf: pubs.usgs.gov/fs/2011/3020/; Anadarko: pubs.usgs.gov/fs/2011/3003/.
114. A well’s estimated ultimate recovery (EUR) equals the cumulative production of that well over a 30-year productive life, using current technology without consideration of economic or operating conditions.
115. “Sweet spot” is an industry term for those select and limited areas within a shale or tight play where the well EURs are significantly greater than the rest of the play, sometimes as much as ten times greater than the lower production areas within a play.
116. USGS Fact Sheet FS-009-03. pubs.usgs.gov/fs/fs-009-03/FS-009-03-508.pdf.
117. A well’s EUR equals the cumulative production of that well over a 30-year productive life, using current technology without consideration of economic or operating conditions.
118. USGS Fact Sheet 2011-3092, pubs.usgs.gov/fs/2011/3092/pdf/1s2011-3092.pdf.
119. USGS Open-File Report 2011-1298, pubs.usgs.gov/of/2011/1298/OF11-1298.pdf, page 2.
120. Well-level production from Pennsylvania is provided in two time intervals (annual and semi-annual). To estimate production on a comparable basis, well-level production is converted to an average daily rate by dividing gas quantity by gas production days. Because wells drilled before 2008 are vertical wells and do not reflect the technology currently being deployed, only wells drilled after 2007 are considered in the EUR evaluation. Well-level production for wells drilled in West Virginia is provided on a monthly basis.

Market trends

Projections by the U.S. Energy Information Administration (EIA) are not statements of what will happen but of what might happen, given the assumptions and methodologies used for any particular case. The Reference case projection is a business-as-usual estimate, given known technology, as well as market, demographic, and technological trends. Most cases in the *Annual Energy Outlook 2012 (AEO2012)* generally assume that current laws and regulations are maintained throughout the projections. Such projections provide a baseline starting point that can be used to analyze policy initiatives. EIA explores the impacts of alternative assumptions in other cases with different macroeconomic growth rates, world oil prices, rates of technology progress, and policy changes.

While energy markets are complex, energy models are simplified representations of energy production and consumption, regulations, and producer and consumer behavior. Projections are highly dependent on the data, methodologies, model structures, and assumptions used in their development. *Behavioral characteristics are indicative of real-world tendencies rather than representations of specific outcomes.*

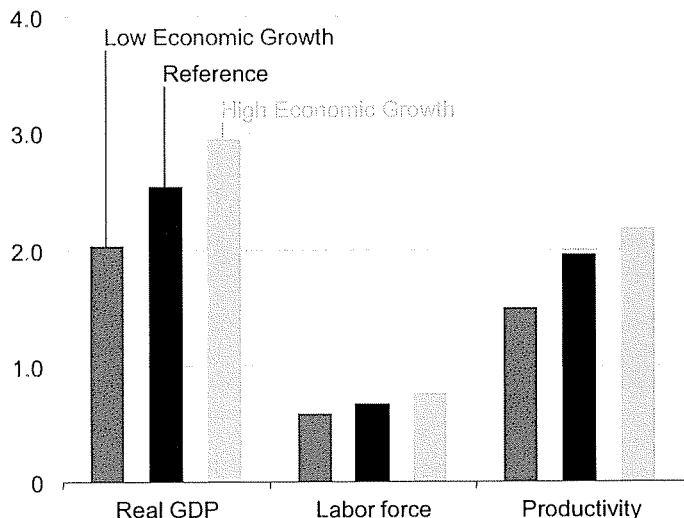
Energy market projections are subject to much uncertainty. Many of the events that shape energy markets are random and cannot be anticipated. In addition, future developments in technologies, demographics, and resources cannot be foreseen with certainty. Many key uncertainties in the *AEO2012* projections are addressed through alternative cases.

EIA has endeavored to make these projections as objective, reliable, and useful as possible; however, they should serve as an adjunct to, not as a substitute for, a complete and focused analysis of public policy initiatives.

Trends in economic activity

Recovery in real gross domestic product growth continues at a modest rate

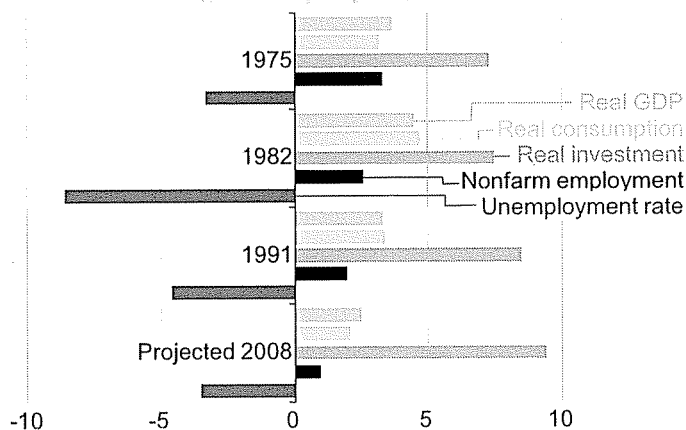
Figure 58. Average annual growth rates of real GDP, labor force, and nonfarm labor productivity in three cases, 2010-2035 (percent per year)



AEO2012 presents three views of U.S. economic growth (Figure 58). In 2011, the world economy experienced shocks that included turmoil in the Middle East and North Africa, a Greek debt crisis with financial impacts spreading to other Eurozone countries, and an earthquake in Japan, all leading to slower economic growth. U.S. growth projections in part reflect those world events.

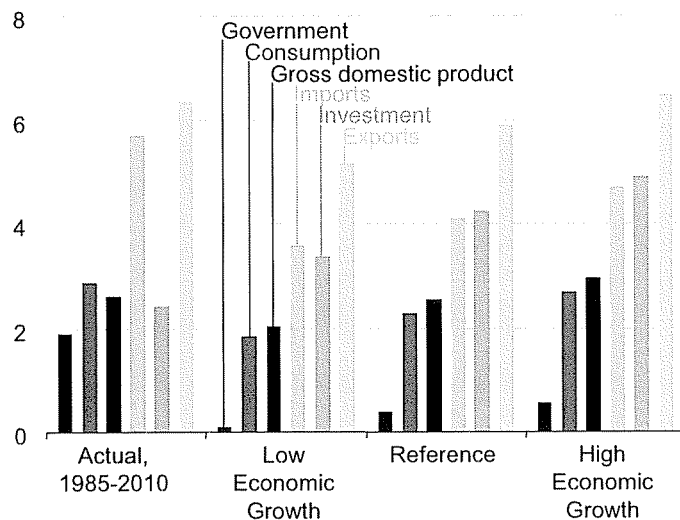
U.S. recovery from the 2007-2008 recession has been slower than past recoveries (Figure 59). A feature of economic recoveries since 1975 has been slowing employment gains, and, following the most recent recession, growth in nonfarm employment has been slower than in any other post-1960 recovery [121]. The average rates of growth are strong starting from the trough of the recessions.

Figure 59. Average annual growth rates over 5 years following troughs of U.S. recessions in 1975, 1982, 1991, and 2008 (percent per year)



Slow consumption growth, fast investment growth, and an ever-improving trade surplus

Figure 60. Average annual growth rates for real output and its major components in three cases, 2010-2035 (percent per year)



AEO2012 presents three economic growth cases: Reference, High, and Low. The High Economic Growth case assumes high growth and low inflation, the Low Economic Growth case assumes low growth and high inflation. Figure 60 compares the average annual growth rates for output and its major components in each of the three cases.

The short-term outlook (5 years) in each case represents current thinking about economic activity in the United States and the rest of the world; about the impacts of domestic fiscal and monetary policies; and about potential risks to economic activity. The long-term outlook projects smooth economic growth, assuming no shocks to the economy.

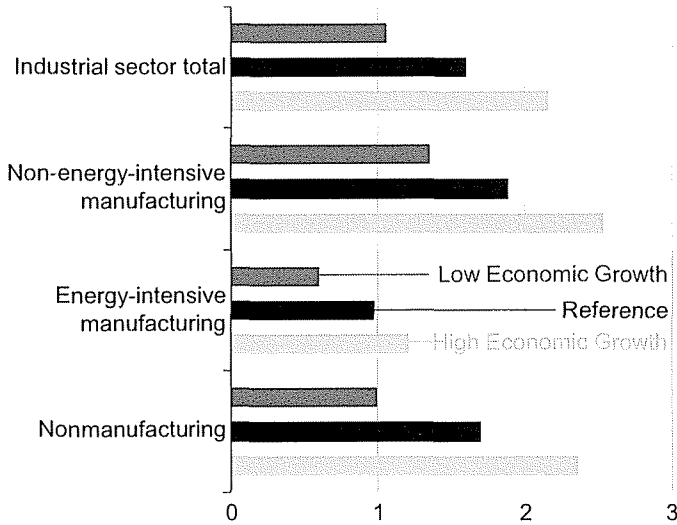
Differences among the Reference case and the High and Low Economic Growth cases reflect different expectations for growth in population (specifically, net immigration), labor force, capital stock, and productivity, which are above trend in the High Economic Growth case and below trend in the Low Economic Growth case. The average annual growth rate for real gross domestic product (GDP) from 2010 to 2035 in the Reference case is 2.5 percent, as compared with about 3.0 percent in the High Economic Growth case and about 2.0 percent in the Low Economic Growth case.

Compared with the 1985-2010 period, investment growth from 2010 to 2035 is faster in all three cases, whereas consumption, government expenditures, and imports grow more slowly in all three cases. Opportunities for trade are assumed to expand in each of the three cases, resulting in real trade surpluses by 2018 that continue through 2035.

Energy trends in the economy

Output growth for energy-intensive industries remains slow

Figure 61. Sectoral composition of industrial output growth rates in three cases, 2010-2035 (percent per year)

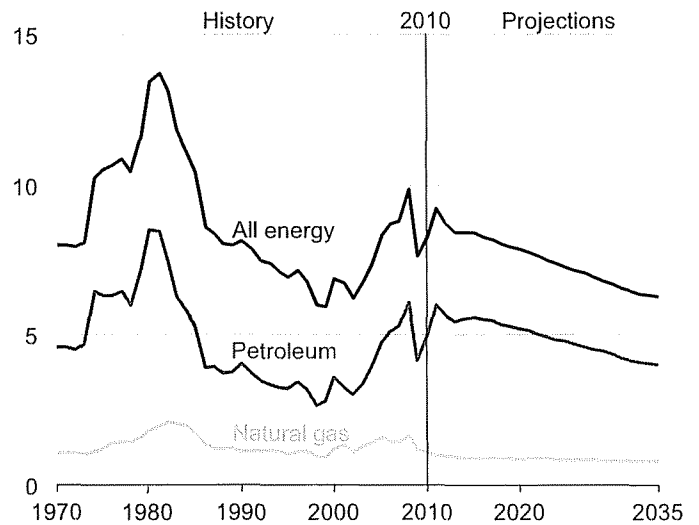


Industrial sector output has grown more slowly than the overall economy in recent decades, with imports meeting a growing share of demand for industrial goods, whereas the service sector has grown more rapidly [122]. In the AEO2012 Reference case, real GDP grows at an average annual rate of 2.5 percent from 2010 to 2035, while both the industrial sector as a whole and its manufacturing component grow by 1.6 percent per year (Figure 61). As the economy recovers from the 2008-2009 recession, growth in U.S. manufacturing output in the Reference case accelerates from 2010 through 2020. After 2020, growth in manufacturing output slows due to increased foreign competition, slower expansion of domestic production capacity, and higher energy prices. These factors weigh heavily on the energy-intensive manufacturing sectors, which taken together grow at a slower rate of about 1.0 percent per year from 2010 to 2035, with variation by industry ranging from 0.8-percent annual growth for bulk chemicals to 1.5-percent annual growth for food processing.

A decline in U.S. dollar exchange rates, combined with modest growth in unit labor costs, stimulates U.S. exports, eventually improving the U.S. current account balance. From 2010 to 2035, real exports of goods and services grow by an average of 5.9 percent per year, and real imports of goods and services grow by an average of 4.1 percent per year. Strong growth in exports is an important component of projected growth in the transportation equipment, electronics, and machinery industries.

Energy expenditures decline relative to gross domestic product and gross output

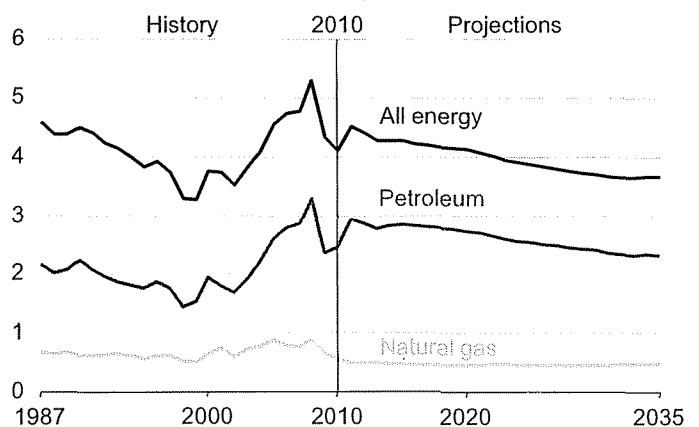
Figure 62. Energy end-use expenditures as a share of gross domestic product, 1970-2035 (nominal expenditures as percent of nominal GDP)



Total U.S. energy expenditures decline relative to GDP in the AEO2012 Reference case (Figure 62) [123]. The projected share of energy expenditures falls from 2011 through 2035, averaging 7.5 percent from 2010 to 2035, which is below the historical average of 8.8 percent from 1970 to 2010.

Gross output corresponds roughly to sales in the U.S. economy. Figure 63 provides an approximation of total energy expenditures relative to total sales. Energy expenditures as a share of gross output show roughly the same pattern as do energy expenditures as a share of GDP. The projected average shares of gross output relative to expenditures for total energy, petroleum, and natural gas are close to their historical averages, at 4.1 percent, 2.1 percent, and 0.5 percent, respectively.

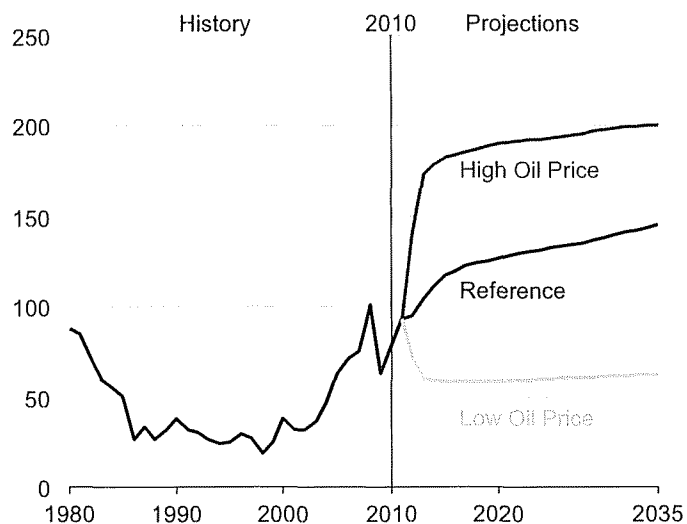
Figure 63. Energy end-use expenditures as a share of gross output, 1987-2035 (nominal expenditures as percent of nominal gross output)



International energy

Oil price cases depict uncertainty in world oil markets

Figure 64. Average annual oil prices in three cases: 1980-2035 (2010 dollars per barrel)



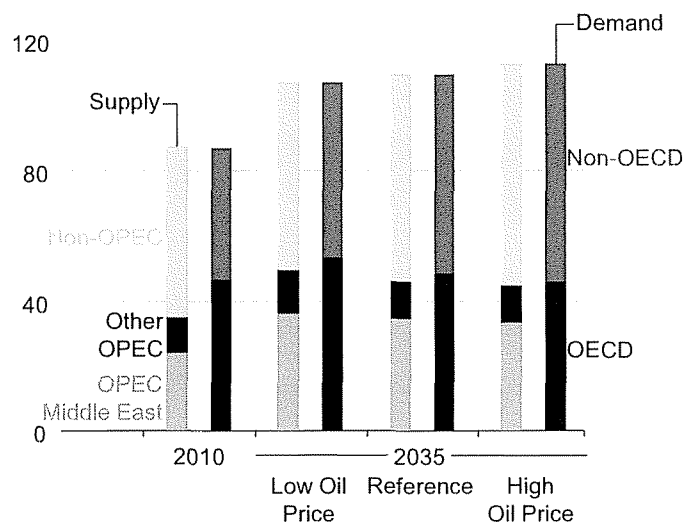
Oil prices in *AEO2012*, defined in terms of the average price of low-sulfur, light crude oil (West Texas Intermediate [WTI]) delivered to Cushing, Oklahoma, span a broad range that reflects the inherent volatility and uncertainty of oil prices (Figure 64). The *AEO2012* price paths are not intended to reflect absolute bounds for future oil prices but rather to provide a basis for analysis of the implications of world oil market conditions that differ from those assumed in the *AEO2012* Reference case. The Reference case assumes that the current price discount for WTI relative to similar “marker” crude oils (such as Brent and Louisiana Light Sweet) will fade when adequate pipeline capacity is built between Cushing and the Gulf of Mexico.

In the Low Oil Price case, GDP growth in countries outside the Organization of the Petroleum Exporting Countries (non-OPEC) is slower than in the Reference case, resulting in lower demand for petroleum and other liquids, and producing countries develop stable fiscal policies and investment regimes that encourage resource development. OPEC nations increase production, achieving approximately a 46-percent market share of total petroleum and other liquids production in 2035.

The High Oil Price case depicts a world oil market in which total GDP growth in countries outside the Organization for Economic Cooperation and Development (non-OECD) is faster than in the Reference case, driving up demand for petroleum and other liquids. Production of crude oil and natural gas liquids (NGL) is restricted by political decisions and limits on access to resources (such as the use of quotas and fiscal regimes) compared with the Reference case. Petroleum and other liquids production in the major producing countries is reduced (for example, the OPEC share averages 40 percent), and the consuming countries turn to more expensive production from other liquids sources to meet demand.

Trends in petroleum and other liquids markets are defined largely by the developing nations

Figure 65. World petroleum and other liquids supply and demand by region in three cases: 2010 and 2035 (million barrels per day)



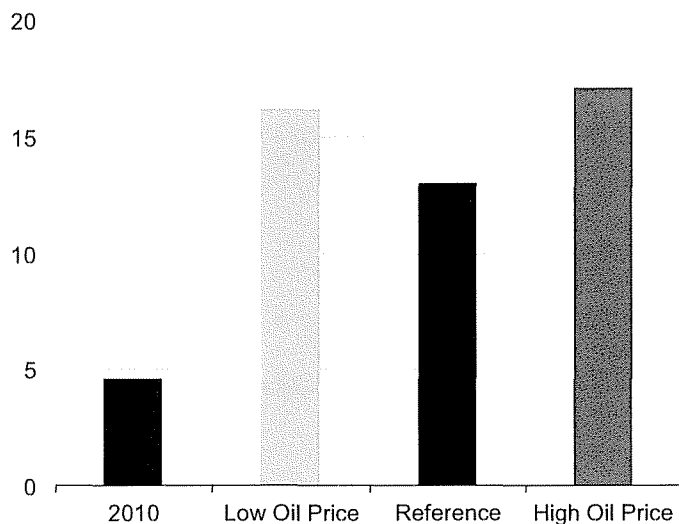
Total use of petroleum and other liquids in the *AEO2012* Reference, High Oil Price, and Low Oil Price cases in 2035 ranges from 107 to 113 million barrels per day (Figure 65). The alternative oil price cases reflect shifts in both supply and demand, with the result that total consumption and production levels do not vary widely. Although demand in the OECD countries is influenced primarily by price, demand in non-OECD regions—where future economic uncertainty is greatest—drives the price projections. That is, non-OECD petroleum and other liquids consumption is lower in the Low Oil Price case and higher in the High Oil Price case than it is in the Reference case.

OECD petroleum and other liquids use grows in the Reference case to 48 million barrels per day in 2035, while non-OECD use grows to 61 million barrels per day. In the Low Oil Price case, OECD petroleum and other liquids use in 2035 is higher than in the Reference case, at 53 million barrels per day, but demand in the slow-growing non-OECD economies in the Low Price case rises to only 54 million barrels per day. In the High Oil Price case the opposite occurs, with OECD consumption falling to 46 million barrels per day in 2035 and fast-growing non-OECD use—driven by higher GDP growth—increasing to 67 million barrels per day in 2035.

The supply response also varies across the price cases. In the Low Oil Price case, OPEC’s ability to constrain market share is weakened, and low prices have a negative impact on non-OPEC crude oil supplies relative to the Reference case. Because non-crude oil technologies achieve much lower costs in the Low Price case, supplies of other liquids are more plentiful than in the Reference case. In the High Oil Price case, OPEC restricts production, non-OPEC resources become more economic, and high prices make other liquids more attractive.

Production from resources other than crude oil and natural gas liquids increases

Figure 66. Total world production of nonpetroleum liquids, bitumen, and extra-heavy oil in three cases, 2010 and 2035 (million barrels per day)



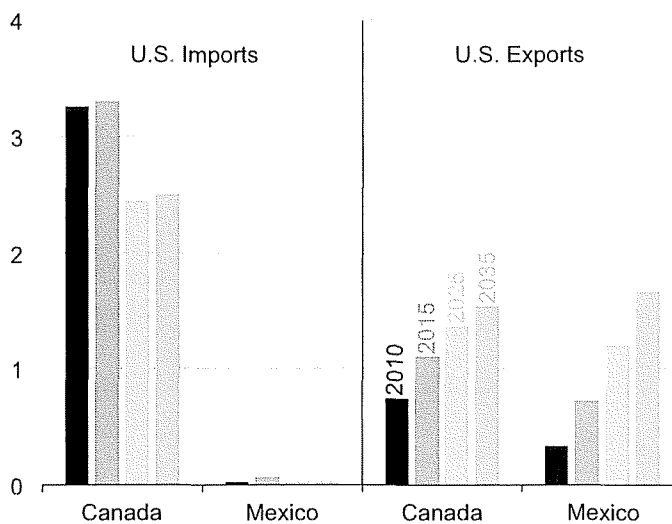
In 2010, world production of liquid fuels from resources other than crude oil and NGL totaled 4.6 million barrels per day, or about 5 percent of all petroleum and other liquids production. Production from those other sources grows to 13.0 million barrels per day (about 12 percent of total global production of petroleum and other liquids) in 2035 in the AEO2012 Reference case, 16.2 million barrels per day (15 percent of the total) in the Low Oil Price case, and 17.1 million barrels per day (15 percent of the total) in the High Oil Price case (Figure 66). The higher levels of production from other resources result from declining technology costs in the Low Oil Price case and from higher oil prices in the High Oil Price case.

Assumptions about the development of other liquids resources differ across the three cases. In the Reference case, increasingly expensive projects become more economically competitive as a result of rising oil prices and advances in production technology. Bitumen in Canada and biofuels in the United States and Brazil are the most important components of production from sources other than crude oil and NGL. Excluding crude oil and NGL, U.S. and Brazilian biofuels and Canadian bitumen account for more than 70 percent of the total world increase in petroleum and other liquids production from 2010 to 2035 in the Reference case.

In the High Oil Price case, rising prices support increased development of nonpetroleum liquids, bitumen, and extra-heavy oil. A smaller increase is projected in the Low Oil Price case, which assumes significant declines in technology costs, particularly for extra-heavy oil production. Bitumen and biofuels continue to be the most important contributors to this supply category through 2035.

U.S. reliance on imported natural gas from Canada declines as exports grow

Figure 67. North American natural gas trade, 2010-2035 (trillion cubic feet)



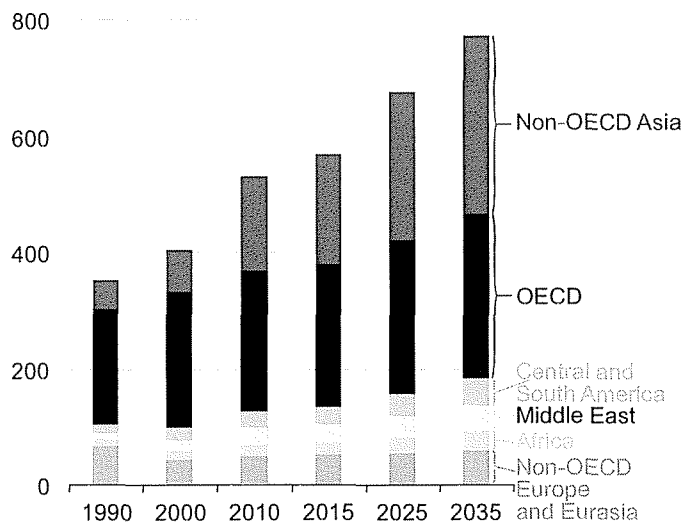
The energy markets of the three North American nations (United States, Canada, and Mexico) are well integrated, with extensive infrastructure that allows cross-border trade between the United States and both Canada and Mexico. The United States, which is by far the region's largest energy consumer, currently relies on Canada and Mexico for supplies of petroleum and other liquid fuels. Canada and Mexico were the largest suppliers of U.S. petroleum and other liquids imports in 2010, providing 2.5 and 1.3 million barrels per day, respectively. In addition, Canada supplies the United States with substantial natural gas supplies, exporting 3.3 trillion cubic feet to U.S. markets in 2010 (Figure 67).

In the AEO2012 Reference case, energy trade between the United States and the two other North American countries continues. In 2035, the United States still imports 3.4 million barrels per day of petroleum and other liquid fuels from Canada in the Reference case, but imports from Mexico fall to 0.8 million barrels per day. With prospects for domestic U.S. natural gas production continuing to improve, the need for imported natural gas declines. U.S. imports of natural gas from Canada fall to 2.4 trillion cubic feet in 2025 in the Reference case and remain relatively flat through the end of the projection. On the other hand, U.S. natural gas exports to both Canada and Mexico increase. Canada's imports of U.S. natural gas grow from 0.7 trillion cubic feet in 2010 to 1.5 trillion cubic feet in 2035, and Mexico's imports grow from 0.3 trillion cubic feet in 2010 to 1.7 trillion cubic feet in 2035 in the AEO2012 Reference case.

International energy

China and India account for half the growth in world energy use

Figure 68. World energy consumption by region, 1990-2035 (quadrillion Btu)



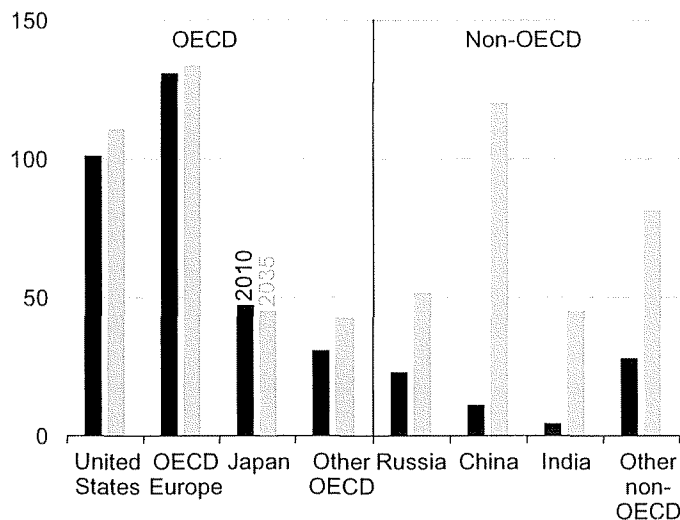
World energy consumption increases by 47 percent from 2010 through 2035 in the AEO2012 Reference case (Figure 68). Most of the growth is projected for emerging economies outside the OECD, where robust economic growth is accompanied by increased demand for energy. Total non-OECD energy use grows by 72 percent, compared with an 18-percent increase in OECD energy use.

Energy consumption in non-OECD Asia, led by China and India, shows the most robust growth among the non-OECD regions, rising by 91 percent from 2010 to 2035. However, strong growth also occurs in much of the rest of the non-OECD regions: 69 percent in Central and South America, 65 percent in Africa, and 62 percent in the Middle East. The slowest growth among the non-OECD regions is projected for non-OECD Europe and Eurasia (including Russia), where substantial gains in energy efficiency are achieved through replacement of inefficient Soviet-era capital equipment.

Worldwide, the use of energy from all sources increases in the projection. Given expectations that oil prices will remain relatively high, petroleum and other liquids are the world's slowest-growing energy sources. High energy prices and concerns about the environmental consequences of greenhouse gas (GHG) emissions lead a number of national governments to provide incentives in support of the development of alternative energy sources, making renewables the world's fastest-growing source of energy in the outlook.

After Fukushima, prospects for nuclear power dim in Japan and Europe but not elsewhere

Figure 69. Installed nuclear capacity in OECD and non-OECD countries, 2010 and 2035 (gigawatts)



The earthquake and tsunami that hit northeastern Japan in March 2011 caused extensive loss of life and infrastructure damage, including severe damage to several reactors at the Fukushima Daiichi nuclear power plant. In the aftermath, governments in several countries that previously had planned to expand nuclear capacity—including Japan, Germany, Switzerland, and Italy—reversed course. Even China announced a temporary suspension of its approval process for new reactors pending a thorough safety review.

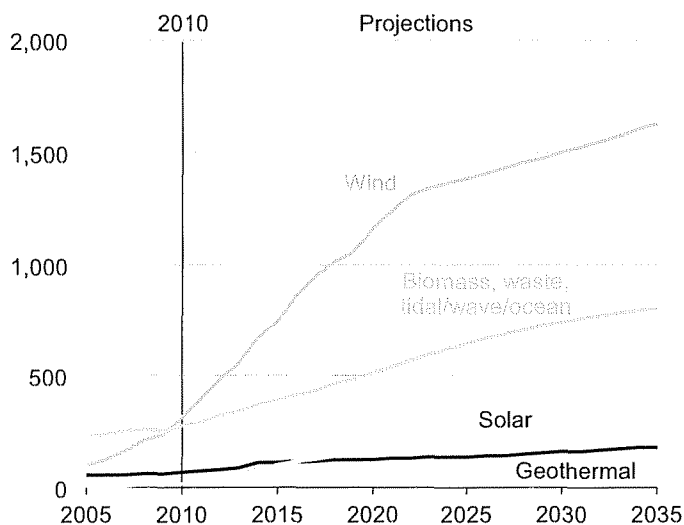
Before the Fukushima event, EIA had projected that all regions of the world with existing nuclear programs would expand their nuclear power capacity. Now, however, Japan's nuclear capacity is expected to contract by about 3 gigawatts from 2010 to 2035 (Figure 69). In OECD Europe, Germany's outlook has been revised to reflect a phaseout of all nuclear power by 2025. As a result, the projected net increase in OECD Europe's nuclear capacity in the AEO2012 Reference case is only 3 gigawatts from 2010 to 2035.

Significant expansion of nuclear power is projected to continue in the non-OECD region as a whole, with total nuclear capacity more than quadrupling. From 2010 to 2035, nuclear power capacity increases by a net 109 gigawatts in China, 41 gigawatts in India, and 28 gigawatts in Russia, as strong growth in demand for electric power and concerns about security of energy supplies and the environmental impacts of fossil fuel use encourage further development of nuclear power in non-OECD countries.

U.S. energy demand

Wind power leads rise in world renewable generation, solar power also grows rapidly

Figure 70. World renewable electricity generation by source, excluding hydropower, 2005-2035 (billion kilowatt-hours)



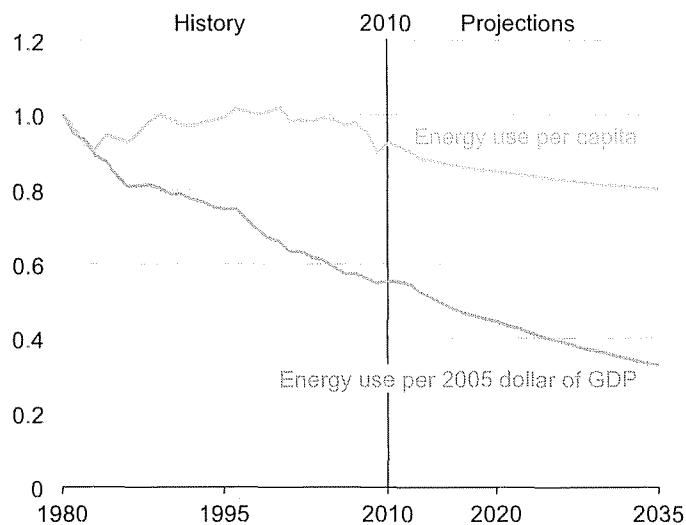
Renewable energy is the world's fastest-growing source of marketed energy in the AEO2012 Reference case, increasing by an average of 3.0 percent per year from 2010 to 2035, compared to an average of 1.6 percent per year for total world energy consumption. In many parts of the world, concerns about the security of energy supplies and the environmental consequences of GHG emissions have spurred government policies that support rapid growth in renewable energy installations.

Hydropower is well-established worldwide, accounting for 83 percent of total renewable electricity generation in 2010. Growth in hydroelectric generation accounts for about one-half of the world increase in renewable generation in the Reference case. In Brazil and the developing nations of Asia, significant builds of mid- and large-scale hydropower plants are expected, and the two regions together account for two-thirds of the total world increase in hydroelectric generation from 2010 to 2035.

Solar power is the fastest-growing source of renewable energy in the outlook, with annual growth averaging 11.7 percent. However, because it currently accounts for only 0.4 percent of total renewable generation, solar remains a minor part of the renewable mix even in 2035, when its share reaches 3 percent. Wind generation accounts for the largest increment in nonhydro-power renewable generation—60 percent of the total increase, as compared with solar's 12 percent (Figure 70). The rate of wind generation slows markedly after 2020 because most government wind goals are achieved and wind must then compete on the basis of economics with fossil fuels. Wind-powered generating capacity has grown swiftly over the past decade, from 18 gigawatts of installed capacity in 2000 to an estimated 179 gigawatts in 2010.

In the United States, average energy use per person declines from 2010 to 2035

Figure 71. Energy use per capita and per dollar of gross domestic product, 1980-2035 (index: 1980 = 1)



Growth in energy use is linked to population growth through increases in housing, commercial floorspace, transportation, and goods and services. These changes affect not only the level of energy use but also the mix of fuels consumed.

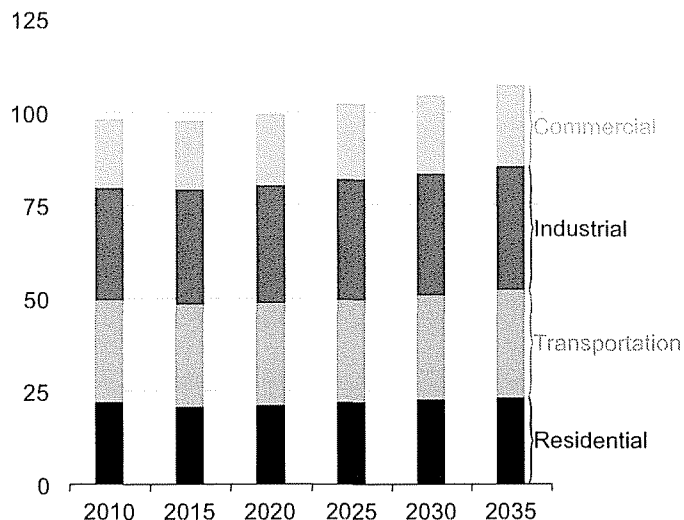
Changes in the structure of the economy and in the efficiency of the equipment deployed throughout the economy also have an impact on energy use per capita. The shift in the industrial sector away from energy-intensive manufacturing toward services is one reason for the projected decline in industrial energy intensity (energy use per dollar of GDP), but its impact on energy consumption per capita is less direct (Figure 71). From 1990 to 2007, the service sectors increased from a 69-percent share of total industrial output to a 75-percent share, but energy use per capita remained fairly constant, between 330 and 350 million British thermal units (Btu) per person, while energy use per dollar of GDP dropped from about 10,500 to 7,700 Btu. Increases in the efficiency of freight vehicles and the shift toward output from the service sectors are projected to continue through 2035, lowering energy use in relation to GDP. Energy use per dollar of GDP is projected to be about 4,400 Btu in 2035, or about one-third of the 1980 level.

Efficiency gains in household appliances and personal vehicles have a direct, downward impact on energy use per capita, as do efficiency gains in the electric power sector, as older, inefficient coal and other fossil steam electricity generating plants are retired in anticipation of lower electricity demand growth, changes in fuel prices, and new environmental regulations. As a result, U.S. energy use per capita declines to 274 million Btu in 2035.

U.S. energy demand

Industrial and commercial sectors lead U.S. growth in primary energy use

Figure 72. Primary energy use by end-use sector, 2010-2035 (quadrillion Btu)



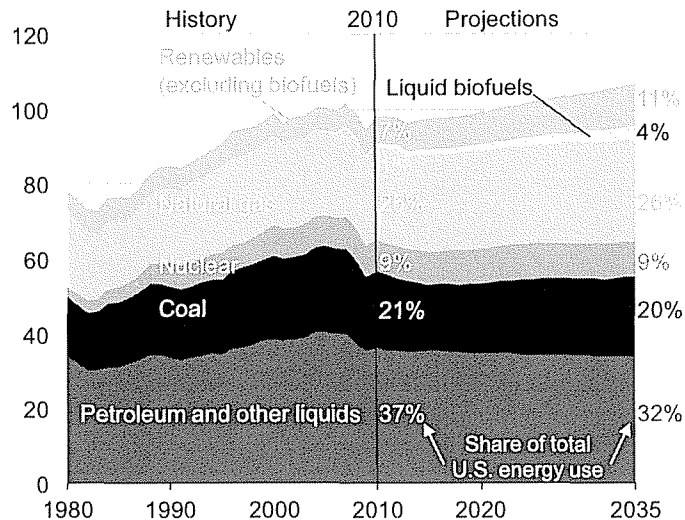
Total primary energy consumption, including fuels used for electricity generation, grows by 0.3 percent per year from 2010 to 2035, to 106.9 quadrillion Btu in 2035 in the AEO2012 Reference case (Figure 72). The largest growth, 3.3 quadrillion Btu from 2010 to 2035, is in the commercial sector, which currently accounts for the smallest share of end-use energy demand. Even as standards for building shells and energy efficiency are being tightened in the commercial sector, the growth rate for commercial energy use, at 0.7 percent per year, is the highest among the end-use sectors, propelled by 1.0 percent average annual growth in commercial floorspace.

The industrial sector, which was more severely affected than the other end-use sectors by the 2008-2009 economic downturn, shows the second-largest increase in total primary energy use, at 3.1 quadrillion Btu from 2008 to 2035. The total increase in industrial energy consumption is 2.1 quadrillion Btu from 2008 to 2035, attributable to increased production of biofuels to meet the Energy Independence and Security Act of 2007 (EISA2007) renewable fuels standard (RFS) as well as increased use of natural gas in some industries, such as food and paper, to generate their own electricity.

Primary energy use in both the residential and transportation sectors grows by 0.2 percent per year, or by just over 1 quadrillion Btu each from 2010 to 2035. In the residential sector, increased efficiency reduces energy use for space heating, lighting, and clothes washers and dryers. In the transportation sector, light-duty vehicle (LDV) energy consumption declines after 2012 to 14.7 quadrillion Btu in 2023 (the lowest point since 1998) before increasing through 2035, when it is still 4 percent below the 2010 level.

Renewable energy sources lead rise in primary energy consumption

Figure 73. Primary energy use by fuel, 1980-2035 (quadrillion Btu)



With the exception of petroleum and other liquids, which falls through 2032 before increasing slightly in the last 3 years of the projection, consumption of all fuels increases in the AEO2012 Reference case. In addition, coal consumption increases at a relatively weak average rate of less than 0.1 percent per year from 2010 to 2035, remaining below 2010 levels until after 2031. As a result, the aggregate fossil fuel share of total energy use falls from 83 percent in 2010 to 77 percent in 2035, while renewable fuel use grows rapidly (Figure 73). The renewable share of total energy use (including biofuels) increases from 8 percent in 2010 to 14 percent in 2035 in response to the Federal RFS, availability of Federal tax credits for renewable electricity generation and capacity, and State renewable portfolio standard (RPS) programs.

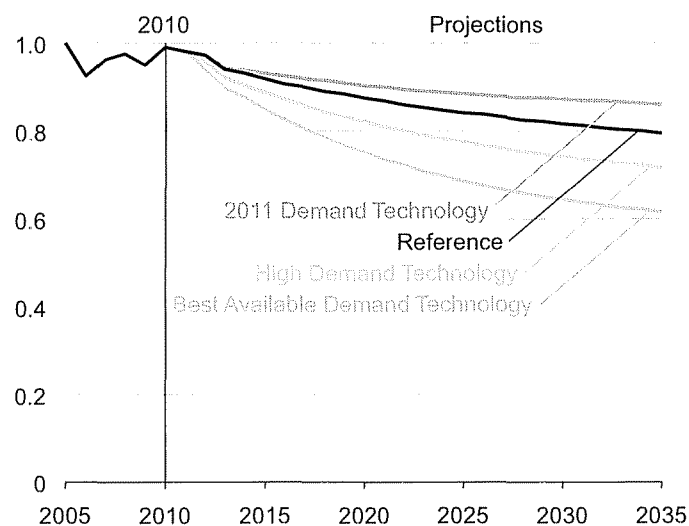
The petroleum and other liquids share of fuel use declines as consumption of other liquids increases. Almost all consumption of liquid biofuels is in the transportation sector. Biofuels, including biodiesel blended into diesel, E85, and ethanol blended into motor gasoline (up to 15 percent), account for 10 percent of all petroleum and other liquids consumption in 2035.

Natural gas consumption grows by about 0.4 percent per year from 2010 to 2035, led by the use of natural gas in electricity generation. Growing production from tight shale keeps natural gas prices below their 2005-2008 levels through 2035.

By the end of 2012, a total of 9.3 gigawatts of coal-fired power plant capacity currently under construction is expected to come online, and another 1.7 gigawatts is added after 2017 in the Reference case, including 0.9 gigawatts with carbon sequestration capability. Additional coal is consumed in the coal-to-liquids (CTL) process to produce heat and power, including electricity generation at CTL plants.

Residential energy use per household declines for a range of technology assumptions

Figure 74. Residential delivered energy intensity in four cases, 2005-2035 (index, 2005 = 1)



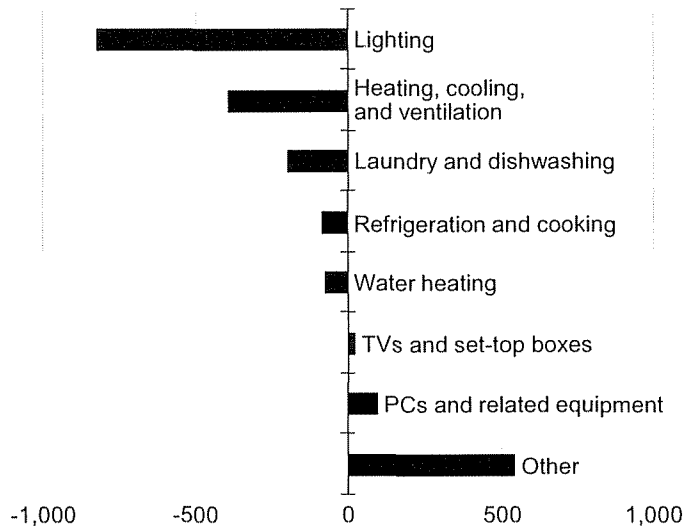
In the AEO2012 Reference case, residential sector energy intensity, defined as average energy use per household per year, declines by 19.8 percent, to 81.9 million Btu per year in 2035 (Figure 74). Total delivered energy use in the residential sector remains relatively constant from 2010 to 2035, but a 27.5-percent growth in the number of households reduces the average energy intensity of each household. Most residential end-use services become less energy-intensive, with space heating accounting for more than one-half of the decrease. Population shifts to warmer and drier climates also contribute to a reduction in demand for space heating.

Three alternative cases show how different technology assumptions affect residential energy intensity. The 2011 Demand Technology case assumes no improvement in efficiency for end-use equipment or building shells beyond those available in 2011. The High Demand Technology case assumes higher efficiency, earlier availability, lower cost, and more frequent energy-efficient purchases for some advanced equipment. The Best Available Demand Technology case limits customers who purchase new and replacement equipment to the most efficient model available in the year of purchase—regardless of cost—and assumes that new homes are constructed to the most energy-efficient specifications.

From 2010 to 2035, household energy intensity declines by 27.7 percent in the High Demand Technology case and by 37.9 percent in the Best Available Demand Technology case. In the 2011 Demand Technology case, household energy intensity also falls as older appliances are replaced with 2011 vintage equipment. Without further gains in efficiency for residential equipment and building shells, the total decline from 2010 to 2035 is only 13.2 percent.

Electricity use increases with number of households despite efficiency improvement

Figure 75. Change in residential electricity consumption for selected end uses in the Reference case, 2010-2035 (kilowatt-hours per household)



Despite a decrease in electricity consumption per household, total delivered electricity use in the residential sector grows at an average rate of 0.7 percent per year in the AEO2012 Reference case, while natural gas use and petroleum and other liquids use fall by 0.2 percent and 1.3 percent per year, respectively, from 2010 to 2035. The increase in efficiency, driven by new standards and improved technology, is not high enough to offset the growth in the number of households and electricity consumption in “other” uses.

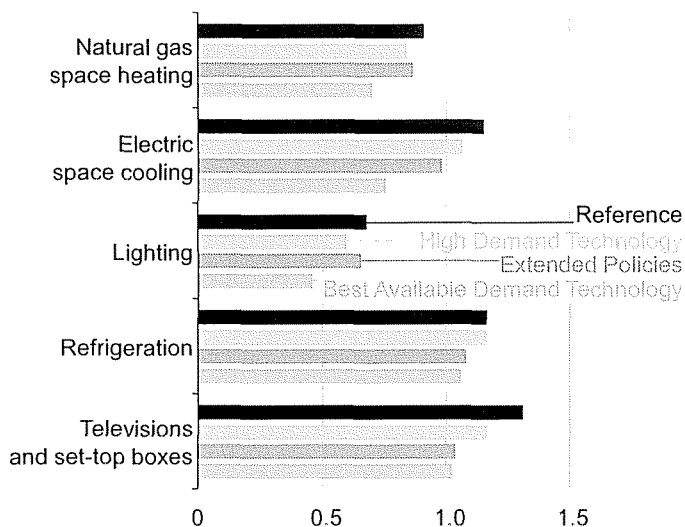
Portions of the Federal lighting standards outlined in EISA2007 went into effect on January 1, 2012. Over the next two years, general-service lamps that provide 310 to 2,600 lumens of light are required to consume about 30 percent less energy than typical incandescent bulbs. High-performance incandescent, compact fluorescent, and light-emitting diode (LED) lamps continue to replace low-efficacy incandescent lamps. In 2035, delivered energy for lighting per household in the Reference case is 827 kilowatt-hours per household lower, or 47 percent below the 2010 level (Figure 75).

Electricity consumption for three groups of electricity end uses increases on a per-household basis in the Reference case. Electricity use for televisions and set-top boxes grows by an average of 1.1 percent per year, accounting for 7.3 percent of total delivered electricity consumption in 2035. Personal computers (PCs) and related equipment account for 4.6 percent of residential electricity consumption in 2035, averaging 1.8-percent annual growth from their 2010 level. Electricity use by other household electrical devices, for which market penetration increases with little coverage by efficiency standards, increases by 1.8 percent annually and accounts for nearly one-fourth of total residential electricity consumption in 2035.

Residential sector energy demand

Residential consumption varies depending on efficiency assumptions

Figure 76. Ratio of residential delivered energy consumption for selected end uses (ratio, 2035 to 2010)



The AEO2012 Reference case and three alternative cases demonstrate opportunities for improved energy efficiency to reduce energy consumption in the residential sector. The Reference, High Demand Technology, and Best Available Demand Technology cases include different levels of efficiency improvement without anticipating the enactment of new appliance standards. The Extended Policies case assumes the enactment of new rounds of standards, generally based on improvements seen in current ENERGY STAR equipment.

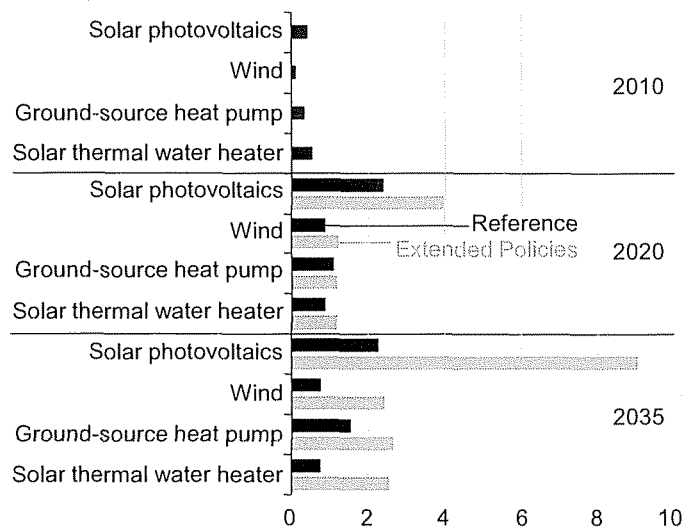
Despite continued growth in the number of households and number of appliances, energy consumption for some end uses is lower in 2035 than in 2010, implying that improved energy efficiency offsets the growth in service demand. In the case of natural gas space heating, population shifts towards warmer and drier climates also reduce consumption; the opposite is true for electric space cooling.

In the Extended Policies case, the enactment of new standards is based on the U.S. Department of Energy's multi-year schedule. For lighting, which already has an EISA2007-based standard that is scheduled to go into effect in 2020, future standards are not assumed until 2026. Among electric end uses, lighting has the largest percentage decline in energy use (more than 50 percent) in the Best Available Demand Technology case from 2010 to 2035 (Figure 76).

Televisions and set-top boxes, which are not currently covered by Federal standards, are assumed to have new standards in 2016 and 2018, respectively, in the Extended Policies case. The enactment of these new standards holds energy use for televisions and set-top boxes at or near their 2010 levels through 2035.

Tax credits could spur growth in renewable energy equipment in the residential sector

Figure 77. Residential market penetration by renewable technologies in two cases: 2010, 2020, and 2035 (percent of households)



Consistent with current law, existing investment tax credits (ITCs) expire at the end of 2016 in the AEO2012 Reference case. The current credits can offset 30 percent of installed costs for a variety of distributed generation (DG) technologies, fostering their adoption. Installations slow dramatically after the ITCs expire, and in several cases their overall market penetration falls because growth in households exceeds the rise in new renewable installations (Figure 77). In the AEO2012 Extended Policies case, the ITCs are extended through 2035, and penetration rates for all renewable technologies continue to rise.

In the Reference case, photovoltaic (PV) and wind capacities grow by average rates of 10.8 percent and 9.2 percent per year, respectively, from 2010 to 2035. In the Extended Policies case, residential PV capacity increases to 54.6 gigawatts in 2035, with annual growth averaging 18.1 percent, and wind capacity grows to 11.0 gigawatts in 2035, averaging 15.9 percent per year.

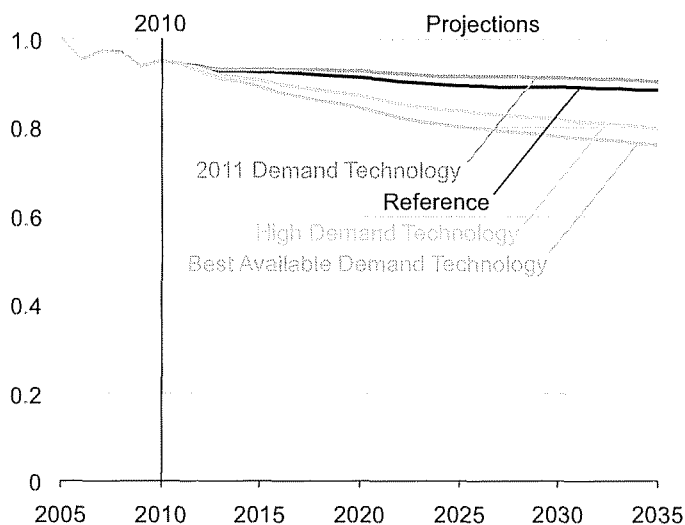
The ITCs also affect the penetration of renewable space-conditioning and water-heating equipment. Ground-source heat pumps reach a 2.6-percent market share in 2035 in the Extended Policies case, after adding nearly 3.5 million units. In the Reference case, without the ITC extension, their market penetration is only 1.5 percent in 2035, with 1.6 million fewer installations than in the Extended Policies case.

Market penetration of solar water heaters in the Extended Policies case is 2.5 percent in 2035, more than triple the Reference case share. In the Reference case, installations increase by 2.5 percent annually from 2010 to 2035, compared with 7.5 percent annually in the Extended Policies case.

Commercial sector energy demand

For commercial buildings, pace of decline in energy intensity depends on technology

Figure 78. Commercial delivered energy intensity in four cases, 2005-2035 (index, 2005 = 1)



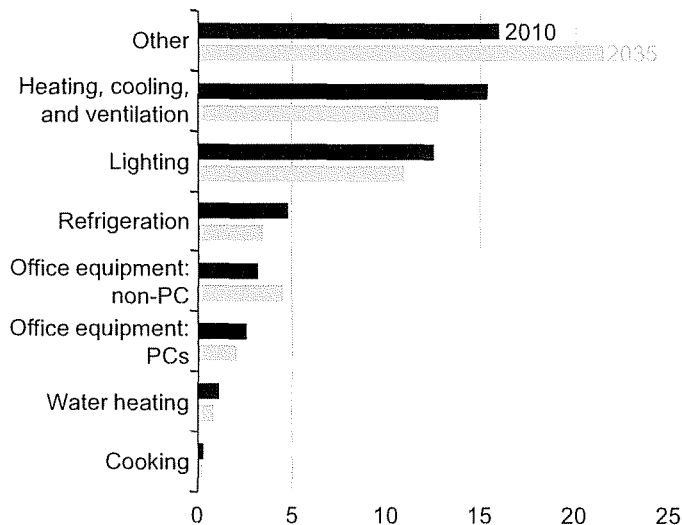
In the AEO2012 Reference case, average delivered energy use per square foot of commercial floorspace declines by 7.0 percent from 2010 to 2035 (Figure 78). Growth in commercial floorspace (26.9 percent) leads to an increase in delivered energy use (18.1 percent), but efficiency improvements in equipment and building shells reduce energy intensity in commercial buildings. Space heating, space cooling, and lighting contribute most to the decrease in intensity, with space heating accounting for significantly more than cooling and lighting combined.

Three alternative cases show the potential impact of energy-efficient technologies on energy intensity in commercial buildings. The 2011 Demand Technology case limits equipment and building shell technologies in later years to the options available in 2011. The High Demand Technology case assumes higher efficiencies for equipment and building shells, lower costs, earlier availability of some advanced equipment, and decisions by commercial customers that place greater importance on future energy savings. The Best Available Technology case assumes more efficient buildings shells for new and existing buildings than in the High Demand Technology case and also requires commercial customers to choose among the most efficient models for each technology when replacing old or purchasing new equipment.

From 2010 to 2035, the intensity of commercial energy use in the 2011 Technology Demand case declines by 5.0 percent, to 101.9 thousand Btu per square foot of commercial floorspace in 2035. In comparison, intensity decreases faster in the High Demand Technology case (16.0 percent) and fastest in the Best Available Demand Technology case (20.0 percent).

Efficiency standards reduce electric energy intensity in commercial buildings

Figure 79. Energy intensity of selected commercial electric end uses, 2010 and 2035 (thousand Btu per square foot)



Electricity, which accounted for 52 percent of total commercial delivered energy use in 2010, increases to 56 percent in 2035 in the AEO2012 Reference case, as commercial floorspace grows at an average annual rate of 1 percent and new electric end uses become more prevalent. Despite such growth, improved efficiency of commercial equipment slows the growth of purchased electricity over the projection period.

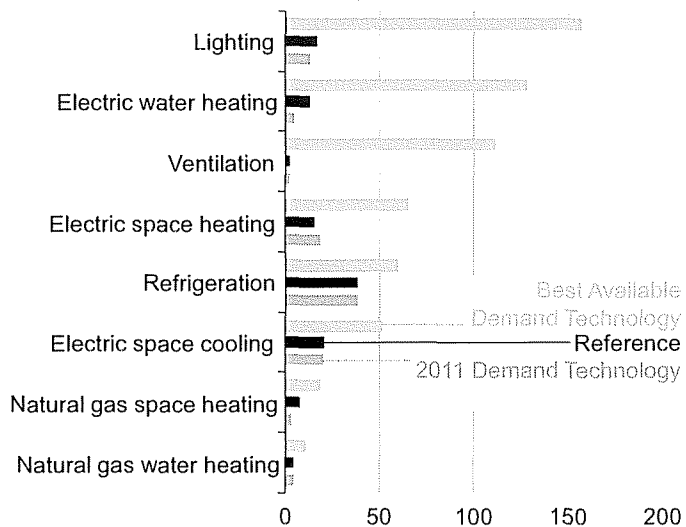
Commercial energy intensity in this figure, defined as the ratio of energy consumption in these appliances to floorspace, decreases for most electric end uses from 2010 to 2035 in the Reference case (Figure 79). Electricity intensity decreases by 1.3 percent annually for both cooking and refrigeration, by 0.5 percent annually for lighting, and by 0.7 percent annually for space conditioning (heating, cooling, and ventilation).

End uses such as space heating and cooling, water heating, refrigeration, and lighting are covered by Federal efficiency standards that act to limit growth in energy consumption to less than the growth in commercial floorspace. "Other" electric end uses, some of which are not subject to standards, account for much of the growth in commercial electricity consumption in the Reference case. Electricity consumption for "other" electrical end uses—including video displays and medical devices—increases by an average of 2.2 percent per year and in 2035 accounts for 38 percent of total commercial electricity consumption. Energy consumption for "other" office equipment—including servers and mainframe computers—increases by 2.3 percent per year from 2010 to 2035, as demand for high-speed networks and internet connectivity continues to grow.

Commercial sector energy demand

Technologies for major energy applications lead efficiency gains in commercial sector

Figure 80. Efficiency gains for selected commercial equipment in three cases, 2035 (percent change from 2010 installed stock efficiency)



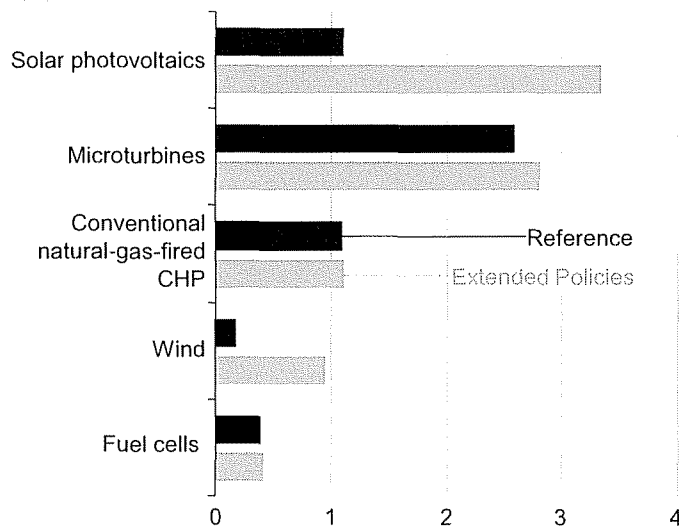
Delivered energy consumption for space heating, ventilation, air conditioning, water heating, lighting, cooking, and refrigeration uses in the commercial sector grows by an average of 0.2 percent per year from 2010 to 2035 in the AEO2012 Reference case, compared with 1.0-percent annual growth in commercial floorspace. The core end uses, which frequently have been the focus of energy efficiency standards, accounted for just over 60 percent of commercial delivered energy demand in 2010. In 2035, their share falls to 53 percent. Energy consumption for all the remaining end uses grows by 1.3 percent per year, led by office equipment other than computers and other electric end uses.

The percentage gains in efficiency in the Reference case are highest for refrigeration, as a result of provisions in the Energy Policy Act of 2005 and EISA2007. Electric space cooling shows the next-largest percentage improvement, followed by lighting and electric space heating (Figure 80).

The Best Available Demand Technology case demonstrates significant potential for further improvement—especially in electric equipment, led by lighting, water heating, and ventilation. In the Best Available Demand Technology case, the share of total commercial delivered energy use in the core end uses falls to 49 percent in 2035, with significant efficiency gains coming from high-efficiency variable air volume ventilation systems, LED lighting, ground-source heat pumps, high-efficiency rooftop heat pumps, centrifugal chillers, and solar water heaters. Those technologies are relatively costly, however, and thus unlikely to gain wide adoption in commercial applications without improved economics. Additional efficiency improvements could also come from an expansion of standards to include some of the rapidly growing miscellaneous electric applications.

Investment tax credits could increase distributed generation in commercial sector

Figure 81. Additions to electricity generation capacity in the commercial sector in two cases, 2010-2035 (gigawatts)



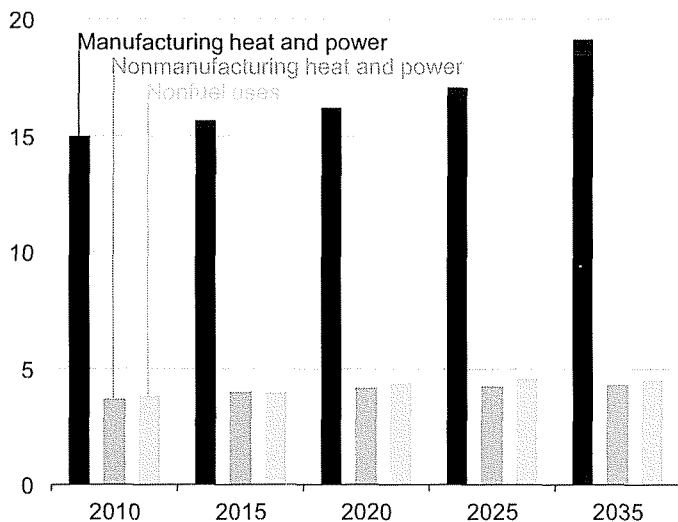
ITCs have a major impact on the growth of renewable DG in the commercial sector. Although most ITCs are set to expire at the end of 2016, the tax credit for solar PV installations reverts from 30 percent to 10 percent and continues indefinitely. Commercial PV capacity increases by 2.7 percent annually from 2010 through 2035 in the AEO2012 Reference Case. Extending the ITCs to all DG technologies through 2035 in the AEO2012 Extended Policies case causes PV capacity to increase at an average annual rate of 5.7 percent (Figure 81).

Growth in small-scale wind capacity more than doubles in the Extended Policies case relative to the Reference case, increasing at an average annual rate of 11.4 percent from 2010 to 2035. Wind accounts for 9.2 percent of the 11.1 gigawatts of total commercial DG capacity in 2035 in the Extended Policies case, and PV accounts for 40.6 percent. In the Extended Policies case, renewable energy accounts for 53 percent of all commercial DG capacity, compared with about 37 percent in the Reference case.

Although ITCs affect the rate of adoption of renewable DG by offsetting a portion of capital costs, their potential effects on nonrenewable DG technologies are offset by rising natural gas prices. In the Reference case, microturbine capacity using natural gas grows by an average of 18.1 percent per year from 42 megawatts in 2010 to 2.6 gigawatts in 2035, and the growth rate in the Extended Policies case is only slightly higher, at 18.4 percent. In the Extended Policies case, the microturbine share of total DG capacity in 2035 is 25.6 percent, as compared with 33.4 percent in the Reference case.

Manufacturing heat and power energy consumption increases modestly

Figure 82. Industrial delivered energy consumption by application, 2010-2035 (quadrillion Btu)



Despite a 49-percent increase in industrial shipments, industrial delivered energy consumption increases by only 15 percent from 2010 to 2035 in the AEO2012 Reference case, reflecting a shift in the share of shipments from energy-intensive manufacturing industries (which include bulk chemicals, petroleum refineries, paper products, iron and steel, food products, aluminum, cement, and glass) to other, less energy-intensive industries, such as plastics, computers, and transportation equipment. Although energy use for most of the energy-intensive industries continues to grow after 2012, with the stronger growth in refining, declines in the energy intensity of heat and power production offset some the growth in their energy use.

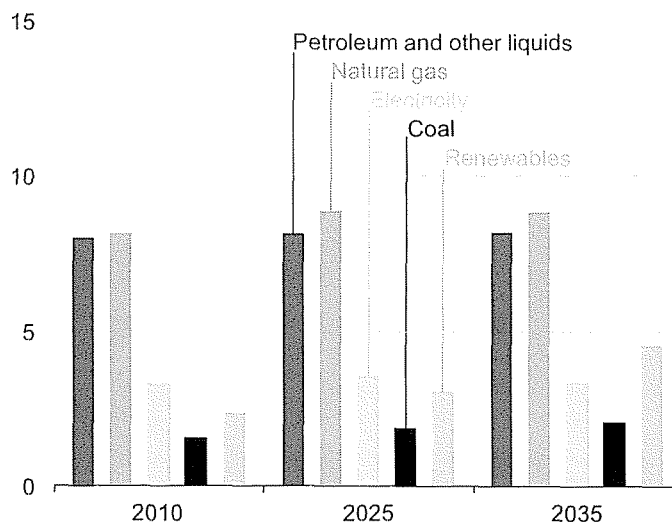
The share of industrial delivered energy consumption used for heat and power in manufacturing increases from 64 percent in 2010 to 71 percent in 2035 (Figure 82). The increase in heat and power energy consumption in manufacturing in the Reference case is primarily a result of a large increase (2 quadrillion Btu) in total energy use in the petroleum refining industry, including production increases for CTL, coal- and biomass-to-liquids (CBTL), and biomass pyrolysis oil production.

Heat and power consumption in the nonmanufacturing industries (agriculture, mining, and construction) is flat in the Reference case projection, accounting for about 16 percent of total industrial energy consumption over the 2010-2035 period. The remaining consumption consists of nonfuel uses of energy—primarily, feedstocks for chemical manufacturing and asphalt for construction. The share of total industrial energy consumption represented by nonfuel use increases by 1.6 percent from 2010 to 2020 as a result of increased shipments of organic chemicals, then declines as competition from foreign producers slows the growth of domestic production.

Industrial sector energy demand

Reliance on natural gas and natural gas liquids rises as industrial energy use grows

Figure 83. Industrial energy consumption by fuel, 2010, 2025 and 2035 (quadrillion Btu)



Led by increasing use of natural gas, total delivered industrial energy consumption grows at an annual rate of 0.6 percent from 2010 through 2035 in the Reference case. The mix of fuels changes slowly, reflecting limited capability for fuel switching with the current capital stock (Figure 83).

Industrial natural gas use grows by 8 percent from 2010 to 2035, reflecting relatively low natural gas prices. As a result, 33 percent of delivered industrial energy consumption is met with natural gas in 2035. The second-largest share is met by petroleum and other liquids (30 percent) and the remainder by renewables, electricity, and coal (37 percent). NGL, an increasingly valuable liquid component of natural gas processing, are consumed as a feedstock in the bulk chemicals industry and also are used for heat in other sectors. Industrial use of all petroleum and other liquids increases slightly from 2010 to 2035, and in 2035 the chemical industries use nearly one-half of the total as feedstock.

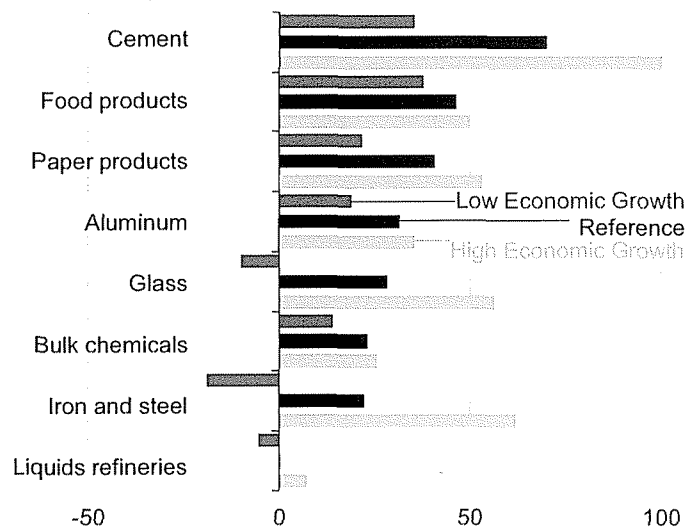
Coal use in the industrial sector for boilers and for smelting in steelmaking declines as more boilers are fired with natural gas and less metallurgical coal is used for steelmaking. After 2016, increased use of coal for CTL and CBTL production fully offsets the decline in the steel industry and boiler fuel use.

A decline in the electricity share of industrial energy consumption reflects modest growth in combined heat and power (CHP), which offsets purchased electricity requirements, as well as efficiency improvements across industries, primarily as a result of rising standards for motor efficiency. With growth in lumber, paper, and other industries that consume biomass-based byproducts, the renewable share of industrial energy use expands.

Industrial sector energy demand

Iron and steel and cement industries are most sensitive to economic growth rate

Figure 84. Cumulative growth in value of shipments from energy-intensive industries in three cases, 2010-2035 (percent)



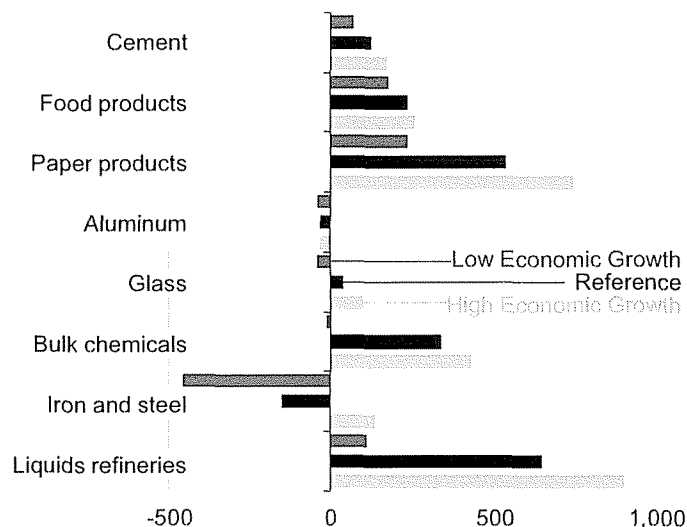
Total shipments from the energy-intensive industries grow by an average of 1 percent per year from 2010 to 2035 in the Reference case, as compared with 0.6 percent in the Low Economic Growth case and 1.2 percent in the High Economic Growth case. The post-recession recovery in shipments is uneven among the industrial subsectors. Paper, bulk chemicals, aluminum, and cement all show strong short-term recoveries from 2010 levels, while shipments from the liquids refinery industry lag. The iron and steel and glass industries show flat to moderate growth in the near term.

Among the energy-intensive industries, the value of shipments in the bulk chemicals, paper, and aluminum take less than 10 years to return to their 2006-2007 pre-recession levels. Others, including cement, iron and steel, and glass, take longer. Shipments from the liquids refinery industry do not reach pre-recession levels by 2035, because demand for transportation fuels is moderated by increasing vehicle efficiencies. Food shipments, which grow in proportion to population and are resistant to recessions, have not shown the same recession-related decline as the other industries. Shipments of bulk chemicals, especially organic chemicals, grow sharply from 2012 to 2025 with the increased use of NGL as feedstock. After 2025, shipments from the bulk chemical industry level off as a result of foreign competition.

The energy-intensive iron and steel and cement industries show the greatest variability in shipments across the three cases (Figure 84), because they supply downstream industries that are sensitive to GDP growth. Construction is a downstream industry for both iron and steel and cement, and the metal-based durables industry is a downstream industry for iron and steel. Shipments in the metal durables industry levels off after 2020, following a decline in iron and steel shipments.

Energy use reflects output and efficiency trends in energy-intensive industries

Figure 85. Change in delivered energy for energy-intensive industries in three cases, 2010-2035 (trillion Btu)



Changes in energy consumption from 2010 to 2035 in the energy-intensive industries ranges from almost nothing in the Low Economic Growth case to 0.8 percent per year or 5 quadrillion Btu in the High Economic Growth case (Figure 85). Changes in energy consumption by the industrial subsector largely reflect the corresponding changes in gross shipments. Energy efficiency improvements and changes in manufacturing methods and requirements, however, also affect energy consumption.

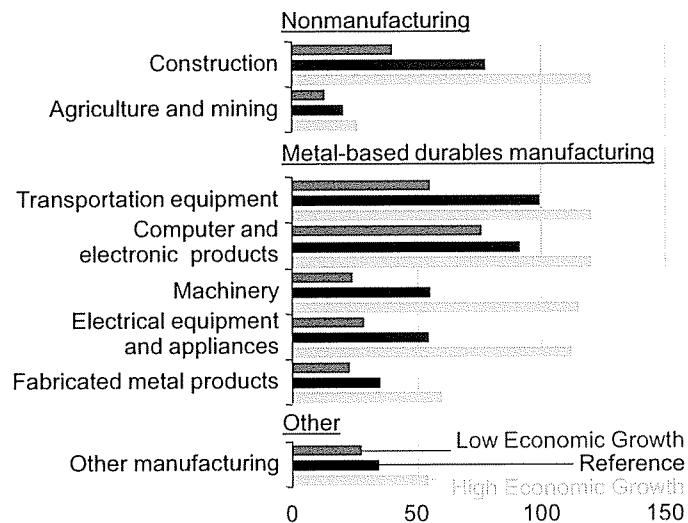
Starting from low levels of economic activity in 2010, shipments from all industries grow over the projection period. For example, steel industry shipments grow by 23 percent in the AEO2012 Reference case from 2010 to 2035, but energy use declines by 12 percent due to a shift from the use of blast furnace steel production to the use of recycled products and electric arc furnaces. The continued decline of primary aluminum production and concurrent rise in less energy-intensive secondary production lead to a similar decline in aluminum industry energy use despite an increase in shipments. The paper industry shows a far less noticeable improvement in energy efficiency because of greater demand for more energy-intensive products such as paperboard by consumers.

The only industrial subsector that shows an increase in energy intensity is refining. In each of the three Economic Growth cases (Reference, Low Growth, and High Growth), the increase in liquids refinery industry energy consumption exceeds the growth in shipments over the projection period as a result of increased use of coal after 2015 for CTL and CBTL production. Production of alternative fuels is inherently more energy-intensive than production of traditional fuels, because they are refined from solids with relatively low energy densities.

Industrial sector energy demand

Transportation equipment shows strongest growth in non-energy-intensive shipments

Figure 86. Cumulative growth in value of shipments from non-energy-intensive industries in three cases, 2010-2035 (percent)



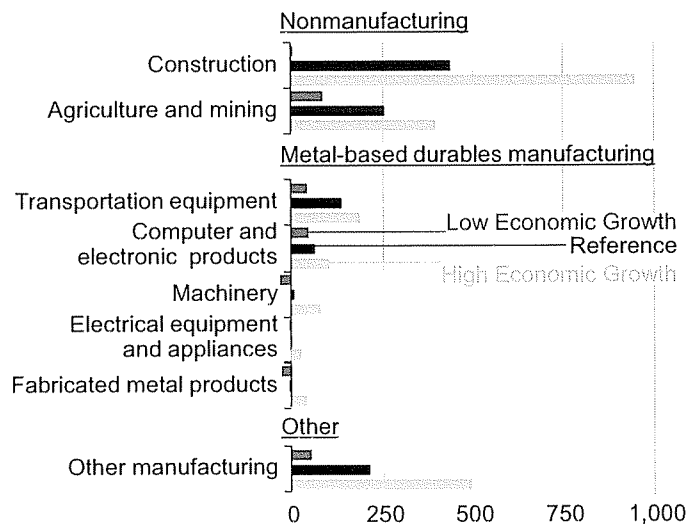
In 2035, non-energy-intensive manufacturing and nonmanufacturing industrial subsectors account for \$6.7 trillion (2005 dollars) in shipments in the Reference case—a 57-percent increase from 2010. From 2010 to 2035, growth in those shipments averages 1.2 percent per year in the Low Economic Growth case and 2.5 percent in the High Economic Growth case, compared with 1.8 percent in the Reference case (Figure 86). Non-energy-intensive manufacturing and nonmanufacturing are segments of the industrial sector that primarily consume fuels for thermal or electrical needs, not as raw materials or feedstocks.

In the three cases, shipments from the two subsectors grow at roughly twice the annual rate projected for energy-intensive manufacturing, based on production of high-tech, high-value goods and strong supply chain linkages between energy-intensive manufacturing and many non-energy-intensive manufacturing industries (such as machinery and transportation equipment produced for the metals industries). Recovery in the two subsectors from 2010 to 2015 is rapid because of increased U.S. competitiveness in the transportation equipment and machinery industries, as well as a recovering construction industry, which saw residential starts bottom out in 2010. After 2015, the growth is more moderate.

In the Reference case, shipments from the non-energy-intensive manufacturing and nonmanufacturing industries generally exceed pre-recession levels by 2017, reflecting a slow and extended economic recovery. Pre-recession shipment levels are exceeded in 2015 and 2024 in the High Economic Growth and Low Economic Growth cases, respectively.

Nonmanufacturing and transportation equipment lead energy efficiency gains

Figure 87. Change in delivered energy for non-energy-intensive industries in three cases, 2010-2035 (trillion Btu)



From 2010 to 2035, total energy consumption in the non-energy-intensive manufacturing and nonmanufacturing industrial subsectors changes by 2 percent or 178 trillion Btu in the Low Economic Growth case, 15 percent or 1,134 trillion Btu in the Reference case, and 30 percent or 2,282 trillion Btu in the High Economic Growth case (Figure 87). In each of the three cases, those industries together account for more than 40 percent of the projected increase in total industrial natural gas consumption.

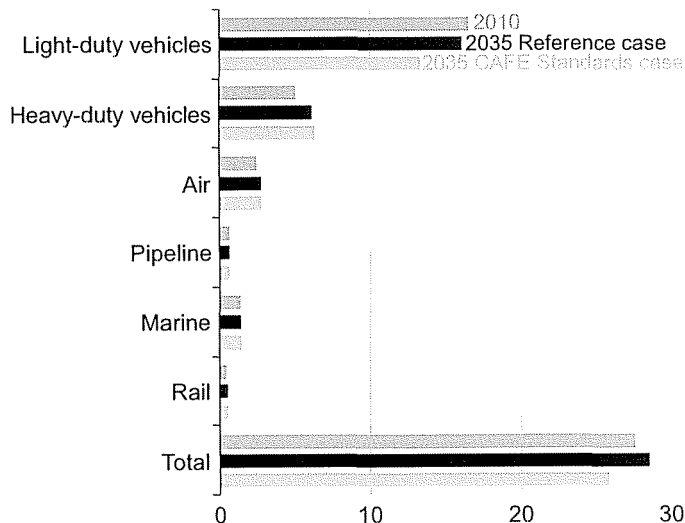
The transportation equipment and construction industries account for roughly 20 percent of the projected increase in energy use but approximately 40 percent of the projected growth in total industrial shipments in all cases. The transportation equipment industry, in particular, shows a rapid decline in energy intensity from 2010 to 2035. Energy consumption increases by 37 percent from 2010 to 2035 and production doubles, yielding an annualized decline in energy intensity of 1.3 percent per year in the transportation equipment industry over the projection period in the AEO2012 Reference case.

Overall, the combined energy intensity of the non-energy-intensive manufacturing and nonmanufacturing industries declines by 25 percent in the Low Economic Growth case and 29 percent in the High Economic Growth case. The more rapid decline in the High Economic Growth case is consistent with an expectation that energy intensity will fall more rapidly when stronger economic growth facilitates additional investment in more energy-efficient equipment.

Transportation sector energy demand

Transportation energy use grows slowly in comparison with historical trend

Figure 88. Delivered energy consumption for transportation by mode in two cases, 2010 and 2035 (quadrillion Btu)



Transportation sector energy consumption grows at an average annual rate of 0.1 percent from 2010 to 2035 (from 27.6 quadrillion Btu to 28.6 quadrillion Btu), much slower than the 1.2-percent average from 1975 to 2010. The slower growth results primarily from improvement in fuel economy for both LDVs and heavy-duty vehicles (HDVs), as well as relatively modest growth in demand for personal travel.

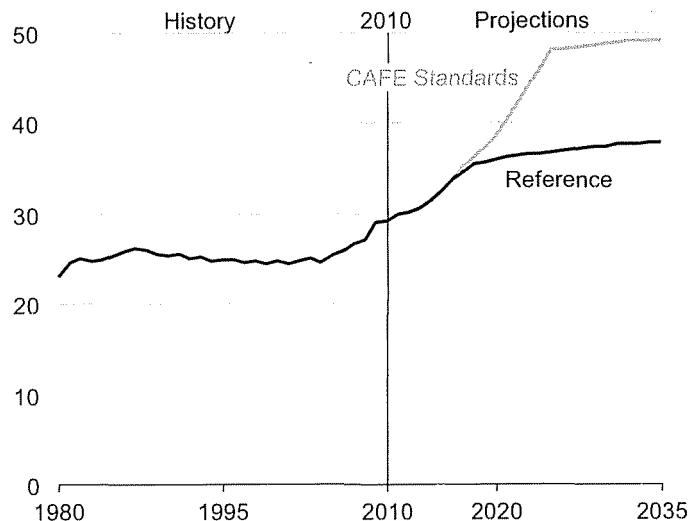
LDV energy demand falls by 3.2 percent (0.5 quadrillion Btu) from 2010 to 2035 (Figure 88). Personal travel demand rises more slowly than in recent history, with the increase more than offset by existing GHG standards for model year (MY) 2012 to 2016 and by EISA2007 fuel economy standards for MY 2017 to 2020. Inclusion of the proposed standards for MY 2017-2025, which are not included in the Reference case, reduce LDV energy demand by 20.0 percent (3.2 quadrillion Btu) from 2010 to 2035.

Energy demand for HDVs (including tractor trailers, buses, vocational vehicles, and heavy-duty pickups and vans) increases by 21 percent, or 1.1 quadrillion Btu, from 2010 to 2035, as a result of increases in vehicle miles traveled (VMT) as economic output recovers. Fuel efficiency and GHG emissions standards temper growth in energy demand even as more miles are traveled overall.

Energy demand for aircraft increases by 11 percent, or 0.3 quadrillion Btu from 2010 to 2035. Higher incomes and moderate growth in fuel costs encourage more personal air travel, the resulting increase in energy use offset by gains in aircraft fuel efficiency. Air freight use of energy grows as a result of export growth. Energy consumption for marine and rail travel also increases, as industrial output grows and more coal is transported. Energy use for pipelines also increases, even though more natural gas production occurs closer to end-use markets.

CAFE and greenhouse gas emissions standards boost vehicle fuel economy

Figure 89. Average fuel economy of new light-duty vehicles in two cases, 1980-2035 (miles per gallon)



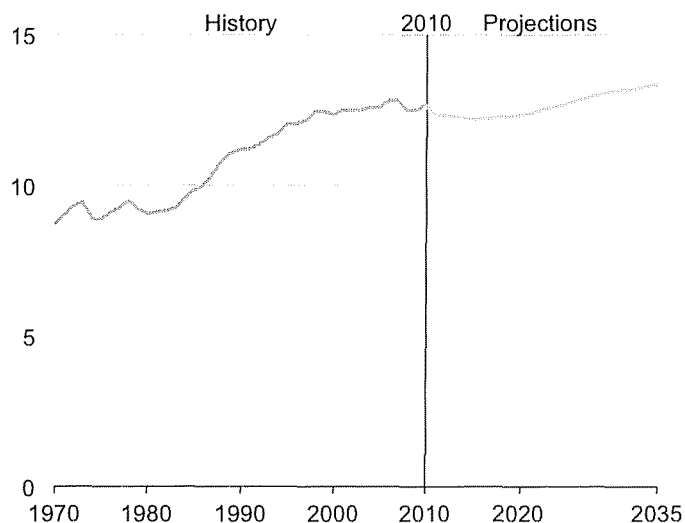
The introduction of Corporate Average Fuel Economy (CAFE) standards for LDVs in 1978 resulted in an increase in fuel economy from 19.9 miles per gallon (mpg) in 1978 to 26.2 mpg in 1987. Over the two decades that followed, despite improvements in LDV technology, fuel economy fell to between 24 and 26 mpg as sales of light-duty trucks increased from 20 percent of new LDV sales in 1980 to almost 55 percent in 2004 [124]. The subsequent rise in fuel prices and reduction in sales of light-duty trucks, coupled with tighter CAFE standards for light-duty trucks starting with MY 2008, led to a rise in LDV fuel economy to 29.2 mpg in 2010.

The National Highway Traffic Safety Administration (NHTSA) introduced attribute-based CAFE standards for MY 2011 LDVs in 2009 and, together with the U.S. Environmental Protection Agency (EPA), in 2010 announced CAFE and GHG emissions standards for MY 2012 to MY 2016. EISA2007 further requires that LDVs achieve an average fuel economy of 35 mpg by MY 2020 [125]. In the AEO2012 Reference case, the fuel economy of new LDVs [126] rises to 30.0 mpg in 2011, 33.8 mpg in 2016, and 35.9 mpg in 2020 (Figure 89). After 2020, CAFE standards remain constant, with LDV fuel economy increasing moderately to 37.9 mpg in 2035 as a result of more widespread adoption of fuel-saving technologies.

In December 2011, NHTSA and EPA proposed more stringent attribute-based CAFE and GHG emissions standards for MYs 2017 to 2025 [127]. The proposal calls for a projected average LDV CAFE of 49.6 mpg by 2025 together with a GHG standard equivalent to 54.5 mpg. With the inclusion of the proposed LDV CAFE standards, LDV fuel economy in the CAFE Standards case increases by nearly 30 percent in 2035 compared to the Reference case.

Travel demand for personal vehicles increases more slowly than in the past

Figure 90. Vehicle miles traveled per licensed driver, 1970-2035 (thousand miles)



Personal vehicle travel demand, measured as VMT per licensed driver, grew at an average annual rate of 1.1 percent from 1970 to 2007, from about 8,700 miles per driver in 1970 to 12,800 miles per driver in 2007. Increased travel was supported by rising incomes, declining costs of driving per mile (determined by fuel economy and fuel price), and demographic changes (such as women entering the workforce). Between 2007 and 2010, VMT per licensed driver declined to around 12,700 miles per driver because of a spike in the cost of driving per mile and the economic downturn. In the AEO2012 Reference case, VMT per licensed driver grows by an average of 0.2 percent per year, to 13,350 miles per driver in 2035 (Figure 90).

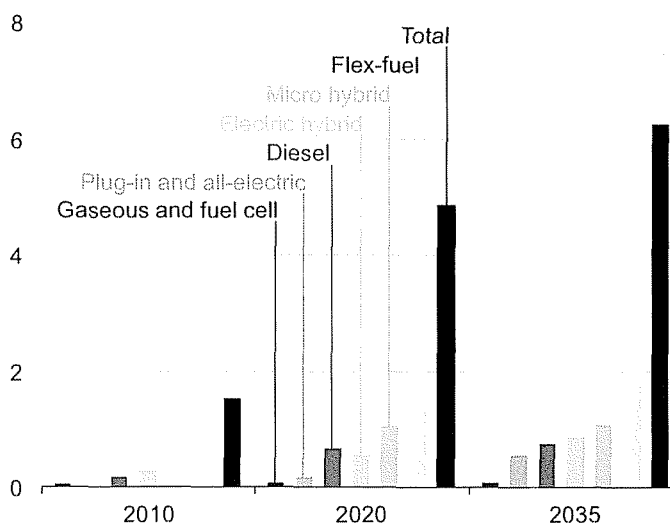
Although the real price of motor gasoline in the transportation sector increases by 48 percent from 2010 to 2035 in the Reference case, VMT per licensed driver still grows as real disposable personal income climbs by 81 percent. Faster growth in income than in fuel prices ensures that travel demand continues to rise by reducing the percentage of income spent on fuel. In addition, the effect of rising fuel costs is moderated by a 30-percent improvement in new vehicle fuel economy following the implementation of more stringent GHG and CAFE standards for LDVs.

Several demographic forces play a role in moderating the growth in VMT per licensed driver despite the rise in real disposable income. Although LDV sales increase through 2035, the number of vehicles per licensed driver remains relatively constant (at just over 1 per licensed driver). Also, unemployment remains above pre-recession levels in the Reference case until later in the projection, further tempering the increase in personal travel demand.

Transportation sector energy demand

Sales of alternative fuel, fuel flexible, and hybrid vehicles rise

Figure 91. Sales of light-duty vehicles using non-gasoline technologies by fuel type, 2010, 2020, and 2035 (million vehicles sold)



LDVs that use diesel, other alternative fuels, hybrid-electric, or all-electric systems play a significant role in meeting more stringent GHG emissions and fuel economy standards, as well as offering fuel savings in the face of higher fuel prices. Sales of such vehicles increase from 14 percent of all new LDV sales in 2010 to 35 percent in 2035 in the AEO2012 Reference case. Sales would be even higher with consideration of the proposed fuel economy standards covering MYs 2017 through 2025 that are not included in the Reference case (see discussion in "Issues in focus").

Flex-fuel vehicles (FFVs), which can use blends of ethanol up to 85 percent, represent the largest share of vehicles, at 17 percent of all new vehicle sales. Manufacturers selling FFVs currently receive incentives in the form of fuel economy credits earned for CAFE compliance through MY 2016. FFVs also play a critical role in meeting the RFS for biofuels.

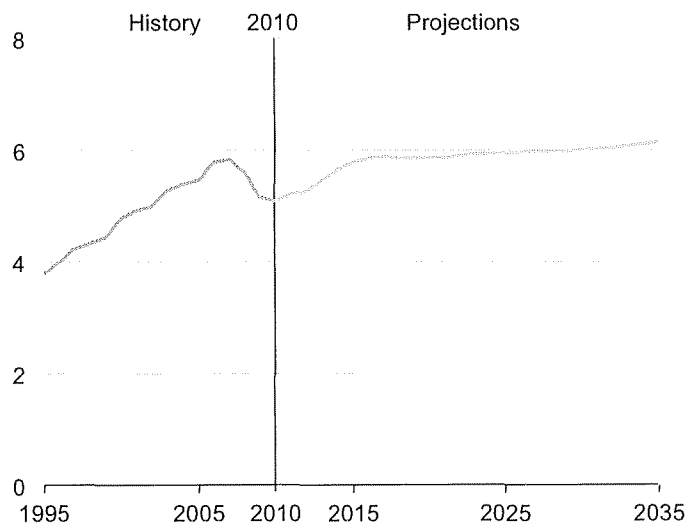
Sales of hybrid electric and all-electric vehicles that use stored electric energy grow considerably in the Reference case (Figure 91). Micro hybrids, which use start/stop technology to manage engine operation while at idle, account for 6 percent of total LDV sales in 2035, which is the largest share for vehicles that use electric storage. Gasoline-electric and diesel-electric hybrid vehicles account for 5 percent of total LDV sales in 2035; and plug-in and all-electric hybrid vehicles account for 3 percent of LDV sales and 9 percent of sales of vehicles using diesel, alternative fuels, hybrid, or all-electric systems.

Sales of diesel vehicles also increase, to 4 percent of total LDV sales in 2035. Light-duty gaseous and fuel cell vehicles account for less than 0.5 percent of new vehicle sales throughout the projection because of the limited availability of a fueling infrastructure and their high incremental cost.

Electricity demand

Heavy-duty vehicle energy demand continues to grow but slows from historical rates

Figure 92. Heavy-duty vehicle energy consumption, 1995-2035 (quadrillion Btu)



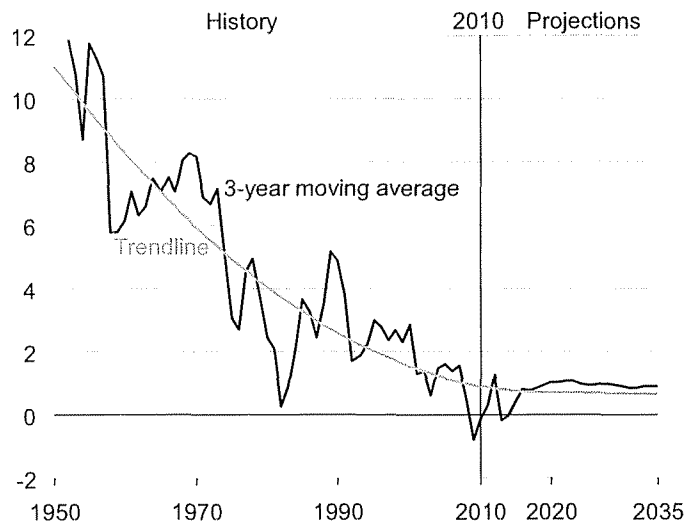
Energy demand for HDVs—including tractor trailers, vocational vehicles, heavy-duty pickups and vans, and buses—increases from 5.1 quadrillion Btu in 2010 to 6.2 quadrillion Btu in 2035, at an average annual growth rate of 0.8 percent, which is the highest among transportation modes. Still, the increase in energy demand for HDVs is lower than the 2-percent annual average from 1995 to 2010, as increases in VMT are offset by improvements in fuel economy following the recent introduction of new standards for HDV fuel efficiency and GHG emissions.

The total number of miles traveled annually by all HDVs grows by 48 percent from 2010 to 2035, from 234 billion miles to 345 billion miles, for an average annual increase of 1.6 percent. The rise in VMT is supported by rising economic output over the projection period and an increase in the number of trucks on the road, from 8.9 million in 2010 to 12.5 million in 2035.

Higher fuel economy for HDVs partially offsets the increase in their VMT, as average new vehicle fuel economy increases from 6.6 mpg in 2010 to 8.2 mpg in 2035. The gain in fuel economy is primarily a consequence of the new GHG emissions and fuel efficiency standards enacted by EPA and NHTSA that begin in MY 2014 and reach the most stringent levels in MY 2018 [128]. Fuel economy continues to improve moderately after 2018, as fuel-saving technologies continue to be adopted for economic reasons (Figure 92)

Residential and commercial sectors dominate electricity demand growth

Figure 93. U.S. electricity demand growth, 1950-2035 (percent, 3-year moving average)



Electricity demand (including retail sales and direct use) growth has slowed in each decade since the 1950s, from a 9.8-percent annual rate of growth from 1949 to 1959 to only 0.7 percent per year in the first decade of the 21st century. In the AEO2012 Reference case, electricity demand growth rebounds somewhat from those low levels but remains relatively slow, as growing demand for electricity services is offset by efficiency gains from new appliance standards and investments in energy-efficient equipment (Figure 93).

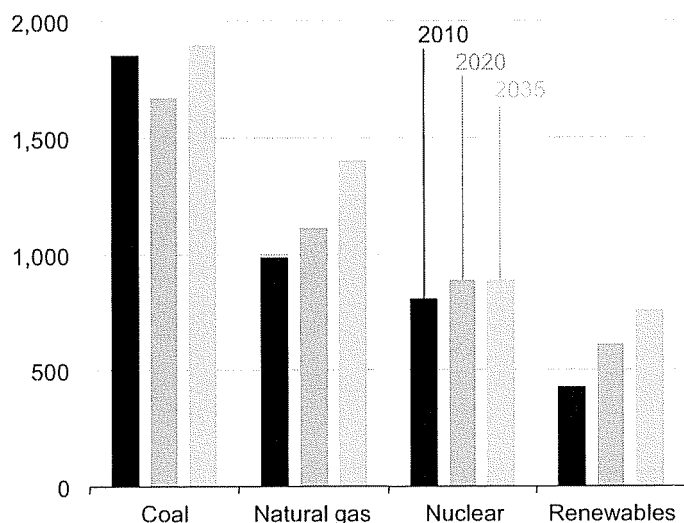
Electricity demand grows by 22 percent in the AEO2012 Reference case, from 3,877 billion kilowatthours in 2010 to 4,716 billion kilowatthours in 2035. Residential demand grows by 18 percent over the same period, to 1,718 billion kilowatthours in 2035, spurred by population growth, rising disposable income, and continued population shifts to warmer regions with greater cooling requirements. Commercial sector electricity demand increases by 28 percent, to 1,699 billion kilowatthours in 2035, led by demand in the service industries. In the industrial sector, electricity demand has been generally declining since 2000, and it grows by only 2 percent from 2010 to 2035, slowed by increased competition from overseas manufacturers and a shift of U.S. manufacturing toward consumer goods that require less energy to produce. Electricity demand in the transportation sector is small, but it is expected to more than triple from 7 billion kilowatthours in 2010 to 22 billion kilowatthours in 2035 as sales of electric plug-in LDVs increase.

Average annual electricity prices (in 2010 dollars) increase by 3 percent from 2010 to 2035 in the Reference case, generally falling through 2020 in response to lower fuel prices used to generate electricity. After 2020, rising fuel costs more than offset lower costs for transmission and distribution.

Electricity generation

Coal-fired plants continue to be the largest source of U.S. electricity generation

Figure 94. Electricity generation by fuel: 2010, 2020, and 2035 (trillion kilowatt-hours)



Coal remains the dominant fuel for electricity generation in the AEO2012 Reference case (Figure 94), but its share declines significantly. In 2010, coal accounted for 45 percent of total U.S. generation; in 2020 and 2035 its projected share of total generation is 39 percent and 38 percent, respectively. Competition from natural gas and renewables is a key factor in the decline. Overall, coal-fired generation in 2035 is 2 percent higher than in 2010 but still 6 percent below the 2007 pre-recession level.

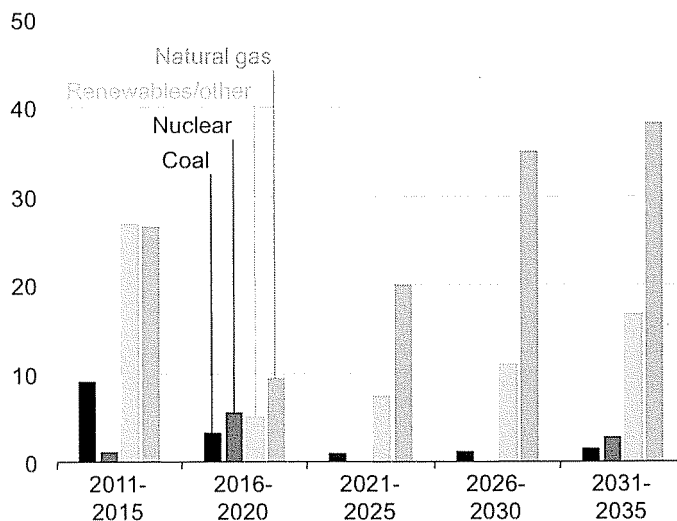
Generation from natural gas grows by 42 percent from 2010 to 2035, and its share of total generation increases from 24 percent in 2010 to 28 percent in 2035. The relatively low cost of natural gas makes the dispatching of existing natural gas plants more competitive with coal plants and, in combination with relatively low capital costs, makes natural gas the primary choice to fuel new generation capacity.

Generation from renewable sources grows by 77 percent in the Reference case, raising its share of total generation from 10 percent in 2010 to 15 percent in 2035. Most of the growth in renewable electricity generation comes from wind and biomass facilities, which benefit from State RPS requirements, Federal tax credits, and, in the case of biomass, the availability of low-cost feedstocks and the RFS.

Generation from U.S. nuclear power plants increases by 10 percent from 2010 to 2035, but the share of total generation declines from 20 percent in 2010 to 18 percent in 2035. Although new nuclear capacity is added by new reactors and uprates of older ones, total generation grows faster and the nuclear share falls. Nuclear capacity grows from 101 gigawatts in 2010 to 111 gigawatts in 2035, with 7.3 gigawatts of additional uprates and 8.5 gigawatts of new capacity between 2010 and 2035. Some older nuclear capacity is retired, which reduces overall nuclear generation.

Most new capacity additions use natural gas and renewables

Figure 95. Electricity generation capacity additions by fuel type, including combined heat and power, 2011-2035 (gigawatts)



Decisions to add capacity, and the choice of fuel for new capacity, depend on a number of factors [129]. With growing electricity demand and the retirement of 88 gigawatts of existing capacity, 235 gigawatts of new generating capacity (including end-use combined heat and power) are projected to be added between 2011 and 2035 (Figure 95).

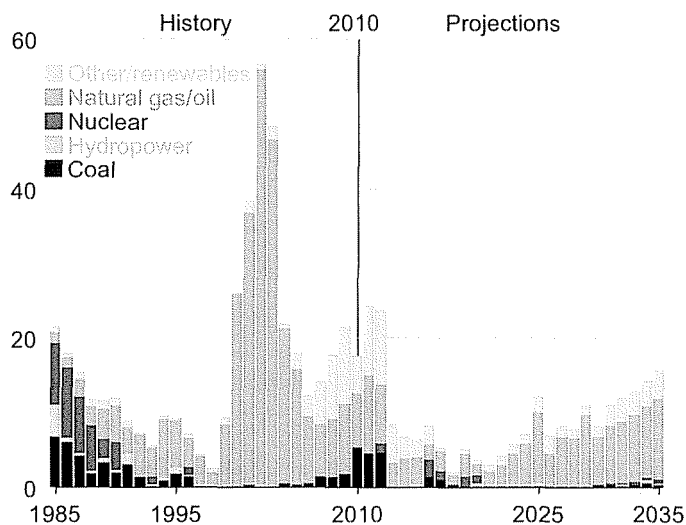
Natural-gas-fired plants account for 60 percent of capacity additions between 2011 and 2035 in the Reference case, compared with 29 percent for renewables, 7 percent for coal, and 4 percent for nuclear. Escalating construction costs have the largest impact on capital-intensive technologies, which include nuclear, coal, and renewables. However, Federal tax incentives, State energy programs, and rising prices for fossil fuels increase the competitiveness of renewable and nuclear capacity. Current Federal and State environmental regulations also affect fossil fuel use, particularly coal. Uncertainty about future limits on GHG emissions and other possible environmental programs also reduces the competitiveness of coal-fired plants (reflected in AEO2012 by adding 3 percentage points to the cost of capital for new coal-fired capacity).

Uncertainty about demand growth and fuel prices also affects capacity planning. Total capacity additions from 2011 to 2035 range from 166 gigawatts in the Low Economic Growth case to 305 gigawatts in the High Economic Growth case. In the AEO2012 Low Tight Oil and Shale Gas Resource case, natural gas prices are higher than in the Reference case and new natural gas fired capacity from 2011 to 2035 accounts for 102 gigawatts, which represents 47 percent of total additions. In the High Tight Oil and Shale Gas Resource case, delivered natural gas prices are lower than in the Reference case and natural gas-fired capacity additions by 2035 are 155 gigawatts, or 66 percent of total new capacity.

Electricity sales

Additions to power plant capacity slow after 2012 but accelerate beyond 2020

Figure 96. Additions to electricity generating capacity, 1985-2035 (gigawatts)



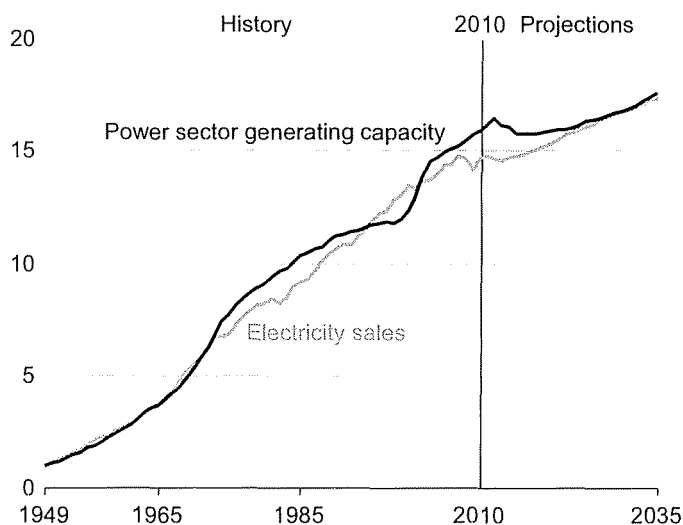
Typically, investments in electricity generation capacity have gone through “boom and bust” cycles. Periods of slower growth have been followed by strong growth in response to changing expectations for future electricity demand and fuel prices, as well as changes in the industry, such as restructuring (Figure 96). A construction boom in the early 2000s saw capacity additions averaging 35 gigawatts a year from 2000 to 2005, much higher than had been seen before. Since then, average annual builds have dropped to 17 gigawatts per year from 2006 to 2010.

In the AEO2012 Reference case, capacity additions between 2011 and 2035 total 235 gigawatts, including new plants built not only in the power sector but also by end-use generators. Annual additions in 2011 and 2012 remain relatively high, averaging 24 gigawatts per year [130]. Of those early builds, about 40 percent are renewable plants built to take advantage of Federal tax incentives and to meet State renewable standards.

Annual builds drop significantly after 2012 and remain below 9 gigawatts per year until 2025. During that period, existing capacity is adequate to meet growth in demand in most regions, given the earlier construction boom and relatively slow growth in electricity demand after the economic recession. Between 2025 and 2035, average annual builds increase to 11 gigawatts per year, as excess capacity is depleted and the rate of total capacity growth is more consistent with electricity demand growth. More than 70 percent of the capacity additions from 2025 to 2035 are natural gas fired, given the higher construction costs for other capacity types and uncertainty about the prospects for future limits on GHG emissions.

Growth in generating capacity parallels rising demand for electricity

Figure 97. Electricity sales and power sector generating capacity, 1949-2035 (index, 1949 = 1.0)



Over the long term, growth in electricity generating capacity parallels the growth in end-use demand for electricity. However, unexpected shifts in demand or dramatic changes affecting capacity investment decisions can cause imbalances that can take years to work out.

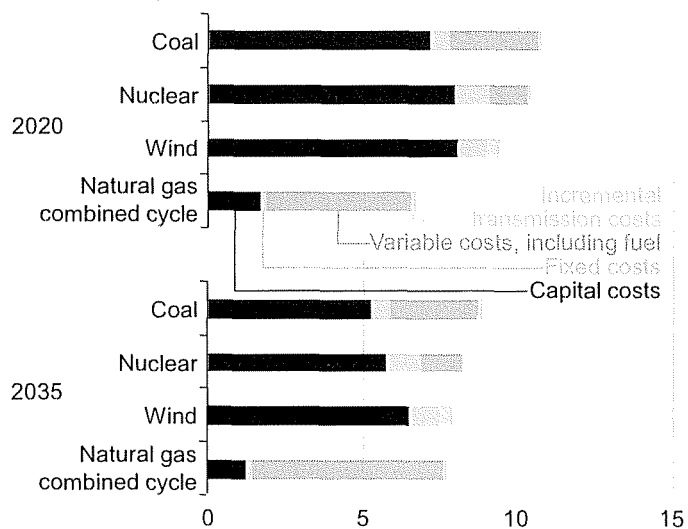
Figure 97 shows indexes summarizing relative changes in total generating capacity and electricity demand. During the 1950s and 1960s, the capacity and demand indexes tracked closely. The energy crises of the 1970s and 1980s, together with other factors, slowed electricity demand growth, and capacity growth outpaced demand for more than 10 years thereafter, as planned units continued to come on line. Demand and capacity did not align again until the mid-1990s. Then, in the late 1990s, uncertainty about deregulation of the electricity industry caused a downturn in capacity expansion, and another period of imbalance followed, with growth in electricity demand exceeding capacity growth.

In 2000, a boom in construction of new natural gas fired plants began, quickly bringing capacity back into balance with demand and, in fact, creating excess capacity. Construction of new intermittent wind capacity that sometimes needs backup capacity also began to grow after 2000. More recently, the 2008-2009 economic recession caused a significant drop in electricity demand, which has recovered only partially in the post-recession period. In combination with slow near-term growth in electricity demand, the slow economic recovery creates excess generating capacity in the AEO2012 Reference case. Capacity currently under construction is completed in the Reference case, but only a limited amount of additional capacity is built before 2025, while older capacity is retired. In 2025, capacity growth and demand growth are in balance again, and they grow at similar rates through 2035.

Electricity capacity

Costs and regulatory uncertainties vary across options for new capacity

Figure 98. Levelized electricity costs for new power plants, excluding subsidies, 2020 and 2035 (2010 cents per kilowatt-hour)



Technology choices for new generating capacity are based largely on capital, operating, and transmission costs. Coal, nuclear, and renewable plants are capital-intensive (Figure 98), whereas operating (fuel) expenditures make up most of the costs for natural gas capacity [137]. Capital costs depend on such factors as equipment costs, interest rates, and cost recovery periods. Fuel costs vary with operating efficiency, fuel price, and transportation costs.

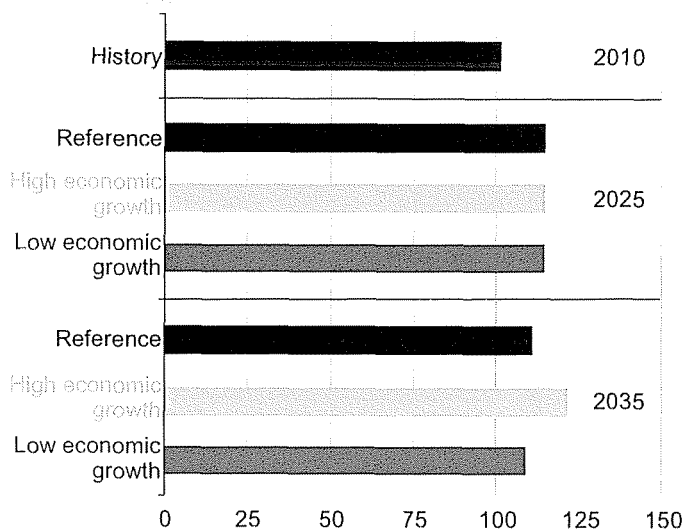
In addition to considerations of levelized costs [132], some technologies and fuels receive subsidies, such as production tax credits and ITCs. Also, new plants must satisfy local and Federal emissions standards and must be compatible with the utility's load profile.

Regulatory uncertainty also affects capacity planning. New coal plants may require carbon control and sequestration equipment, resulting in higher material, labor, and operating costs. Alternatively, coal plants without carbon controls could incur higher costs for siting and permitting. Because nuclear and renewable power plants (including wind plants) do not emit GHGs, their costs are not directly affected by regulatory uncertainty in this area.

Capital costs can decline over time as developers gain technology experience, with the largest rate of decline in new technologies. In the AEO2012 Reference case, the capital costs of new technologies are adjusted upward initially to compensate for the optimism inherent in early estimates of project costs, then decline as project developers gain experience. The decline continues at a progressively slower rate as more units are built. Operating efficiencies also are assumed to improve over time, resulting in reduced variable costs unless increases in fuel costs exceed the savings from efficiency gains.

Nuclear power plant capacity grows slowly through uprates and new builds

Figure 99. Electricity generating capacity at U.S. nuclear power plants in three cases, 2010, 2025, and 2035 (gigawatts)



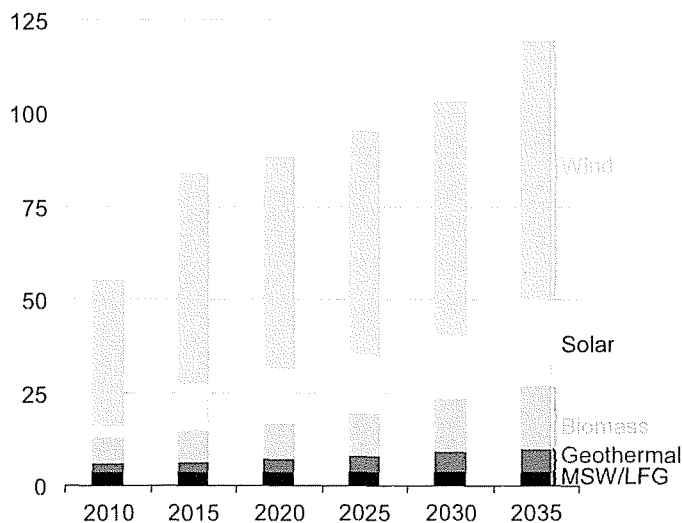
In the AEO2012 Reference case, nuclear power capacity increases from 101.2 gigawatts in 2010 to a high of 114.7 gigawatts in 2025, before declining to 110.9 gigawatts in 2035 (Figure 99), largely as a result of plant retirements. The capacity increase through 2025 includes 7.3 gigawatts of expansion at existing plants and 6.8 gigawatts of new capacity, which includes completion of two conventional reactors at the Watts Bar and Bellefonte sites. Four advanced reactors, reported as under construction, are also assumed to be brought online by 2020 and to be eligible for Federal financial incentives. High construction costs for nuclear plants, especially relative to natural gas fired plants, make additional options for new nuclear capacity uneconomical until the later years of the projection, when an additional 1.8 gigawatts is added. Nuclear capacity additions vary with assumptions about overall demand for electricity. Across the Economic Growth cases, nuclear capacity additions from 2011 to 2035 range from 6.8 gigawatts in the Low Economic Growth case to 19.2 gigawatts in the High Economic Growth case.

One nuclear unit, Oyster Creek, is expected to be retired at the end of 2019, as announced by Exelon in December 2010. An additional 5.5 gigawatts of nuclear capacity is assumed to be retired by 2035. All other existing nuclear units continue to operate through 2035 in the Reference case, which assumes that they will apply for and receive operating license renewals, including in some cases a second 20-year extension after 60 years of operation (for more discussion, see "Issues in focus"). With costs for natural gas fired generation rising in the Reference case and uncertainty about future regulation of GHG emissions, the economics of keeping existing nuclear power plants in operation are favorable.

Renewable capacity

Wind dominates renewable capacity growth, but solar and biomass gain market share

Figure 100. Nonhydropower renewable electricity generation capacity by energy source, including end-use capacity, 2010-2035 (gigawatts)



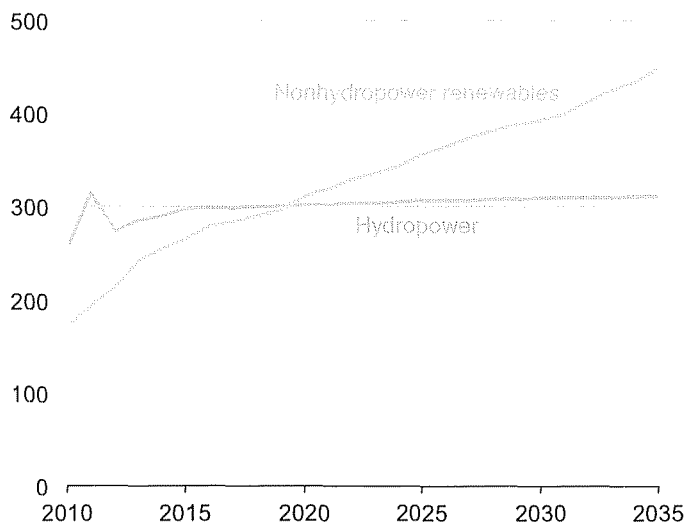
From 2010 to 2035, total nonhydropower renewable generating capacity more than doubles in the AEO2012 Reference case (Figure 100). Wind accounts for the largest share of that new capacity, increasing from 39 gigawatts in 2010 to 70 gigawatts in 2035. Both solar capacity and biomass capacity grow at faster rates than wind capacity, but they start from smaller levels.

Excluding new projects already under construction, PV accounts for nearly all solar capacity additions both in the end-use sectors (where 11 gigawatts of PV capacity is added from 2010 to 2035) and in the electric power sector (8 gigawatts added from 2010 to 2035). While end-use solar capacity grows throughout the projection, the growth of solar capacity in the electric power sector is concentrated primarily in the last decade of the projection period (2025-2035) when the technology becomes more cost-competitive. Geothermal capacity nearly triples over the projection period, but in 2035 it still accounts for only about 5 percent of total nonhydropower renewable generating capacity.

Renewable capacity additions are supported by State RPS programs, the Federal RFS, and Federal tax credits. Total renewable capacity—particularly, wind and solar—grows rapidly in the near term in the AEO2012 Reference case. There is, however, relatively little projected need for new generation capacity of any type, including renewables, for the remainder of the current decade, primarily because there is an abundance of existing natural gas fired capacity that can be operated at higher capacity factors. After 2020 there is a need for new generation capacity in the Reference case, resulting in a resurgence in renewable capacity growth.

Nonhydropower renewable generation surpasses hydropower by 2020

Figure 101. Hydropower and other renewable electricity generation, including end-use generation, 2010-2035 (billion kilowatthours)



In the AEO2012 Reference case, nonhydropower renewable generation grows at an average annual rate of 3.9 percent, nearly tripling from 2010 to 2035. Generation from nonhydropower renewable sources has been small historically in comparison with hydroelectric generation; however, nonhydropower renewable generation surpasses hydroelectric generation in 2020 in the Reference case (Figure 101).

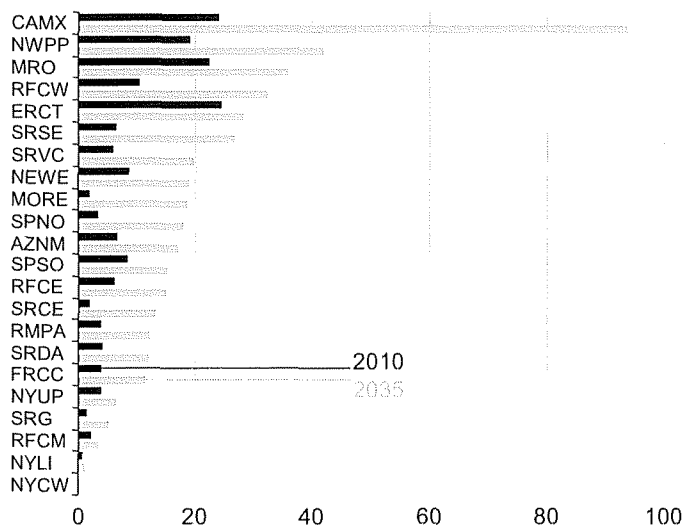
The share of the total electricity generation accounted for by nonhydropower renewable generation increases from about 4 percent in 2010 to 9 percent in 2035. Although wind remains the largest source of nonhydropower renewable generation through 2035, both solar and biomass generation grow at faster annual rates. Solar generation increases by an average of nearly 10 percent per year, and biomass generation increases by 6 percent per year.

Both solar and wind energy are intermittent resources, and as a result their contributions to the generation mix are less than their contribution to the capacity mix. Biomass-fired generation, on the other hand, is dispatchable and grows to levels approaching wind generation by the end of the projection, at 145 billion kilowatthours in 2035, as compared with 194 billion kilowatthours for wind-powered generation. Most of the growth in biomass generation comes from CHP units used in the production of biomass-based liquid fuels, primarily in response to the Federal RFS. Biomass co-firing and end-use generation play an important role in satisfying State RPS mandates, particularly from 2010 to 2020, when overall capacity growth is modest.

Natural gas prices

State renewable portfolio standards increase renewable electricity generation

Figure 102. Regional growth in nonhydroelectric renewable electricity generation, including end-use generation, 2010-2035 (billion kilowatt-hours)



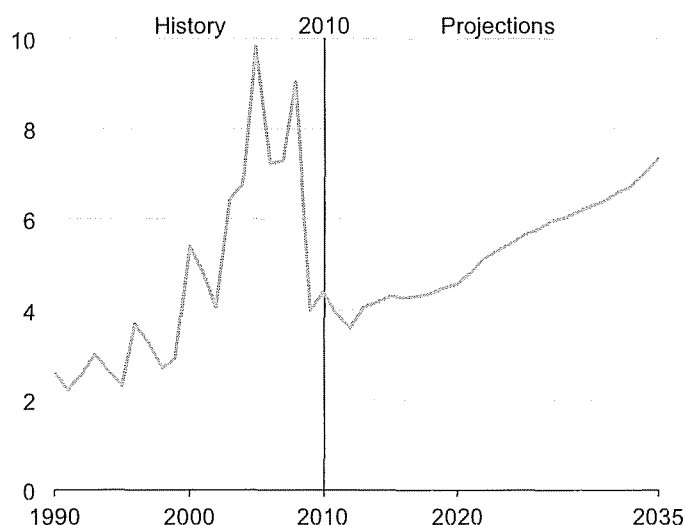
Regional growth in renewable electricity generation is based largely on two factors: availability of renewable energy resources and the existence of State RPS programs that require the use of renewable generation. After a period of robust RPS enactments in several States, the past few years have been relatively quiet in terms of State program expansions, primarily due to the subdued economic climate.

The highest level of nonhydroelectric renewable generation in 2035, 93.9 billion kilowatt-hours, occurs in the WECC California (CAMX) region (Figure 102), whose area approximates the California State boundaries. (For a map of the electricity regions presented, see Appendix F.) The three largest contributors to the total are wind, solar, and geothermal generation. The region encompassing the Pacific Northwest has more overall renewable generation, the vast majority of which comes from hydroelectric sources.

Although the Western and Southwestern States have the most projected solar installations, State RPS programs heavily influence the growth of solar capacity in the eastern States, where both the Reliability First Corporation/East (RFCE) and the Reliability First Corporation/West (RFCW) regions have large amounts of end-use solar generation, with 1.7 billion kilowatt-hours and 1.9 billion kilowatt-hours, respectively. The two regions are not known for a strong solar resource base, and the installations are in response to the ITC as well as solar requirements embedded in State RPS programs. Most biomass capacity—confined largely to the end-use sectors—is built at the sites of cellulosic ethanol plants, many of which are in the Southeast.

Natural gas prices are expected to rise with the marginal cost of production

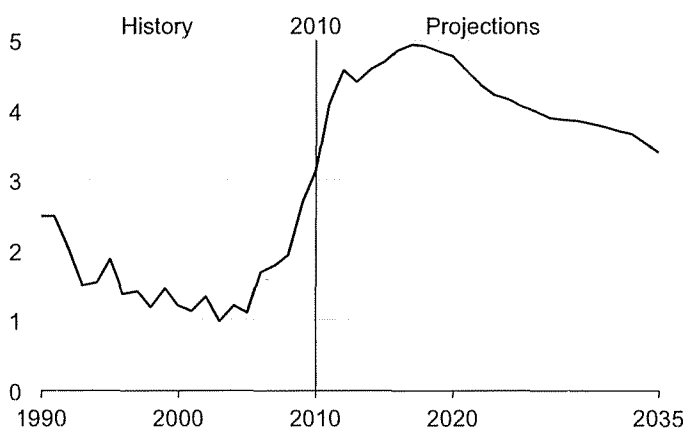
Figure 103. Annual average Henry Hub spot natural gas prices, 1990-2035 (2010 dollars per million Btu)



U.S. natural gas prices are determined largely by supply and demand conditions in North American markets. At current (2012) price levels, natural gas prices are below average replacement cost. However, over time natural gas prices rise with the cost of developing incremental production capacity (Figure 103). After 2017, natural gas prices rise in the AEO2012 Reference case more rapidly than crude oil prices, but oil prices remain at least three times higher than natural gas prices through the end of the projection (Figure 104).

As of January 1, 2010, total proved and unproved natural gas resources are estimated at 2,203 trillion cubic feet. Development costs for natural gas wells are expected to grow slowly. Henry Hub spot prices for natural gas rise by 2.1 percent per year from 2010 through 2035 in the Reference case, to an annual average of \$7.37 per million Btu (2010 dollars) in 2035.

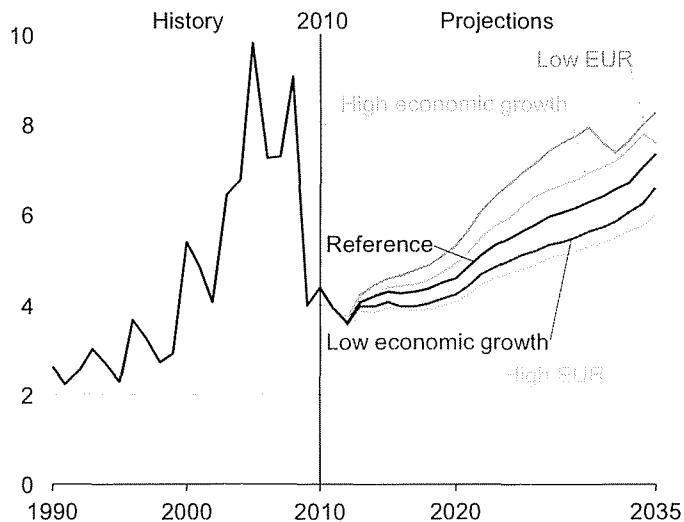
Figure 104. Ratio of low-sulfur light crude oil price to Henry Hub natural gas price on energy equivalent basis, 1990-2035



Natural gas production

Natural gas prices vary with economic growth and shale gas well recovery rates

Figure 105. Annual average Henry Hub spot natural gas prices in dry costs, 1990-2035 (2010 dollars per million Btu)



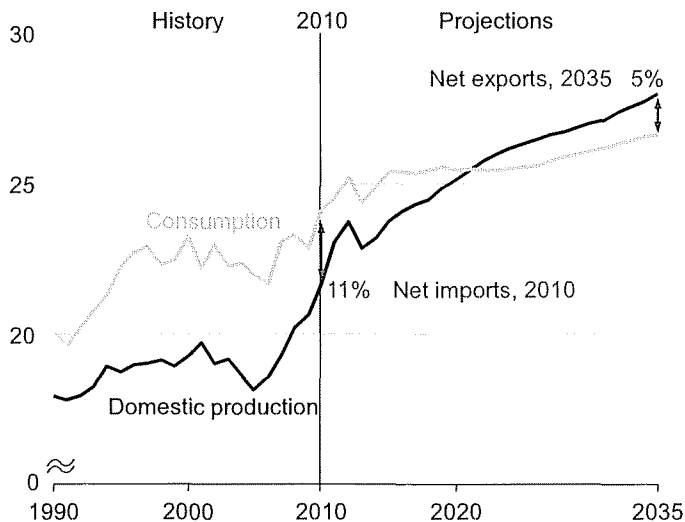
The rate at which natural gas prices change in the future can vary, depending on a number of factors. Two important factors are the future rate of macroeconomic growth and the expected cumulative production of shale gas wells over their lifetimes—the estimated ultimate recovery (EUR) per well. Alternative cases with different assumptions for these factors are shown in Figure 105.

Higher rates of economic growth lead to increased consumption of natural gas, causing more rapid depletion of natural gas resources and a more rapid increase in the cost of developing new incremental natural gas production. Conversely, lower rates of economic growth lead to lower levels of natural gas consumption and, ultimately, a slower increase in the cost of developing new production.

In the High and Low EUR cases, the EUR per shale gas well is increased and decreased by 50 percent, respectively. Future shale gas well recovery rates are an important determinant of future prices. Changes in well recovery rates affect the long-run marginal cost of shale gas production, which in turn affects both natural gas prices and the volumes of new shale gas production developed (further analysis and discussion are included in the “Issues in focus” section of this report). In the Low EUR case, an Alaska gas pipeline starts operating in 2031, accompanied by a dip in natural gas prices. A recent proposal to build a natural gas pipeline along the route of the Alyeska oil pipeline with an LNG export facility could speed up construction. In the High Economic Growth case, the pipeline begins operation in 2035, with a similar effect on prices.

With rising domestic production, the United States become a net exporter of natural gas

Figure 106. Total U.S. natural gas production, consumption, and net imports, 1990-2035 (trillion cubic feet)



The United States consumed more natural gas than it produced in 2010, importing 2.6 trillion cubic feet from other countries. In the AEO2012 Reference case, domestic natural gas production grows more quickly than consumption. As a result, the United States becomes a net exporter of natural gas by around 2022, and in 2035 net exports of natural gas from the United States total about 1.4 trillion cubic feet (Figure 106).

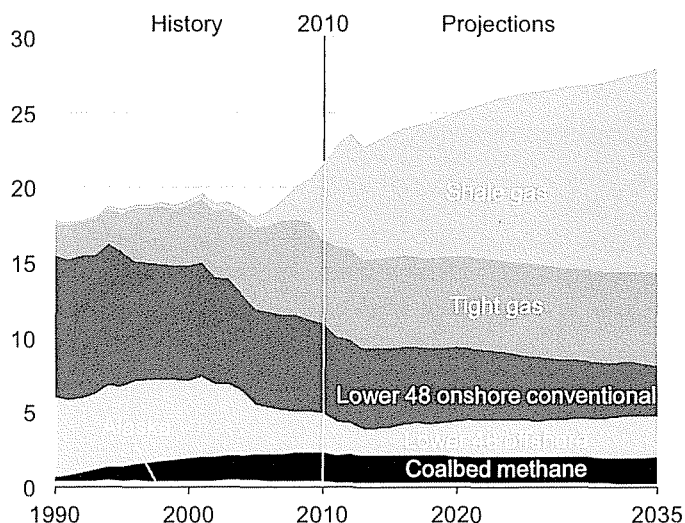
U.S. natural gas consumption grows at a rate of 0.4 percent per year from 2010 to 2035 in the Reference case, or by a total of 2.5 trillion cubic feet, to 26.6 trillion cubic feet in 2035. Growth in domestic natural gas consumption depends on many factors, including the rate of economic growth and the delivered prices of natural gas and other fuels. Natural gas consumption in the commercial and industrial sectors grows by less than 0.5 percent per year through 2035, and consumption for electric power generation grows by 0.8 percent per year. Residential natural gas consumption declines over the same period, by a total of 0.3 trillion cubic feet from 2010 to 2035.

U.S. natural gas production grows by 1.0 percent per year, to 27.9 trillion cubic feet in 2035, more than enough to meet domestic needs for consumption, which allows for exports. The prospects for future U.S. natural gas exports are highly uncertain and depend on many factors that are difficult to anticipate, such as the development of new natural gas production capacity in foreign countries, particularly from deepwater reservoirs, shale gas deposits, and the Arctic.

Natural gas production

Shale gas provides largest source of growth in U.S. natural gas supply

Figure 107. Natural gas production by source, 1990-2035 (trillion cubic feet)



The increase in natural gas production from 2010 to 2035 in the AEO2012 Reference case results primarily from the continued development of shale gas resources (Figure 107). Shale gas is the largest contributor to production growth; there is relatively little change in production levels from tight formations, coalbed methane deposits, and offshore fields.

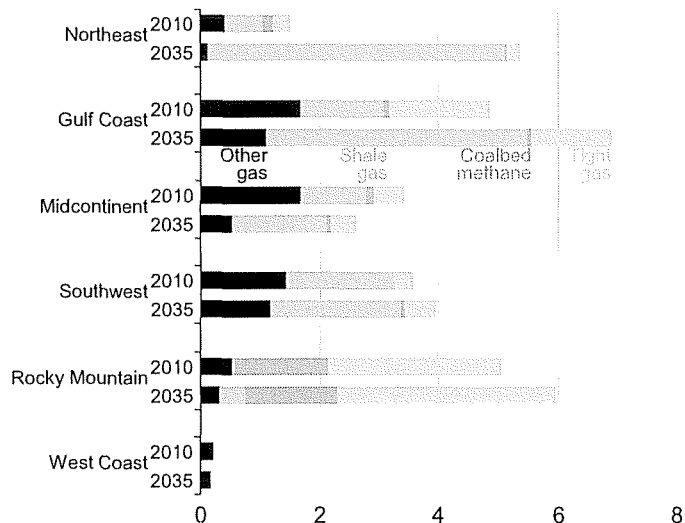
Shale gas accounts for 49 percent of total U.S. natural gas production in 2035, more than double its 23-percent share in 2010. In the Reference case, estimated proved and unproved shale gas resources amount to a combined 542 trillion cubic feet, out of a total U.S. resource of 2,203 trillion cubic feet. Estimates of shale gas resources and well productivity remain uncertain (see "Issues in focus" for discussion).

Tight gas produced from low permeability sandstone and carbonate reservoirs is the second-largest source of domestic supply in the Reference case, averaging 6.1 trillion cubic feet of production per year from 2010 to 2035. Coalbed methane production remains relatively constant throughout the projection, averaging 1.8 trillion cubic feet per year.

Offshore natural gas production declines by 0.8 trillion cubic feet from 2010 through 2014, following the 2010 moratorium on offshore drilling, as exploration and development activities in the Gulf of Mexico focus on oil-directed activity. After 2014 offshore production continues to rise throughout the remainder of the projection period.

In most U.S. regions, natural gas production growth is led by shale gas development

Figure 108. Lower 48 onshore natural gas production by region, 2010 and 2035 (trillion cubic feet)



Shale gas production, which more than doubles from 2010 to 2035, is the largest contributor to the projected growth in total U.S. natural gas production in the Reference case. Regional production growth largely reflects expected increases in production from shale beds. See Figure F4 in Appendix F for a map of U.S. natural gas supply regions.

In the Northeast, natural gas production grows by an average of 5.2 percent per year, or a total of 3.9 trillion cubic feet from 2010 to 2035 (Figure 108). The Marcellus shale, which accounts for 3.0 trillion cubic feet of the expected increase, is particularly attractive for development because of its large resource base, its proximity to major natural gas consumption markets, and the extensive pipeline infrastructure that already exists in the Northeast.

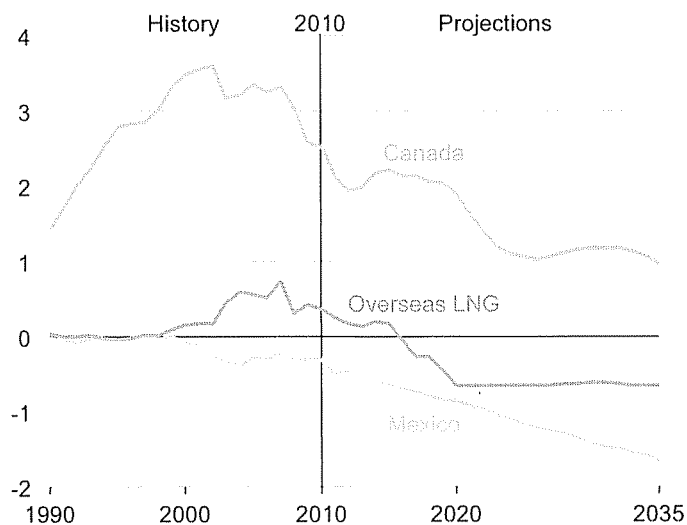
In the Gulf Coast region, natural gas production grows by 2.0 trillion cubic feet from 2010 to 2035, at an average rate of 1.4 percent per year. Natural gas production from the Haynesville/Bossier and Eagle Ford formations increases by 2.8 trillion cubic feet over the period, but declines in production from other natural gas fields in the region offset some of the gains, so that the net increase in production for the region as a whole is only about 2 trillion cubic feet.

In the Rocky Mountain region, natural gas production grows by 0.9 trillion cubic feet from 2010 through 2035, with tight sandstone and carbonate production increasing by 0.8 trillion cubic feet and shale gas production by 0.4 trillion cubic feet. As in the Gulf Coast region, production growth in the Rocky Mountain region is offset in part by production declines in the region's other natural gas fields.

Petroleum and other liquids consumption

The U.S. becomes a net natural gas exporter

Figure 109. U.S. net imports of natural gas by source, 1990-2035 (trillion cubic feet)



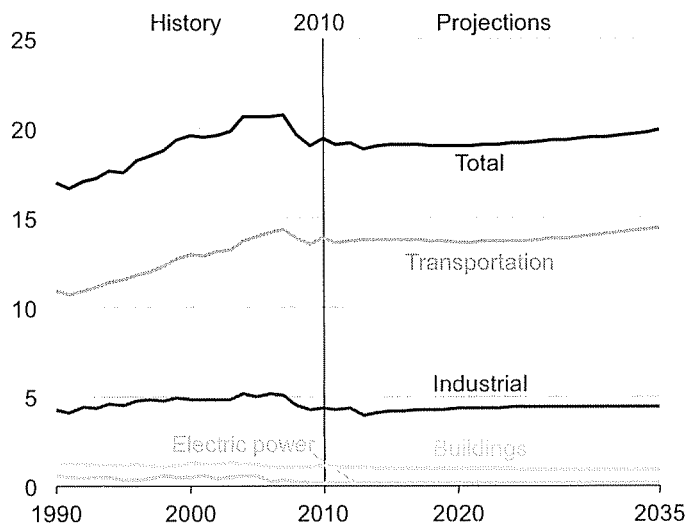
In 2010, the United States imported 11 percent of its total natural gas supply. In the AEO2012 Reference case, U.S. natural gas production grows faster than consumption, so that early in the next decade exports exceed imports. In 2035, U.S. net natural gas exports are about 1.4 trillion cubic feet (about 4 billion cubic feet per day), half of which is exported overseas as liquefied natural gas (LNG). The other half is transported by pipelines, primarily to Mexico.

U.S. LNG exports supplied from lower 48 natural gas production are assumed to start when LNG export capacity of 1.1 billion cubic feet per day goes into operation in 2016. An additional 1.1 billion cubic feet per day of capacity is expected to come on line in 2019. At full capacity, the facilities could ship 0.8 trillion cubic feet of LNG to overseas consumers per year. Net U.S. LNG exports are somewhat lower than those figures imply, however, because LNG imports to the New England region are projected to continue. In general, future U.S. exports of LNG depend on a number of factors that are difficult to anticipate and thus are highly uncertain.

Net natural gas imports from Canada decline over the next decade in the Reference case and then stabilize at about 1.1 trillion cubic feet per year (Figure 109), when natural gas prices in the U.S. lower 48 States become high enough to motivate Canadian producers to expand their production of shale gas and tight gas. In Mexico, natural gas consumption shows robust growth through 2035, while Mexico's production grows at a slower rate. As a result, increasing volumes of imported natural gas from the United States fill the growing gap between Mexico's production and consumption.

Transportation uses lead growth in consumption of petroleum and other liquids

Figure 110. Consumption of petroleum and other liquids by sector, 1990-2035 (million barrels per day)



U.S. consumption of petroleum and other liquids totals 19.9 million barrels per day in 2035 in the AEO2012 Reference case, an increase of 0.7 million barrels per day over the 2010 total (Figure 110). With the exception of the transportation sector, where consumption grows by about 0.6 million barrels per day from 2010 through 2035, petroleum and other liquids consumption remains relatively flat. The transportation sector accounts for 72 percent of total petroleum and other liquids consumption in 2035. Proposed fuel economy standards covering MYs 2017 through 2025 that are not included in the Reference case would further reduce projected petroleum use (see "Issues in focus").

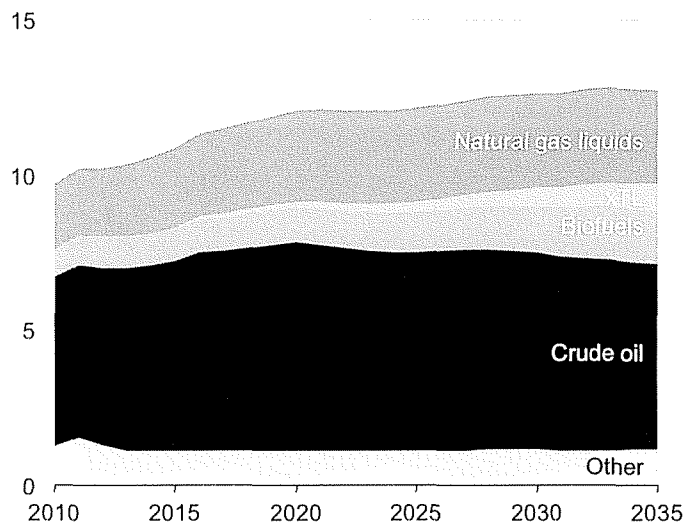
Motor gasoline, ultra-low-sulfur diesel fuel, and jet fuel are the primary transportation fuels, supplemented by biofuels such as ethanol and biodiesel. Petroleum-based motor gasoline consumption drops by approximately 0.9 million barrels per day from 2010 to 2035 in the Reference case, displaced by increased ethanol use in the form of higher blends in gasoline and by E85 consumption, which increases from virtually zero in 2010 to 0.8 million barrels per day in 2035. Diesel fuel consumption increases from 3.3 million barrels per day in 2010 to 4.1 million barrels per day in 2035.

Biodiesel and a number of next-generation biofuels account for a large share of the increase in petroleum and other liquids consumption (excluding ethanol) for transportation from 2010 to 2035 (about 0.7 million barrels per day). The growth in biofuels consumption (including ethanol) is attributable to the EISA2007 RFS mandates, as well as high crude oil prices. The growth in diesel fuel use results primarily from increased sales of light-duty diesel vehicles needed to meet more stringent CAFE standards, with a corresponding increase in domestic production of diesel fuel.

Petroleum and other liquids supply

Biofuels and natural gas liquids lead growth in total petroleum and other liquids supply

Figure 111. U.S. production of petroleum and other liquids by source, 2010-2035 (million barrels per day)

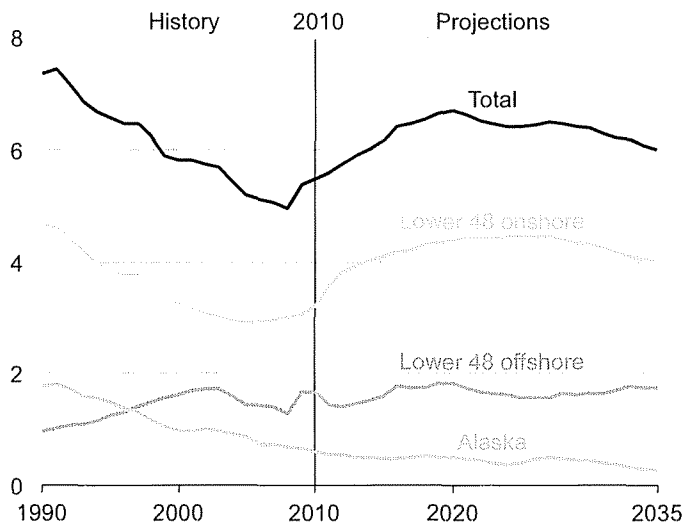


In the AEO2012 Reference case, domestic production of petroleum and other liquids grows by 3.1 million barrels per day from 2010 to 2035 (Figure 111). Total production grows rapidly, from 9.7 million barrels per day in 2010 to 12.1 million barrels per day in 2020, as production of crude oil and NGL from tight oil formations (including shale plays) increases sharply. After 2020, total U.S. production of petroleum and other liquids grows more slowly, to 12.7 million barrels per day in 2035, as tight oil production levels off despite continued increases in crude oil prices. As production of other liquid fuels increases, the crude oil share of total domestic petroleum and other liquids production declines from 56 percent in 2010 to 47 percent in 2035. NGL production increases by more than 0.9 million barrels per day, to 3.0 million barrels per day in 2035, mainly as a result of strong growth in production of both tight oil and shale gas, which contain significant volumes of NGLs.

Biofuels production grows by 0.8 million barrels per day from 2010 to 2035 as a result of the EISA2007 RFS, with ethanol and biodiesel accounting for 0.7 and 0.1 million barrels per day, respectively, of the increase in the Reference case. The increase in domestic ethanol production reduces consumption of petroleum-based motor gasoline components by about 6 percent in 2035 on an energy-equivalent basis. In the early years of the projection, ethanol is used primarily for blending in E10 (motor gasoline blends containing up to 10 percent ethanol) and E15 (15 percent ethanol). In 2035, 37 percent of domestic ethanol production is used in E85 (85 percent ethanol) and 63 percent in E10 and E15 blends. In addition, growth in next-generation "xTL" production, which includes both biomass-to-liquids and CTL, contributes significantly to the growth in total U.S. petroleum and other liquids production, particularly after 2020, adding about 0.6 and 0.3 million barrels per day of production, respectively, from 2010 to 2035.

U.S. crude oil production increases, led by lower 48 onshore production

Figure 112. Domestic crude oil production by source, 1990-2035 (million barrels per day)



As world oil prices increase in the AEO2012 Reference case, U.S. production of tight oil (liquid oil embedded in low-permeable sandstone, carbonate, and shale rock) and production using carbon dioxide-enhanced oil recovery (CO₂-EOR) techniques add to the projected increase in domestic crude oil production from 2010 to 2035 (Figure 112). Growth in lower 48 onshore crude oil production comes primarily from the continued development of tight oil resources, mostly from the Bakken and Eagle Ford formations. Tight oil production surpasses 1.3 million barrels per day in 2027 and then declines to about 1.2 million barrels per day in 2035 as "sweet spots" are depleted. AEO2012 also includes six other tight formations in the projections for tight oil production: the Austin Chalk, Avalon/Bone Springs, Monterey, Niobrara, Spraberry, and Woodford formations. Additional tight oil resources are likely to be identified in the future as more work is completed to identify currently producing reservoirs that may be better categorized as tight formations, and as new tight oil plays are identified and incorporated (see next column).

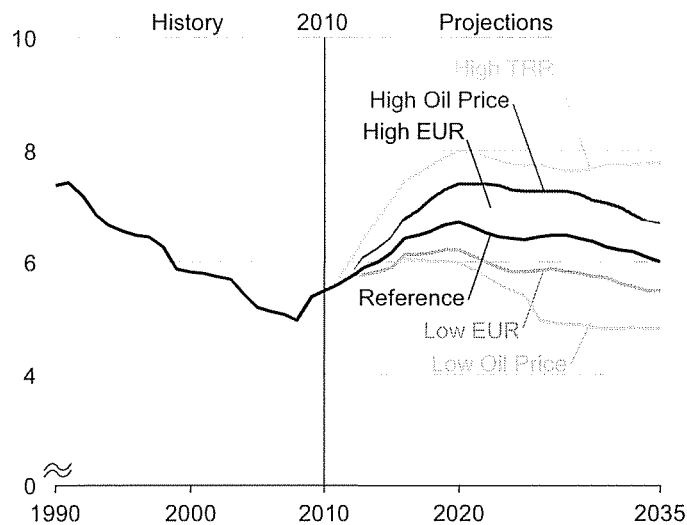
Crude oil production using CO₂-EOR increases significantly after 2020, when oil prices are higher, the more profitable tight oil deposits are depleted, and affordable anthropogenic sources of carbon dioxide (CO₂) are available. It plateaus at about 650,000 barrels per day from 2032 to 2035, when its profitability is limited by reservoir quality and CO₂ availability. From 2011 through 2035, CO₂-EOR production exceeds 4 billion barrels of oil.

Lower 48 offshore oil production remains relatively constant in the Reference case. The decline in currently producing fields is offset primarily by exploration and development of new fields in the deep waters of the Gulf of Mexico and, after 2029, in the Pacific Outer Continental Shelf.

Petroleum and other liquids supply

U.S. crude oil production varies with price and resource assumptions

Figure 113. Total U.S. crude oil production in six cases, 1990-2035 (million barrels per day)

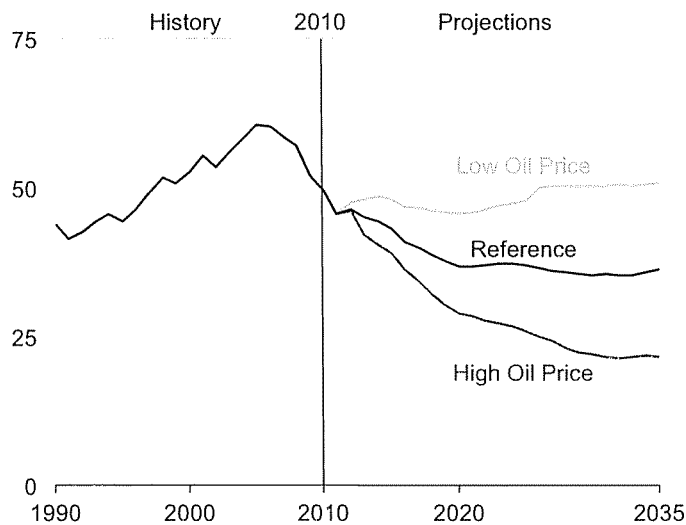


U.S. crude oil production varies with changes in assumptions about the extent of productivity improvement and well spacing in emerging tight oil resources examined in the High Technically Recoverable Resources (TRR) case and in the High and Low EUR cases (see discussion in "Issues in focus") and with changes in assumptions about crude oil prices in the Low and High Crude Oil Price cases (Figure 113). In the High TRR case, assumptions for tight oil allow for more rapid growth in crude oil production in the short and long term than in the Reference case, with production reaching nearly 8 million barrels per day in 2020. In the Low EUR case there is very little growth in domestic crude oil production over the projection period.

Higher oil prices lead to an increase in the level of investment in new oil projects. However, the returns from increased investment diminish as the average size and quality of available reservoirs decline. For example, in the High Oil Price case tight oil production is, on average, 225,000 barrels per day higher from 2020 to 2030 than in the Reference case but returns to Reference case levels in 2035. In contrast, low oil prices result in less investment in new oil projects and encourage producers to plug and abandon existing fields at earlier dates. For example, in the Low Oil Price case, oil production from the Alaska North Slope is shut down by around 2025, when the projected operating costs exceed wellhead production revenues (see "Issues in focus"). From 2020 to 2035, tight oil production is, on average, roughly 300,000 barrels per day lower in the Low Oil Price case than in the Reference case.

U.S. net imports of petroleum and other liquids fall in the Reference case

Figure 114. Net import share of U.S. petroleum and other liquids consumption in three cases, 1990-2035 (percent)



U.S. imports of petroleum and other liquids (including crude oil, petroleum liquids, and liquids derived from nonpetroleum sources) grew steadily from the mid-1980s to 2005 but have declined since then. In the AEO2012 Reference and High Oil Price cases, U.S. imports of petroleum and other liquids continue to decline from 2010 to 2035, even as they provide a major part of total U.S. supply. Tighter fuel efficiency standards, increased use of biofuels, and greater production of domestic petroleum and other liquids contribute to the decrease in the share of imports. The combination of higher prices and renewable fuel mandates leads to more domestic production of petroleum and biofuels, which, combined with declines in the petroleum share of finished products after 2015, results in sustained net product exports.

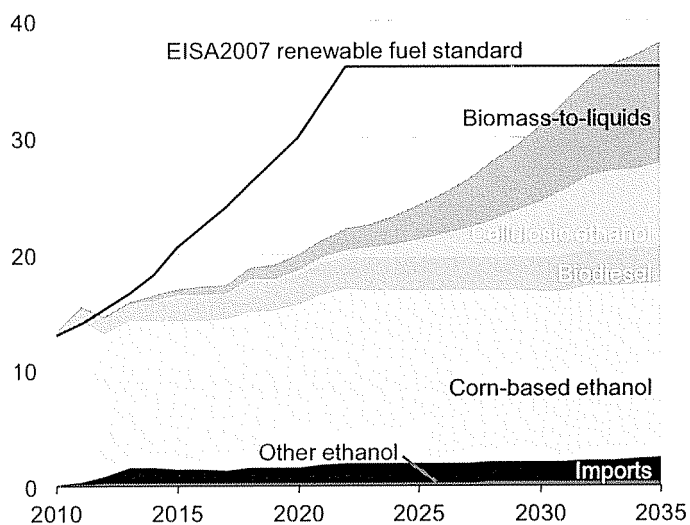
The net import share of U.S. petroleum and other liquids consumption, which fell from 60 percent in 2005 to 50 percent in 2010, continues to decline in the Reference case, with the net import share falling to 36 percent in 2035 (Figure 114). In the High Oil Price case, the net import share falls even lower to a 22-percent share in 2035. In the Low Oil Price case, the net import share remains flat in the near term but rises to 51 percent in 2035, as domestic demand increases and imports become cheaper than crude oil produced domestically.

As a result of increased domestic production and slow growth in consumption, the United States becomes a net exporter of petroleum products, with net exports in the Reference case increasing from 0.18 million barrels per day in 2011 to 0.34 million barrels per day in 2035. In the High Oil Price case, net exports of petroleum products increase to 0.9 million barrels per day in 2035.

Petroleum and other liquids supply

U.S. consumption of cellulosic biofuels exceeds renewable fuels standard in 2035

Figure 115. EISA2007 RFS credits earned in selected years: 2010-2035 (billion credits)



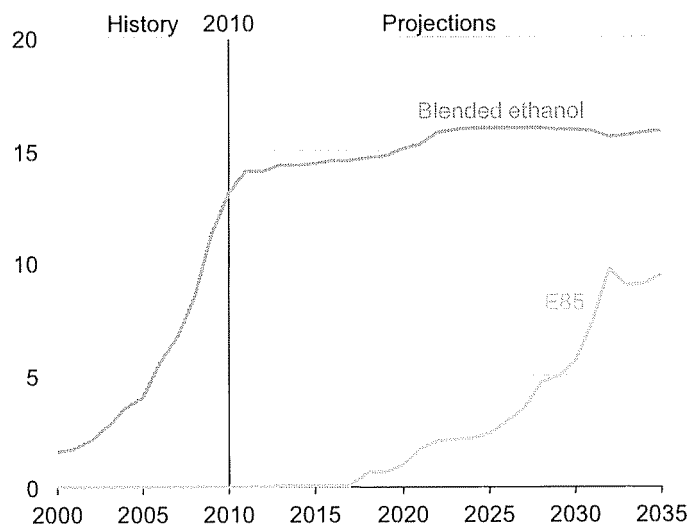
Although biofuel production increases substantially in the AEO2012 Reference case, it does not meet the mandated RFS of 36 billion gallons in 2022 (Figure 115). Financial and technological hurdles delay the start of many advanced biofuel projects, particularly cellulosic biofuel projects. Three consecutive years of substantial reductions in the cellulosic biofuels mandate [133, 134, 135] have significantly reduced the possibility that the original RFS levels mandated in EISA2007 will be reached by 2022.

Between 2012 and 2022, it is expected that the EPA will evaluate the status of biofuel capacity annually and revise the production mandates for the following year, according to provisions in the RFS [136]. In 2011, after the EPA reduced the cellulosic biofuel mandate for both 2010 and 2011 from 100 million and 250 million gallons, respectively, to approximately 6 million gallons in both years, it also reduced the 2012 mandate from 500 million gallons to about 8 million gallons. Taking into account those modifications and anticipated future changes, only 22.1 billion of RFS credits are generated in 2022 in the Reference case, with 15 billion gallons of credits coming from domestic production of corn-based ethanol.

In the Reference case, the remainder of the biofuel supply consists of imported ethanol, biodiesel, cellulosic ethanol, and smaller volumes of next-generation biofuels. U.S. consumption of cellulosic ethanol grows from 0.6 billion gallons in 2022 to 7.2 billion gallons in 2035, when imports of ethanol and biodiesel total 2.2 billion gallons and 0.2 billion gallons, respectively.

Infrastructure hurdles limit near-term growth in consumption of E15 and E85 fuels

Figure 116. U.S. ethanol use in blended gasoline and E85, 2000-2035 (billion gallons per year)



A number of factors have recently limited the amount of ethanol that can be consumed domestically. Currently, given the limited availability of E85, the primary use of ethanol is as a blendstock for gasoline. With rapid growth in ethanol capacity and production in recent years, ethanol consumption in 2010 approached the legal gasoline blending limit of 10 percent (E10). As of January 2011, the EPA increased the blending limit to 15 percent for vehicles built in 2001 and later [137]. Once the final requirements are put in place, blenders will no longer be prohibited from blending beyond 10 percent for the general stock; however, a number of issues are expected to limit the rate at which terminals and retail outlets choose to take advantage of the option.

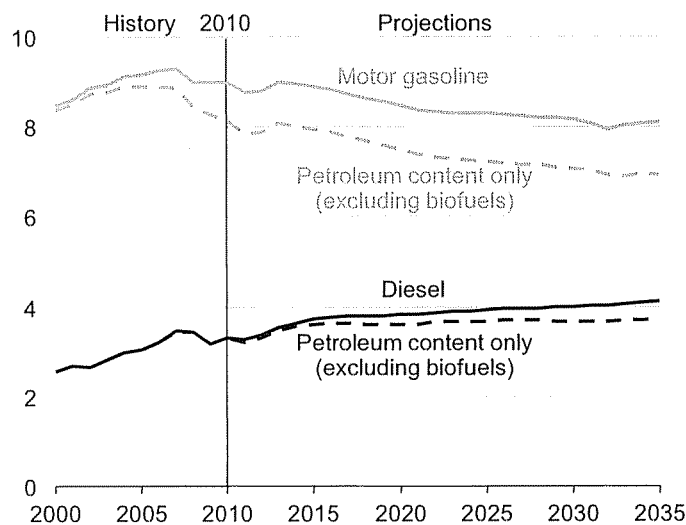
Liability from potential misfueling and infrastructure problems is one of the top concerns expected to slow the widespread adoption of E15. Retailers are hesitant to sell E15, even with the EPA's warning label, if they are not relieved of responsibility for damage to consumers' vehicles that may result from misfueling with the higher ethanol blend or from malfunctions of storage equipment or infrastructure. Consumer acceptance of the new fuel blend will also play a part, and warning labels may deter customers from risking potential damage from the use of E15, which potentially could void vehicle warranties.

In light of those potential issues, ethanol blending in gasoline increases slowly in the Reference case, from 13.2 billion gallons in 2010 (about 9 percent of the gasoline pool) to 15.0 billion gallons in 2020 (about 11 percent) and 15.8 billion gallons in 2035 (12.5 percent). Given the blending limitations, the remaining growth in ethanol use is in E85, which grows from about 0.6 billion gallons in 2018 to 9.5 billion gallons in 2035 (Figure 116).

Coal production

Shifts in fuel consumption guide future investment decisions for refiners

Figure 117. U.S. motor gasoline and diesel fuel consumption, 2000-2035 (million barrels per day)



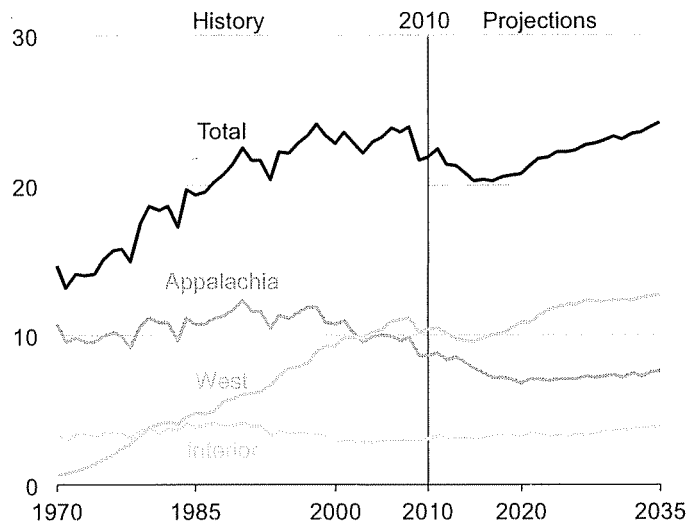
Tighter vehicle efficiency standards for LDVs require new LDVs to average 35 mpg by 2020, and newly issued regulations require increased use of ethanol. The Reference case does not include the proposed fuel economy standards covering MYs 2017 through 2025 that would raise vehicle efficiency standards even higher. Demand for motor gasoline declines in the Reference case. In combination with a tighter market for diesel fuel, the decrease in gasoline consumption leads to a shift in refinery outputs and investments. As some smaller and less integrated refineries begin to idle capacity as a result of higher costs, new refinery projects are focused on shifting production from gasoline to distillate fuels. The restructuring results in a net reduction in refinery capacity of 2.4 million barrels per day over the projection period.

In the Reference case, new capacity that was planned before the economic downturn of 2008-2009 comes on line early in the projection period, adding approximately 400,000 barrels per day of new refining distillation capacity from 2010 to 2015. As a result of refinery economics and concerns about the potential for enactment of legislation that could constrain carbon emissions, raise refiners' costs, and limit the growth in demand for petroleum and other liquids, no additional refinery capacity is built after 2015 until around 2030. Total refining capacity in the United States declines gradually after 2015 as additional capacity is idled.

Motor gasoline consumption and diesel fuel consumption (either including or excluding biofuels) trend in opposite directions in the Reference case (Figure 117). Consumption of diesel fuel increases by approximately 0.8 million barrels per day from 2010 to 2035, while motor gasoline consumption falls by 0.9 million barrels per day.

Early declines in coal production are more than offset by growth after 2015

Figure 118. Coal production by region, 1970-2035 (quadrillion Btu)



Although higher coal exports provide some support in 2011, U.S. coal production declines for four years thereafter as a result of low natural gas prices, rising coal prices, lack of growth in electricity demand, and increasing generation from renewables. In addition, new requirements to control emissions of nitrogen oxides (NO_x), sulfur dioxide (SO₂), and air toxics (such as mercury and acid gases), result in the retirement of some coal-fired generating capacity, contributing to the reduction in demand for coal. After 2015, coal production grows at an average annual rate of 1.0 percent through 2035, with coal use for electricity generation increasing as electricity demand grows and natural gas prices rise. More coal is also used for production of synthetic liquids, and coal exports increase.

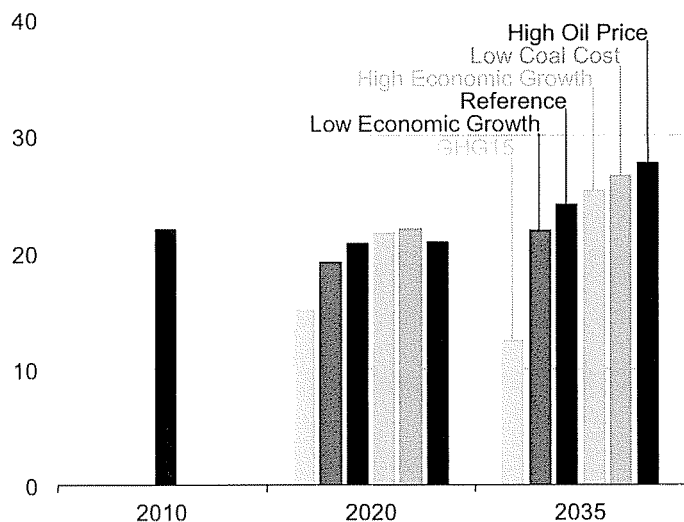
Western coal production grows through 2035 (Figure 118) but at a much slower rate than in the past, as demand growth continues to slow. Low-cost supplies of coal from the West satisfy much of the additional need for fuel at coal-fired power plants east of the Mississippi River and supply most of the coal used at new CTL and CBTL plants.

Coal production in the Interior region, which has trended downward slightly since the early 1990s, recovers to near historic highs in the AEO2012 Reference case. Additional production from the Interior region originates from mines tapping into the substantial reserves of mid- and high-sulfur bituminous coal in Illinois, Indiana, and western Kentucky and from lignite mines in Texas and Louisiana. Appalachian coal production declines substantially from current levels, as coal produced from the extensively mined, higher cost reserves of Central Appalachia is supplanted by lower cost coal from other supply regions. An expected increase in production from the northern part of the Appalachia basin, however, moderates the overall production decline in Appalachia.

Coal production and prices

U.S. coal production is affected by actions to cut GHG emissions from existing power plants

Figure 119. U.S. total coal production in six cases, 2010, 2020, and 2035 (quadrillion Btu)



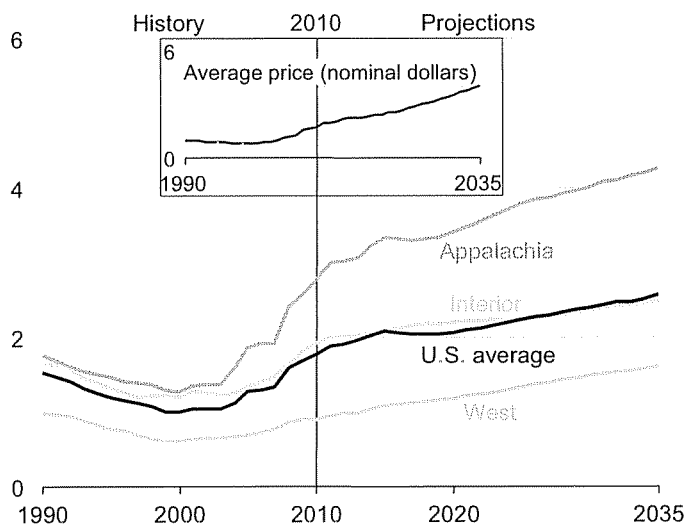
U.S. coal production varies across the AEO2012 cases, reflecting different assumptions about the costs of producing and transporting coal, the outlook for economic growth, the outlook for world oil prices, and possible restrictions on GHG emissions (Figure 119). As shown in the GHG15 case, where a CO₂ emissions price that grows to \$44 per metric ton in 2035 is assumed, actions to restrict or reduce GHG emissions can significantly affect the outlook for U.S. coal production.

Assumptions about economic growth primarily affect the projections for overall electricity demand, which in turn determine the need for coal-fired electricity generation. In contrast, assumptions about the costs of producing and transporting coal primarily affect the choice of technologies for electricity generation, with coal capturing a larger share of the U.S. electricity market in the Low Coal Cost case. In the High Oil Price case, higher oil prices stimulate the demand for coal-based synthetic liquids, leading to more coal use at CTL and CBTL plants. Production of coal-based synthetic liquids totals 1.3 million barrels per day in 2035 in the High Oil Price case, more than four times the amount in the Reference case.

From 2010 to 2035, changes in total annual coal production across the cases (excluding the GHG case) range from a decrease of 1 percent to an increase of 26 percent. In the earlier years of the projections, coal production is lower than in 2010 in most cases, as other sources of electricity generation displace coal-fired generation. From 2010 to 2020, changes in coal production across the cases (excluding the GHG case) range from a decline of 13 percent to virtually no change, with a 6-percent decline projected in the AEO2012 Reference case.

Average minemouth price continues to rise, but at a slower pace than in recent years

Figure 120. Average annual minemouth coal prices by region, 1990-2035 (2010 dollars per million Btu)



In the AEO2012 Reference case, the average real minemouth price for U.S. coal increases by 1.5 percent per year, from \$1.76 per million Btu in 2010 to \$2.56 in 2035, continuing the upward trend in coal prices that began in 2000 (Figure 120). A key factor underlying the higher coal prices in the projection is an expectation that coal mining productivity will continue to decline, but at slower rates than during the 2000s.

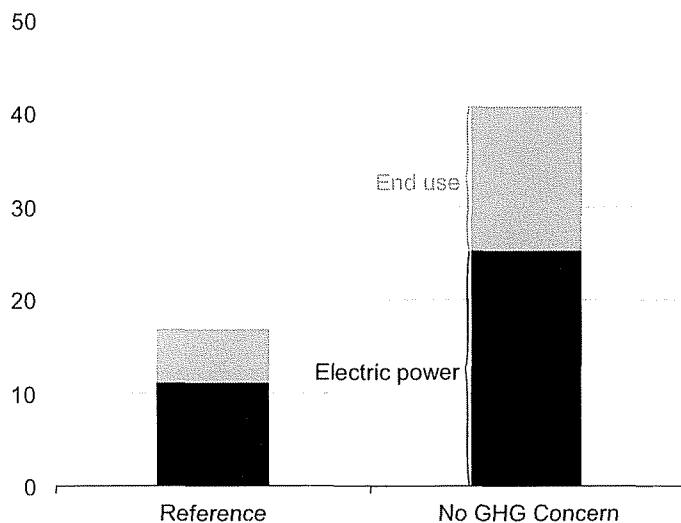
In the Appalachian region, the average minemouth coal price increases by 1.7 percent per year from 2010 to 2035. In addition to continued declines in coal mining productivity, the higher price outlook for the Appalachian region reflects a shift to higher-value coking coal, resulting from the combination of growing exports of coking coal and declining shipments of steam/thermal coal to domestic markets. Recent increases in the average price of Appalachian coal, from \$1.28 per million Btu in 2000 to \$2.77 per million Btu in 2010, in part a result of significant declines in mining productivity over the past decade, have substantially reduced the competitiveness of Appalachian coal with coal from other regions.

In the Western and Interior coal supply regions, declines in mining productivity, combined with increasing production, lead to increases in the real minemouth price of coal, averaging 2.3 percent per year for the Western region and 1.0 percent per year for the Interior region from 2010 to 2035.

Emissions from energy use

Concerns about future GHG policies affect investments in emissions-intensive capacity

Figure 121. Cumulative coal-fired generating capacity additions by sector in two cases, 2011-2035 (gigawatts)

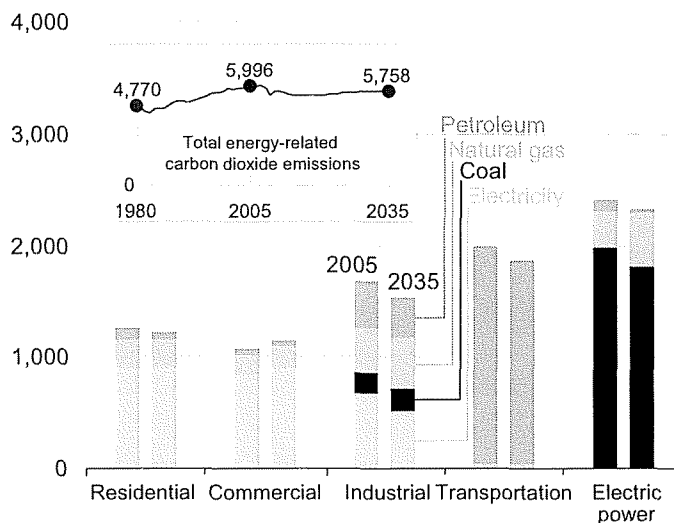


In the AEO2012 Reference case, the cost of capital for investments in GHG-intensive technologies—including new coal-fired power plants without carbon capture and storage (CCS), new CTL and CBTL plants, and capital investment projects at existing coal-fired power plants (excluding CCS)—is increased by 3 percentage points to reflect the behavior of utilities, other energy companies, and regulators concerning the possible enactment of GHG legislation that could require owners to purchase emissions allowances, invest in CCS, or invest in other projects to offset their emissions in the future. The No GHG Concern case illustrates the potential impact on energy investments when the additional 3 percentage points added to the cost of capital for GHG-intensive technologies is removed.

In the No GHG Concern case, the lower cost of capital leads to 40 gigawatts of new coal-fired capacity additions from 2011 to 2035, up from 17 gigawatts in the Reference case (Figure 121). As a result, additions of both natural gas and renewable generating capacity are lower in the No GHG Concern case than in the Reference case. In the end-use sectors, all new coal-fired capacity additions in the No GHG Concern case are at CTL and CBTL plants, where part of the electricity is used to produce synthetic liquids and the remaining portion is sold to the grid. As a result, production of coal-based synthetic liquids totals 0.7 million barrels per day in 2035, compared with 0.3 million barrels per day in the Reference case. Total coal consumption (including coal converted to synthetic fuels) increases to 24.3 quadrillion Btu in 2035 in the No GHG Concern case, 2.6 quadrillion Btu (12 percent) higher than in the Reference case. Energy-related CO₂ emissions in 2035 are 5,900 million metric tons in the No GHG Concern case, about 2 percent higher than in the Reference case and 2 percent lower than their 2005 level.

Projected energy-related carbon dioxide emissions remain below their 2005 level

Figure 122. U.S. energy-related carbon dioxide emissions by sector and fuel, 2005 and 2035 (million metric tons)



On average, energy-related CO₂ emissions in the AEO2012 Reference case decline by 0.1 percent per year from 2005 to 2035, as compared with an average increase of 0.9 percent per year from 1980 to 2005. Reasons for the decline include an expected slow and extended recovery from the recession of 2008-2009, growing use of renewable technologies and fuels, efficiency improvements, slower growth in electricity demand, and more use of natural gas, which is less carbon-intensive than other fossil fuels. In the Reference case, energy-related CO₂ emissions remain below 2005 levels through 2035, when they total 5,758 million metric tons—238 million metric tons (4.0 percent) below their 2005 level (Figure 122).

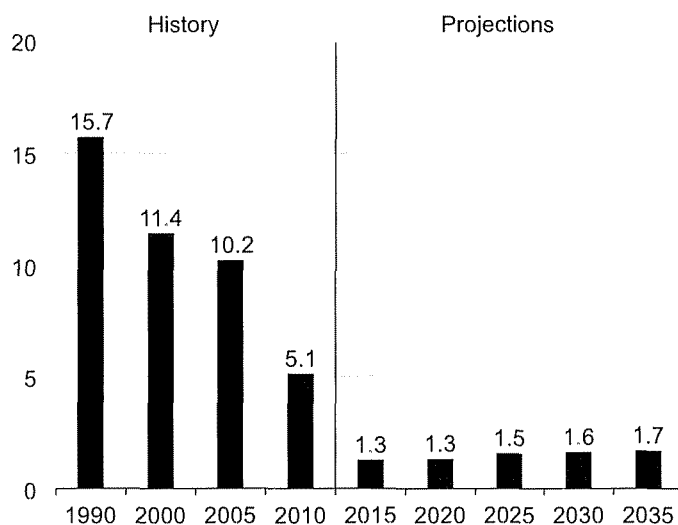
Petroleum remains the largest source of U.S. CO₂ emissions over the projection period, but its share falls to 40 percent in 2035 from 44 percent in 2005. CO₂ emissions from petroleum use, mainly in the transportation sector, were at relatively low levels in 2009. Although they increase somewhat from 2025 to 2035, emissions from petroleum use remain fairly stable, as improvements in transportation fuel economy and the expanded use of ethanol and other biofuels outweigh expected increases in travel demand. CO₂ emissions from petroleum would be even lower if proposed fuel economy standards covering MYs 2017 through 2025 were included in the Reference case.

Emissions from coal, the second largest source of CO₂ emissions, remain below 2005 levels through 2035 in the Reference case. Coal's share of total U.S. CO₂ emissions remains relatively unchanged through 2035, because the percentage decline in emissions from coal combustion is roughly the same as the percentage decline in total CO₂ emissions over the period. The natural gas share of CO₂ emissions increases from just under 20 percent in 2005 to 25 percent in 2035 as the use of natural gas to fuel electricity generation and industrial applications increases.

Emissions from energy use

Power plant emissions of sulfur dioxide are reduced by further environmental controls

Figure 123. Sulfur dioxide emissions from electricity generation, 1990-2035 (million short tons)



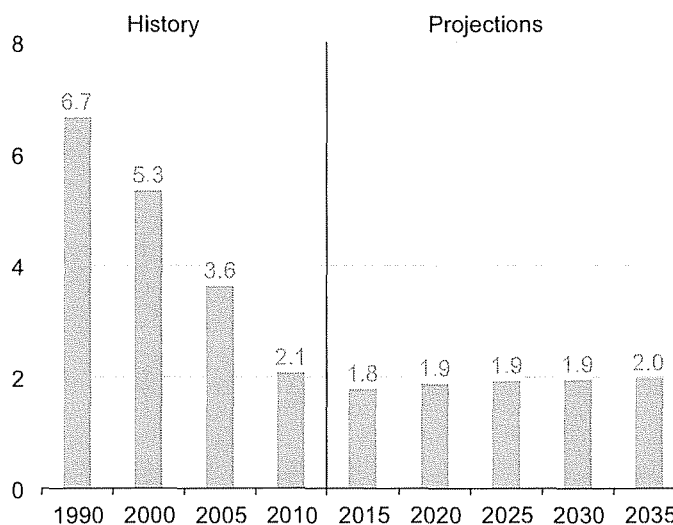
In the AEO2012 Reference case, SO₂ emissions from the U.S. electric power sector fall from 5.1 million short tons in 2010 to a range of 1.3 to 1.7 million short tons in the 2015-2035 projection period. The reduction occurs in response to the EPA's Cross-State Air Pollution Rule (CSAPR) and Mercury and Air Toxics Standards (MATS) [138]. Although SO₂ is not directly regulated by the MATS, the reductions are achieved as a result of the technology requirements for acid gas and non-mercury metal controls on coal-fired power plants. AEO2012 assumes that, in order to continue operating, coal plants must have either flue gas desulfurization (FGD) or dry sorbent injection (DSI) systems installed by 2015. Both technologies, which are used to reduce acid gas emissions, also reduce SO₂ emissions.

EIA assumes a 95-percent SO₂ removal efficiency for FGD units and a 70-percent SO₂ removal efficiency for DSI systems. DSI systems can achieve 70-percent efficiency when they include a baghouse filter, which also is assumed to be needed for compliance with the non-mercury metal component of the MATS.

From 2010 to 2035, approximately 48 gigawatts of coal-fired capacity is retrofitted with FGD units in the Reference case, and another 58 gigawatts is retrofitted with DSI systems. By 2015, all operating coal-fired power plants are assumed to have either DSI or FGD systems installed on units larger than 25 megawatts. As a result, after a 75-percent decrease from 2010 to 2015, SO₂ emissions increase slowly from 2016 to 2035 (Figure 123), as total electricity generation from coal-fired power plants increases.

Nitrogen oxide emissions show little change from 2010 to 2035 in the Reference case

Figure 124. Nitrogen oxide emissions from electricity generation, 1990-2035 (million short tons)



Annual emissions of NO_x from the electric power sector, which totaled 2.1 million short tons in 2010, range between 1.8 and 2.0 million short tons from 2015 to 2035 (Figure 124). Annual NO_x emissions from electricity generation dropped by 43 percent from 2005 to 2010 due to implementation of the Clean Air Interstate Rule (CAIR), which led to the installation of additional NO_x pollution control equipment.

In the AEO2012 Reference case, NO_x emissions are 5 percent below 2010 levels in 2035, despite a 2-percent increase in coal-fired electricity generation over the same period. The drop in emissions is a result primarily of CSAPR [139], which includes both annual and seasonal cap-and-trade systems for NO_x in 28 States. A slight rise in NO_x emissions after 2015 corresponds to a recovery in coal-fired generation as natural gas prices rise in the later years of the projection period.

The MATS does not have a direct effect on NO_x emissions, because none of the potential technologies required to comply with MATS has a significant impact on NO_x emissions. However, because MATS contributes to a reduction in coal-fired generation overall, it indirectly reduces NO_x emissions in the power sector in States without CSAPR where coal- and oil-fired units are used.

Coal-fired power plants can be retrofitted with one of three types of NO_x control technologies: selective catalytic reduction (SCR), selective noncatalytic reduction (SNCR), or low-NO_x burners. The type of retrofit used depends on the specific characteristics of the plant, including the boiler configuration and the type of coal used. From 2010 to 2035, 28 gigawatts of coal-fired capacity is retrofitted with NO_x controls in the Reference case: 69 percent with SCR, 3 percent with SNCR, and 29 percent with low-NO_x burners.

Endnotes for Market trends

Links current as of June 2012

121. In the recessions highlighted in Figure 46, percentage changes in annual GDP relative to the previous year were negative.
122. The industrial sector includes manufacturing, agriculture, construction, and mining. The energy-intensive manufacturing sectors include food, paper, bulk chemicals, petroleum refining, glass, cement, steel, and aluminum.
123. Energy expenditures relative to GDP are not the energy share of GDP, because they include energy as an intermediate product. The energy share of GDP corresponds to the share of value added by domestic energy-producing sectors, excluding the value of energy as an intermediate product.
124. S.C. Davis, S.W. Diegel, and R.G. Boundy, *Transportation Energy Databook: Edition 30*, ORNL-6986 (Oak Ridge, TN: June 2011), Chapter 4, "Light Vehicles and Characteristics," website cta.ornl.gov/data/index.shtml.
125. The AEO2012 Reference case does not include the proposed LDV GHG and fuel economy standards published by the EPA and NHTSA in December 2011. (See "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards," website www.nhtsa.gov/fuel-economy/.)
126. LDV fuel economy includes AFVs and banked credits toward compliance.
127. U.S. Environmental Protection Agency and National Highway Transportation Safety Administration, "2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Proposed Rule," Federal Register, Vol. 76, No. 231 (Washington, DC, December 1, 2011), website www.nhtsa.gov/staticfiles/rulesmaking/pdf/cAFE/2017-LD_VEHICLE_INPRM.pdf. 49 CFR Parts 523, 531, 533, 536, and 537.
128. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles; Final Rule," Federal Register, Vol. 76, No. 179 (Washington, DC: September 15, 2011), pp. 57106-57513, website www.gpo.gov/fdsys/pkg/FR-2011-09-15/html/2011-20740.html.
129. The factors that influence decisionmaking on capacity additions include electricity demand growth, the need to replace inefficient plants, the costs and operating efficiencies of different generation options, fuel prices, State RPS programs, and the availability of Federal tax credits for some technologies.
130. The 24 gigawatts include the 1.12 gigawatt Watts Bar 2 unit in 2012 that was subsequently delayed by TVA until 2015 due to cost overruns; www.tva.gov/news/updates/april12/0426_board.htm.
131. Unless otherwise noted, the term "capacity" in the discussion of electricity generation indicates utility, nonutility, and CHP capacity. Costs reflect the average of regional costs.
132. For detailed discussion of levelized costs, see U.S. Energy Information Administration, "Levelized Cost of New Generation Resources in the Annual Energy Outlook 2012," website www.eia.gov/forecasts/aec/electricity_generation.cfm.
133. U.S. Environmental Protection Agency, "EPA Finalizes Regulations for the National Renewable Fuel Standard Program for 2010 and Beyond," EPA-420-F-10-007 (Washington, DC: February 2010), website www.epa.gov/otaq/renewablefuels/420F10007.pdf.
134. U.S. Environmental Protection Agency, "EPA Finalizes 2011 Renewable Fuel Standards," EPA-420-F-10-056 (Washington, DC: November 2010), website www.epa.gov/otaq/fuels/renewablefuels/420F10056.pdf.
135. U.S. Environmental Protection Agency, "EPA Finalizes 2012 Renewable Fuel Standards," EPA-420-F-11-044 (Washington, DC: December 2011), website www.epa.gov/otaq/fuels/renewablefuels/documents/420F11044.pdf.
136. EISA2007, Section 211(o)(7) of the Clean Air Act.
137. U.S. Environmental Protection Agency, "E15 (a blend of gasoline and ethanol)," website www.epa.gov/otaq/reus/fuels/additive/e15.
138. U.S. Environmental Protection Agency, "Mercury and Air Toxics Standards," website www.epa.gov/mats.
139. U.S. Environmental Protection Agency, "Cross-State Air Pollution Rule (CSAPR)," website epa.gov/airtransport.

Comparison with other projections

Energy Information Administration (EIA) and other contributors have endeavored to make these projections as objective, reliable, and useful as possible; however, they should serve as an adjunct to, not a substitute for, a complete and focused analysis of public policy initiatives. None of the EIA or any of the other contributors shall be responsible for any loss sustained due to reliance on the information included in this report.

Comparison of other outlooks

Only IHS Global Insight (IHSGI) produces a comprehensive energy projection with a time horizon similar to that of the *Annual Energy Outlook 2012 (AEO2012)*. Other organizations, however, address one or more aspects of the U.S. energy market. The most recent projection from IHSGI, as well as others that concentrate on economic growth, international oil prices, energy consumption, electricity, natural gas, petroleum, and coal, are compared here with the AEO2012 Reference case.

1. Economic growth

The range of projected economic growth in the outlooks included in the comparison tends to be wider over the first 5 years of the projection period than over a longer period, because the group of variables—such as population, productivity, and labor force growth—that are used to influence long-run economic growth is smaller than the group of variables that affect projections of short-run growth. The average annual rate of growth of real gross domestic product (GDP) from 2010 to 2015 (in 2005 dollars) ranges from 2.4 percent to 3.4 percent (Table 22). From 2010 to 2020, the 10-year average annual growth rate ranges from 2.5 percent to 3.1 percent.

From 2010 to 2015, real GDP is projected to grow at a 2.5-percent average annual rate in the AEO2012 Reference case, lower than projected by the Office of Management and Budget (OMB), Congressional Budget Office (CBO), Blue Chip Consensus (Blue Chip), Social Security Administration (in *The 2011 Annual Report of the Board of Trustees of the Federal Old-Age and Survivors Insurance and Federal Disability Insurance Trust Funds*), ExxonMobil, and the Interindustry Forecasting Project at the University of Maryland (INFORUM) and higher than projected by Strategic Energy and Economic Research, Inc. (SEER). The AEO2012 projection of GDP growth is similar to the IHSGI average annual rate of 2.5 percent over the same period.

The average annual GDP growth of 2.5 percent in the AEO2012 Reference case from 2010 to 2020 is at the low end of the range of outlooks, with OMB, INFORUM, and the Social Security Administration projecting the strongest recovery from the 2008-2009 recession. INFORUM projects average annual GDP growth of 3.1 percent from 2010 to 2020, while OMB and the Social Security Administration project annual average growth of 3.0 percent over the same period. The CBO, ExxonMobil, Blue Chip, the International Energy Agency's (IEA) November 2011 *World Energy Outlook Current Policies Scenario*, and SEER also project higher growth than the AEO2012 Reference case from 2010 to 2020, ranging between 2.6 and 2.8 percent per year over the next 10 years.

There are few public or private projections of GDP growth for the United States that extend to 2035. The AEO2012 Reference case projects 2.5-percent average annual GDP growth from 2010 to 2035, consistent with trends in labor force and productivity growth. IHSGI, ExxonMobil, and the Social Security Administration project GDP growth averaging 2.5 percent per year from 2010 to 2035, and INFORUM (at 2.7 percent) and SEER (at 2.8 percent) project higher GDP growth than in the AEO2012 Reference Case over the same period. IEA projects a slightly lower rate of 2.4 percent per year from 2010 to 2035.

2. Oil prices

In the AEO2012 Reference case, oil prices [West Texas Intermediate (WTI)] rise from \$79 per barrel in 2010 to about \$117 per barrel in 2015 and \$127 per barrel in 2020 (Table 23). From the 2020 level, prices increase slowly to \$145 per barrel in 2035. This price trend is slightly higher than the trend shown in last year's AEO2011 Reference case.

Table 22. Projections of average annual economic growth, 2010-2035

Projection	Average annual percentage growth rates			
	2010-2015	2010-2020	2020-2035	2010-2035
AEO2012 (Reference case)	2.5	2.5	2.6	2.5
AEO2011 (Reference case)	3.0	2.8	2.6	2.7
IHSGI (November 2011)	2.5	2.5	2.5	2.5
OMB (January 2012) ^a	3.1	3.0	--	--
CBO (January 2012) ^a	2.7	2.8	--	--
INFORUM (January 2012)	3.4	3.1	2.4	2.7
Social Security Administration (August 2011)	3.3	3.0	2.1	2.5
IEA (2011) ^b	--	2.6	2.4	2.4
Blue Chip Consensus (October 2011) ^a	2.6	2.6	--	--
ExxonMobil	2.7	2.7	2.3	2.5
SEER	2.4	2.7	2.8	2.8

-- = not reported

^aOMB, CBO, and Blue Chip forecasts end in 2022, and growth rates cited are for 2010-2022

^bIEA publishes U.S. growth rates for certain intervals: 2009-2020 growth is 2.6 percent, and 2009-2035 growth rate is 2.4 percent

Market volatility and different assumptions about the future of the world economy are reflected in the range of price projections for both the short term and the long term; however, most projections show prices rising over the entire course of the projection period. The projections range from \$82 per barrel to \$117 per barrel in 2015 (a span of \$35 per barrel) and from \$98 per barrel to \$145 per barrel in 2035 (a span of \$47 per barrel). The wide range underscores the uncertainty inherent in the projections. The range of the projections is encompassed in the range of the *AEO2012* Low and High Oil Price cases, from \$58 per barrel to \$182 per barrel in 2015 and from \$62 per barrel to \$200 per barrel in 2035.

The measure of oil prices is, by and large, comparable across projections. EIA reports the price of low-sulfur, light crude oil, approximately the same as the WTI price widely cited in the trade press. The only series that do not report projections in WTI terms are IEA, with prices in the Current Policies Scenario expressed as the price of imported crude oil, and INFORUM, with prices expressed as the average U.S. refiner acquisition cost (RAC) of imported crude oil.

3. Total energy consumption

Five projections by other organizations—INFORUM, IHS&I, ExxonMobil, IEA, and BP—include energy consumption by sector. To allow comparison with the IHS&I projection, the *AEO2012* Reference case was adjusted to remove coal-to-liquids (CTL) heat and power, biofuels heat and co-products, and natural gas feedstock use. To allow comparison with the ExxonMobil projection, electricity consumption in each sector was removed from the *AEO2012* Reference case projections. To allow comparison with the IEA and BP projections, the *AEO2012* Reference case projections for the residential and commercial sectors were combined to produce a buildings sector projection. BP does not include the electric power sector in its projection for total energy consumption; however, it does include conversion losses that allow comparison on the basis of total energy consumption. The IEA projections have a base year of 2009, as opposed to 2010 in the other projections, and BP's projections extend only through 2030, not 2035.

Total energy consumption is higher in all projection years in both the IHS&I and INFORUM projections than in the *AEO2012* Reference case. ExxonMobil, IEA, and BP show lower total energy consumption in all years (Table 24). ExxonMobil and BP include a cost for carbon dioxide (CO₂) emissions in their outlooks, which helps to explain the lower level of consumption in those outlooks. While the IEA reference case also includes a cost for CO₂ emissions, the IEA Current Policies Scenario (which assumes that no new policies are added to those in place in mid-2011) was used for comparison in this analysis, because it corresponds better with the assumptions in *AEO2012*.

The INFORUM projection of total energy consumption in 2035 is almost 8 quadrillion Btu higher than the *AEO2012* Reference case projection, with the industrial and electric power sectors each about 2 quadrillion Btu higher and the transportation sector about 3 quadrillion Btu higher. For the transportation sector, the difference appears to result from a higher number of light-duty vehicle miles traveled in the INFORUM results, which offsets slightly higher motor gasoline prices in the INFORUM projection. Vehicle efficiency is essentially the same in the INFORUM and *AEO2012* projections. INFORUM also projects higher revenue passenger-miles for air travel than *AEO2012*. Diesel prices are lower in the INFORUM projection, which leads to higher demand (about 1 quadrillion Btu) than in *AEO2012*. In the industrial sector, INFORUM projects industrial shipments in 2035 that are approximately 1.5 times the level of those in the *AEO2012* Reference case, which helps to explain the higher level of industrial energy consumption in the INFORUM projection relative to *AEO2012*.

IHS&I projects significantly higher electricity consumption for all sectors than in the *AEO2012* Reference case, which helps to explain much of the difference in total energy consumption between the two projections. In the IHS&I projection, the electric power sector consumes 13 quadrillion Btu more energy in 2035 than in the *AEO2012* Reference case. The greater use of electricity in the IHS&I projection, including 300 trillion Btu used by electric vehicles, also results in higher electricity prices than in the *AEO2012* Reference case.

Table 23. Projections of oil prices, 2015-2035
(2010 dollars per barrel)

Projection	2015	2020	2025	2030	2035
<i>AEO2012</i> (Reference case)	116.91	126.68	132.56	138.49	144.98
<i>AEO2011</i> (Reference case)	95.41	109.05	118.57	124.17	126.03
EVA	82.24	84.75	89.07	94.78	102.11
IEA (Current Policies Scenario)	106.30	118.10	127.30	134.50	140.00
INFORUM	91.78	105.84	113.35	117.83	116.76
IHS&I	99.16	72.89	87.19	95.65	98.08
Purvin & Gertz	98.75	103.77	106.47	107.37	107.37
SEER	94.20	101.57	107.13	111.26	121.94

Although there are differences in energy consumption by sector between the ExxonMobil and BP projections, in both cases total energy consumption declines from 2010 levels and is lower than in the *AEO2012* Reference case. The difference appears to result primarily from the inclusion of a tax on CO₂ emissions in both the ExxonMobil and BP projections, which is not considered in the *AEO2012* projection. Energy consumption in the transportation sector declines from 2010 levels in both the ExxonMobil and BP projections, driven by policy changes and technology improvement; however, BP projects a much larger drop in transportation energy consumption, a total of 4 quadrillion Btu (or four times the decline in the ExxonMobil projection) between 2010 and 2030.

Although energy consumption in all sectors in the IEA projection is higher in 2035 than in 2010, energy consumption in the transportation and industrial sectors declines from 2020 to 2030, by less than 1 quadrillion Btu in each sector.

Continuation with other projection.

IEA projects little change for energy use in those two sectors from 2030 to 2035, with industrial energy consumption declining very slowly and transportation energy consumption increasing very slightly. IEA projects total energy consumption that is higher than BP in 2030 and higher than ExxonMobil in 2035 but considerably lower than in the AEO2012 Reference case.

4. Electricity

Table 25 compares summary results for the electric power sector from the AEO2012 Reference case with projections by Energy Ventures Analysis (EVA), IHSGI, and INFORUM. In 2015, total electricity sales range from a low of 3,753 billion kilowatthours in the AEO2012 Reference case to a high of 4,173 billion kilowatthours in the IHSGI projection. IHSGI shows higher sales across

Table 24. Projections of energy consumption by sector, 2010-2035 (quadrillion Btu)

Sector	AEO2012					
	Reference	INFORUM	IHSGI	ExxonMobil	IEA	BP
2010						
Residential	11.7	11.4	11.2	--	--	--
Residential excluding electricity	6.7	6.5	6.2	6.0	--	--
Commercial	8.7	8.5	8.6	--	--	--
Commercial excluding electricity	4.2	3.9	4.0	4.0	--	--
Buildings sector	20.4	20.0	19.8	10.0	19.1 ^a	21.8
Industrial	23.4	23.1	--	--	22.9 ^a	23.0
Industrial excluding electricity	20.1	19.9	--	20.0	--	--
Losses ^b	0.8	--	--	--	--	--
Natural gas feedstocks	0.5	--	--	--	--	--
Industrial removing losses and feedstocks	22.0	--	21.4	--	--	--
Transportation	27.6	27.4	26.6	27.0	22.9 ^a	22.8
Electric power	39.6	40.1	40.8	37.0	35.6 ^a	--
Less: electricity demand ^c	12.8	12.8	12.8	--	14.3 ^a	--
Electric power losses	26.8	27.3	--	--	--	23.1
Total primary energy	98.2	97.8	--	94.0	85.7^a	90.7
Excluding losses ^b and feedstocks	96.8	--	95.8	--	--	--
2020						
Residential	11.4	11.2	11.8	--	--	--
Residential excluding electricity	6.4	6.4	5.8	6.0	--	--
Commercial	9.2	9.5	9.5	--	--	--
Commercial excluding electricity	4.3	4.3	4.0	4.0	--	--
Buildings sector	20.5	20.7	21.3	9.0	20.4	21.9
Industrial	24.6	27.4	--	--	24.8	23.4
Industrial excluding electricity	21.2	23.9	--	20.0	--	--
Losses ^b	1.2	--	--	--	--	--
Natural gas feedstocks	0.5	--	--	--	--	--
Industrial removing losses and feedstocks	22.9	--	22.5	--	--	--
Transportation	27.3	29.0	27.4	28.0	23.8	21.0
Electric power	40.2	41.6	48.6	39.0	39.3	--
Less: electricity demand ^c	13.3	13.6	15.7	--	16.4	--
Electric power losses	26.9	28.0	--	--	--	23.7
Total primary energy	99.3	105.1	--	96.0	91.4	90.1
Excluding losses ^b and feedstocks	97.6	--	104.1	--	--	--

-- = not reported

See notes at end of table.

(continued on next page)

Comparison with other projections

all sectors in 2015 in comparison with the other projections. Total electricity sales in 2035 in the IHSGI projection (5,652 billion kilowatthours) are higher than in the others: 4,415 billion kilowatthours in the AEO2012 Reference case, 4,483 billion kilowatthours in the INFORUM projection, and 4,726 billion kilowatthours in the EVA projection. Although IHSGI projects higher electricity sales in all sectors in 2035, the largest percentage differences between the IHSGI and other projections are in the industrial sector. Electricity sales in the industrial sector in 2035 in the IHSGI projection are 1,387 billion kilowatthours, as compared with 977 billion kilowatthours in the AEO2012 Reference case, 941 billion kilowatthours in the EVA projection, and 968 billion kilowatthours in the INFORUM projection.

Table 24. Projections of energy consumption by sector, 2010-2035 (quadrillion Btu) (continued)

Sector	AEO2012					
	Reference	INFORUM	IHSGI	ExxonMobil	IEA	BP
	2030					
Residential	11.7	11.6	12.6	--	--	--
Residential excluding electricity	6.2	6.3	5.7	5.0	--	--
Commercial	9.9	10.6	10.4	--	--	--
Commercial excluding electricity	4.4	4.5	4.0	4.0	--	--
Buildings sector	21.6	22.1	23.0	9.0	22.0	23.0
Industrial	26.1	28.8	--	--	24.1	23.2
Industrial excluding electricity	22.7	25.3	--	19.0	--	--
Losses ^b	2.4	--	--	--	--	--
Natural gas feedstocks	0.5	--	--	--	--	--
Industrial removing losses and feedstocks	23.3	--	23.0	--	--	--
Transportation	27.9	30.7	27.5	26.0	22.9	18.5
Electric power	43.2	45.0	54.3	41.0	41.6	--
Less: electricity demand ^c	14.5	14.8	18.1	--	17.9	--
Electric power losses	28.7	30.1	--	--	--	24.1
Total primary energy	104.3	111.8	--	94.0	92.3	88.9
Excluding losses ^b and feedstocks	101.5	--	109.7	--	--	--
	2035					
Residential	11.9	11.7	13.0	--	--	--
Residential excluding electricity	6.1	6.2	5.5	5.0	--	--
Commercial	10.3	11.1	10.8	--	--	--
Commercial excluding electricity	4.5	4.6	4.0	3.0	--	--
Buildings sector	22.2	22.8	23.8	8.0	22.9	--
Industrial	26.9	29.1	--	--	23.9	--
Industrial excluding electricity	23.6	25.7	--	18.0	--	--
Losses ^b	3.2	--	--	--	--	--
Natural gas feedstocks	0.4	--	--	--	--	--
Industrial removing losses and feedstocks	23.3	--	23.3	--	--	--
Transportation	28.6	31.9	27.8	25.0	23.1	--
Electric power	44.2	46.2	57.2	40.0	42.5	--
Less: electricity demand ^c	15.1	15.3	19.3	--	18.6	--
Electric power losses	29.2	30.8	--	--	--	--
Total primary energy	106.9	114.7	--	92.0	93.4	--
Excluding losses ^b and feedstocks	103.3	--	112.7	--	--	--

-- ■ not reported

^aIEA data are for 2009^bLosses in CTL and biofuel production^cEnergy consumption in the sectors includes electricity demand purchases from the electric power sector, which are subtracted to avoid double counting in deriving total primary energy consumption

Comparison with other projections

Table 25. Comparison of electricity projections, 2015, 2025, and 2035 (Billion kilowatthours, except where noted)

Projection	2010	AEO2012	Other projections		
		Reference case	EVA	IHSGI	INFORUM
			2015		
Average end-use price (2010 cents per kilowatthour) ^a	9.8	9.7	--	10.2	--
Residential	11.5	11.8	12.8	12.0	10.5
Commercial	10.1	9.9	11.5	10.7	9.3
Industrial	6.7	6.5	7.9	7.0	6.2
Total generation plus imports	4,152	4,181	4,053	4,611	--
Coal	1,851	1,581	1,591	1,905	--
Petroleum	37	28	--	45	--
Natural gas ^b	982	1,130	1,090	1,223	--
Nuclear	807	830	827	839	--
Hydroelectric/other ^c	449	583	515	576	--
Net imports	26	29	29	24	--
Electricity sales	3,749	3,753	3,921	4,173	3,854
Residential	1,451	1,392	1,481	1,563	1,365
Commercial/other ^d	1,336	1,354	1,414	1,489	1,438
Industrial	962	1,008	1,025	1,121	1,051
Capacity, including CHP (gigawatts) ^e	1,036	1,042	1,094	1,101	--
Coal	318	286	289	309	--
Oil and natural gas	459	464	514	491	--
Nuclear	101	104	106	104	--
Hydroelectric/other ^f	158	188	185	197	--
			2025		
Average end-use price (2010 cents per kilowatthour) ^a	9.8	9.7	--	10.9	--
Residential	11.5	11.6	13.2	12.8	10.5
Commercial	10.1	9.9	11.7	11.4	9.3
Industrial	6.7	6.7	8.0	7.4	6.2
Total generation plus imports	4,152	4,578	4,514	5,417	--
Coal	1,851	1,786	1,653	1,774	--
Petroleum	37	29	--	45	--
Natural gas ^b	982	1,140	1,335	1,760	--
Nuclear	807	917	870	918	--
Hydroelectric/other ^c	449	683	629	896	--
Net imports	26	22	27	25	--
Electricity sales	3,749	4,090	4,298	4,942	4,167
Residential	1,451	1,533	1,650	1,887	1,468
Commercial/other ^d	1,336	1,525	1,679	1,793	1,660
Industrial	962	1,032	969	1,261	1,039
Capacity, including CHP (gigawatts) ^e	1,036	1,091	1,119	1,274	--
Coal	318	282	267	283	--
Oil and natural gas	459	493	518	566	--
Nuclear	101	115	110	114	--
Hydroelectric/other ^f	158	201	224	312	--

-- = not reported.

See notes at end of table

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Comparison of electricity projections

Only IHSGI and the AEO2012 Reference case provide average electricity price projections through 2035. Average electricity prices in the AEO2012 Reference case are 9.8 cents per kilowatthour in 2010 and 9.7 cents per kilowatthour in 2015 and 2025 before reaching 10.1 cents per kilowatthour in 2035. In the IHSGI projection, the average electricity price rises continuously (with the exception of a small decrease from 2017 to 2018), from 9.8 cents per kilowatthour in 2010 to 10.2 cents in 2015, 10.9 cents in 2025, and 12.1 cents per kilowatthour in 2035.

In all the projections, average electricity prices by sector follow patterns similar to changes in the weighted average electricity price across all sectors (including transportation services). The lowest prices by sector in 2015 are in the INFORUM projection (10.5 cents per kilowatthour in the residential sector, 9.3 cents per kilowatthour in the commercial sector, and 6.2 cents per kilowatthour in the industrial sector). The highest average electricity prices by sector in 2015 are in the EVA projection (12.8 cents per kilowatthour in the residential sector, 11.5 cents per kilowatthour in the commercial sector, and 7.9 cents per kilowatthour in the industrial sector).

In the AEO2012 Reference case, electricity prices for the residential sector are 11.8 cents per kilowatthour in both 2015 and 2035, electricity prices for the commercial sector increase from 9.9 cents per kilowatthour in 2015 to 10.1 cents per kilowatthour in 2035, and electricity prices for the industrial sector increase from 6.5 cents per kilowatthour in 2015 to 7.1 cents per kilowatthour in 2035. When compared with the AEO2012 Reference case prices in 2035, the largest difference is with the IHSGI projection. The IHSGI price projections are much higher than those in the AEO2012 Reference case. IHSGI shows real electricity prices rising to 14.3 cents per kilowatthour for the residential sector, 12.5 cents per kilowatthour for the commercial sector, and 8.1 cents per kilowatthour for the industrial sector in 2035.

Table 25. Comparison of electricity projections: 2010, 2025, and 2035 (billion kilowatthours, *except where noted) (continued)

Projection	2010	AEO2012	Other projections		
		Reference case	EVA	IHSGI	INFORUM
		2035			
Average end-use price (2010 cents per kilowatthour) ^a	9.8	10.1	--	12.1	--
Residential	11.5	11.8	12.9	14.3	10.5
Commercial	10.1	10.1	11.3	12.5	9.3
Industrial	6.7	7.1	7.6	8.1	6.2
Total generation plus imports	4,152	5,004	--	6,199	--
Coal	1,851	1,897	--	1,618	--
Petroleum	37	30	--	45	--
Natural gas ^b	982	1,398	--	2,354	--
Nuclear	807	887	--	1,030	--
Hydroelectric/other ^c	449	780	--	1,124	--
Net imports	26	12	--	28	--
Electricity sales	3,749	4,415	4,726	5,652	4,483
Residential	1,451	1,718	1,778	2,178	1,611
Commercial/other ^d	1,336	1,721	2,008	2,088	1,904
Industrial	962	977	941	1,387	968
Capacity, including CHP (gigawatts)^e	1,036	1,190	--	1,450	--
Coal	318	285	--	262	--
Oil and natural gas	459	568	--	665	--
Nuclear	101	111	--	128	--
Hydroelectric/other ^f	158	226	--	396	--

-- = not reported.

^aAverage end-use price includes the transportation sector.

^bIncludes supplemental gaseous fuels. For EVA, represents total oil and natural gas.

^c"Other" includes conventional hydroelectric, pumped storage, geothermal, wood, wood waste, municipal waste, other biomass, solar and wind power, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, petroleum coke, and miscellaneous technologies.

^d"Other" includes sales of electricity to government and other transportation services.

^eEIA capacity is net summer capacity, including CHP plants.

^f"Other" includes conventional hydro, geothermal, wood, wood waste, all municipal waste, landfill gas, other biomass, solar, wind power, pumped storage, and fuel cells.

Electricity Generation and Imports

Total electricity generation plus imports in 2015 ranges from a low of 4,053 billion kilowatthours in the EVA projection to a high of 4,611 billion kilowatthours in the IHS&I projection, compared with 4,181 billion kilowatthours in the AEO2012 Reference case. Although coal represents the largest share of generation in 2015 in all the projections, the natural gas share of total generation grows from 2015 to 2035 in all the projections, particularly IHS&I. In the IHS&I projection, coal has a 33-percent share of total generation in 2025, and the natural gas share is 32 percent. IHS&I shows natural gas overtaking coal as a share of total generation by 2035 as a result of the carbon tax assumed in the IHS&I projection and the need to replace existing units that are uneconomical or are being retired for various regulatory or environmental reasons. In 2035, the coal share in the IHS&I projection is 26 percent of total generation, and the natural gas share is 38 percent. In the AEO2012 Reference case, which does not include a carbon tax, the coal share also decreases but only to 38 percent of total generation, while the natural gas share increases to 28 percent.

Nuclear generation in 2015 ranges from a low of 827 billion kilowatthours in the EVA projection to a high of 839 billion kilowatthours in the IHS&I projection. From 2015 to 2025, EVA projects a 5-percent increase in nuclear generation, to 870 billion kilowatthours. IHS&I and AEO2012 project increases of 9 percent and 10 percent, respectively. In the IHS&I projection, nuclear generation totals 1,030 billion kilowatthours in 2035, a 12-percent increase from 2025. The AEO2012 Reference case shows nuclear generation declining to 887 billion kilowatthours in 2035, a 3-percent decrease from 2025, as units are retired when they reach the end of their useful generation lifetimes.

Total generating capacity by fuel in 2015 is relatively similar across the projections, ranging from 1,042 gigawatts in the AEO2012 Reference case to 1,101 gigawatts in the IHS&I projection, but IHS&I shows a much larger decrease in capacity in 2025. IHS&I projects more aggressive growth in total generating capacity, due to what appears to be a much higher demand projection. Natural gas and oil-fired capacity grows to 566 gigawatts in 2025 in the IHS&I projection, compared with 493 gigawatts in AEO2012 and 518 gigawatts in the EVA projections. Hydroelectric/other capacity grows to 312 gigawatts in 2025 in the IHS&I projection, higher than the 201 gigawatts in AEO2012. The faster growth in natural gas and hydroelectric/other capacity in the IHS&I projection continues through 2035. Natural gas and oil-fired capacity grows to 665 gigawatts in 2035, and hydroelectric/other capacity grows to 396 gigawatts in 2035 in the IHS&I projection. By comparison, natural gas and oil-fired capacity grows to 568 gigawatts and hydroelectric/other capacity grows to 226 gigawatts in the AEO2012 Reference case in 2035.

5. Natural Gas

The projections of natural gas consumption, production, imports, and prices (Table 26) vary significantly as a result of differences in assumptions. For example, the AEO2012 Reference case assumes that current laws and regulations remain unchanged throughout the projection period (including the implication that laws which include sunset dates do, in fact, become ineffective at the time of those sunset dates), whereas the other projections may include anticipated policy developments over the next 25 years. In particular, the AEO2012 Reference case does not assume changes in CO₂ emissions policies.

Each of the projections shows an increase in overall natural gas consumption from 2010 to 2035, with the IHS&I projection showing the largest increase, 39 percent. The ExxonMobil projection includes an increase of around 20 percent. The EVA projection shows an increase of 26 percent from 2010 to 2030 (EVA does not extend to 2035). Total natural gas consumption in the AEO2012, Deloitte, and SEER projections increases from 2010 to 2035, with total natural gas consumption growing from 4 to 31 percent. IHS&I shows the largest increase and INFORUM the smallest. The IHS&I projection for total natural gas consumption in 2035 is 36 percent higher than the INFORUM projection. In the AEO2012 Reference case, total natural gas consumption grows by 5 percent from 2015 to 2035.

The IHS&I and ExxonMobil projections for natural gas consumption by electricity generators are much higher than the other projections shown in Table 26. In 2035, natural gas consumption by electricity generators in the IHS&I projection is more than double the consumption projected by INFORUM, and the ExxonMobil projection is 77 percent higher than the INFORUM projection. The AEO2012 Reference case, SEER, and INFORUM projections show similar levels of natural gas consumption in the electricity generation sector in 2035, with average annual growth of 1 percent or less across the projection period, while consumption grows by an average of 3 percent in the ExxonMobil and IHS&I projections. The slower rate of growth in the AEO2012 Reference case reflects relatively slower growth in electricity consumption and faster growth in renewable energy consumption than in the other projections.

Industrial natural gas consumption is similar across the projections, but with more rapid growth projected by EVA, Deloitte, and INFORUM. Natural gas consumption increases by 23 percent from 2010 to 2030 in the EVA projection and by 23 percent and 11 percent, respectively, from 2010 to 2035 in the INFORUM and Deloitte projections. All of the growth in industrial natural gas consumption in the Deloitte and INFORUM projections is between 2010 and 2015. In the AEO2012 Reference case, in contrast, industrial natural gas consumption grows by 6 percent from 2010 to 2035. In the ExxonMobil projection, industrial natural gas consumption remains constant over the projection period; in the IHS&I projection industrial natural gas consumption falls from 2010 to 2035; and in the INFORUM, SEER, and Deloitte projections, after an initial increase, industrial natural gas consumption declines from 2015 to 2035.

The levels of commercial sector natural gas consumption are similar across the projections, but projections for the residential sector vary significantly [140]. Three of the seven projections (INFORUM, Deloitte, and EVA) show similar growth in residential consumption through 2030, and INFORUM and Deloitte are similar through 2035; however, the IHS&I and AEO2012 projections

Comparison of natural gas projections

show larger declines in residential consumption of natural gas from 2010 to 2035 (11 percent and 6 percent, respectively). The SEER projection for residential natural gas consumption shows a decrease of 4 percent from 2015 to 2025, then a partial recovery by 2035.

Table 26. Comparison of natural gas projections, 2015, 2025, and 2035 (trillion cubic feet, except where noted)

Projection	2010	AEO2012 Reference case	Other projections							
			IHSGI	EVA	Deloitte	SEER	ExxonMobil	INFORUM		
			2015							
Dry gas production ^a	21.58	23.65	23.81	23.80	24.52	23.66	24.00	24.29		
Net imports	2.58	1.73	1.62	2.20	1.30	1.73	1.20	--		
Pipeline	2.21	1.56	--	1.80	1.22	1.56	--	--		
LNG	0.37	0.16	--	0.40	0.08	0.16	--	--		
Consumption	24.13	25.39	25.52	26.60	24.07^b	26.05	25.00^c	23.61^b		
Residential	4.94	4.85	4.64	4.90	4.86	4.91	8.00 ^d	4.87		
Commercial	3.20	3.33	3.10	3.20	3.23	3.41	--	3.43		
Industrial ^e	6.60	7.01	6.64	7.00	7.51	7.64	8.00	8.19		
Electricity generators ^f	7.38	8.08	9.02	9.30	8.46	8.06	9.00	7.12		
Others ^g	2.01	2.12	2.11	2.20	--	2.04	--	--		
Henry Hub spot market price (2010 dollars per million Btu)	4.39	4.29	4.75	4.07	4.25	4.28	--	--		
End-use prices (2010 dollars per thousand cubic feet)										
Residential	11.36	10.56	11.82	--	--	11.68	--	--		
Commercial	9.32	8.82	9.88	--	--	8.31	--	--		
Industrial ^h	5.65	5.00	6.95	--	--	4.63	--	--		
Electricity generators	5.25	4.65	5.20	--	--	5.17	--	--		
					2025					
Dry gas production ^a	21.58	26.28	27.23	26.70	27.32	25.88	27.00	27.57		
Net imports	2.58	-0.79	2.13	1.30	0.38	0.29	1.50	--		
Pipeline	2.21	-0.13	--	0.90	0.29	1.03	--	--		
LNG	0.37	-0.66	--	0.40	0.09	-0.74	--	--		
Consumption	24.13	25.53	29.39	29.00	26.36^b	27.10	29.00^c	23.43^b		
Residential	4.94	4.76	4.53	5.00	5.05	4.71	8.00 ^d	4.90		
Commercial	3.20	3.44	3.15	3.30	3.46	3.53	--	3.60		
Industrial ^e	6.60	7.14	6.52	7.70	7.58	7.47	8.00	8.20		
Electricity generators ^f	7.38	7.87	12.78	10.50	10.27	9.27	13.00	6.74		
Others ^g	2.01	2.31	2.42	2.50	--	2.12	--	--		
Henry Hub spot market price (2010 dollars per million Btu)	4.39	5.63	4.82	6.47	5.80	6.29	--	--		
End-use prices (2010 dollars per thousand cubic feet)										
Residential	11.36	12.33	11.70	--	--	14.40	--	--		
Commercial	9.32	10.27	9.81	--	--	10.68	--	--		
Industrial ^h	5.65	6.19	6.99	--	--	6.96	--	--		
Electricity generators	5.25	5.73	5.28	--	--	7.47	--	--		

-- = not reported.

See notes at end of table.

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With the exception of ExxonMobil, which shows a decline in U.S. production of domestic natural gas between 2030 and 2035, all the projections show increasing U.S. production of domestic natural gas over the projection period, although at different rates. The highest level of natural gas production is projected by IHSGI, exceeding the ExxonMobil projection by 21 percent in 2035. Coupled with a significant decline in net pipeline imports, SEER, INFORUM, and the AEO2012 Reference case project a strong increase in the share of total U.S. natural gas supply accounted for by domestic production. The other projections show relatively stable and similar percentages for the contribution of domestic natural gas production to total supply, with the exception of IHSGI, which shows a notable increase in net imports after 2015. In all the projections, with the exception of EVA, net LNG imports remain below the 2010 level of 0.4 trillion cubic feet throughout the projection period. In all the projections, however, net pipeline imports decline from 2010 levels, with AEO2012, SEER, and Deloitte projecting more severe declines than EVA (only through 2030 since EVA does not show 2035).

The AEO2012 Reference case and SEER show similar levels of natural gas production and Henry Hub spot prices, both with increasing production and prices over time. EVA shows similar levels of natural gas production as the AEO2012 Reference case through 2025, but higher Henry Hub spot prices. IHSGI projects a larger increase in natural gas production but at relatively stable prices. In 2015, the Henry Hub spot price in the IHSGI projection is 11 percent higher than the price in the SEER projection; however, the SEER Henry Hub spot price quickly surpasses the IHSGI price, and it is 50 percent higher in 2035. Deloitte, ExxonMobil, and INFORUM did not include price projections.

Only IHSGI and SEER included delivered natural gas prices that can be compared with those in the AEO2012 Reference case [141]. However, there appear to be definitional differences in the projections, based on an examination of 2010 price levels. In particular,

*Table 26. Comparison of natural gas projections, 2015, 2025, and 2035 (trillion cubic feet, except where noted)
(continued)*

Projection	2010	AEO2012	Other projections					
		Reference case	IHSGI	EVA	Deloitte	SEER	ExxonMobil	INFORUM
						2035		
Dry gas production ^a	21.58	27.93	31.35	--	27.87	27.00	26.00	30.71
Net imports	2.58	-1.36	2.36	--	0.14	-0.46	2.50	--
Pipeline	2.21	-0.70	--	--	0.07	0.28	--	--
LNG	0.37	-0.66	--	--	0.08	-0.74	--	--
Consumption	24.13	26.63	33.54	--	27.30 ^b	27.24	29.00 ^c	24.66 ^b
Residential	4.94	4.64	4.38	--	5.03	4.80	7.00 ^d	4.83
Commercial	3.20	3.60	3.18	--	3.60	3.64	--	3.83
Industrial ^e	6.60	7.00	6.35	--	7.31	7.30	8.00	8.09
Electricity generators ^f	7.38	8.96	16.90	--	11.37	9.37	14.00	7.90
Others ^g	2.01	2.43	2.72	--	--	2.13	--	--
Henry Hub spot market price (2010 dollars per million Btu)	4.39	7.37	5.13	7.26	6.63	7.70	--	--
End-use prices (2010 dollars per thousand cubic feet)								
Residential	11.36	14.33	11.81	--	--	17.15	--	--
Commercial	9.32	11.93	9.99	--	--	13.09	--	--
Industrial ^h	5.65	7.73	7.22	--	--	9.20	--	--
Electricity generators	5.25	7.37	5.62	--	--	9.75	--	--

-- = not reported.

^aDoes not include supplemental fuels

^bDoes not include lease, plant, and pipeline fuel and fuel consumed in natural gas vehicles

^cDoes not include lease, plant, and pipeline fuel

^dNatural gas consumed in the residential and commercial sectors

^eIncludes consumption for industrial combined heat and power (CHP) plants and a small number of industrial electricity-only plants, and natural gas-to-liquids heat/power production; excludes consumption by nonutility generators.

^fIncludes consumption of energy by electricity-only and CHP plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes electric utilities, small power producers, and exempt wholesale generators.

^gIncludes lease, plant, and pipeline fuel and fuel consumed in natural gas vehicles

^hThe 2010 industrial natural gas price for IHSGI is \$6.53.

Comparison of liquids projections

the IHSGI industrial delivered natural gas price is difficult to compare. The industrial delivered natural gas price for 2010 in the IHSGI projection is \$0.88 higher than the industrial price for 2010 in the AEO2012 Reference case and \$1.13 higher than the 2010 industrial price in the SEER projection (all prices in 2010 dollars per thousand cubic feet). From 2010 to 2035, the delivered price for electricity generators increases by 7 percent in the IHSGI projection, by 40 percent in the AEO2012 Reference case, and by 86 percent in the SEER projection. The SEER projection also shows the largest increases in residential and commercial delivered prices, at 51 percent and 40 percent, respectively, over the same period. IHSGI shows the smallest increases in residential and commercial delivered prices over the projection period, at 4 percent and 7 percent, respectively. The AEO2012 Reference case projects a 26-percent increase in residential delivered natural gas prices and a 28-percent increase in commercial prices.

6. Liquid fuels

In the AEO2012 Reference case, the U.S. RAC for imported crude oil (in 2010 dollars) increases to \$113.97 per barrel in 2015, \$121.21 per barrel in 2025, and \$132.95 per barrel in 2035 (Table 27). Prices are lower in the INFORUM projection, ranging from \$91.78 per barrel in 2015 to \$116.76 per barrel in 2035. BP, EVA, and Purvin & Gertz (P&G) did not report projections of RAC prices.

Domestic crude oil production increases from about 5.5 million barrels per day in 2010 to a peak of 6.7 million barrels per day in 2020, then declines to about 6.0 million barrels per day in 2035 in the AEO2012 Reference case. Overall, the production level in 2035 is more than 9 percent higher than the 2010 level. The INFORUM projection shows a steady increase in production, to 5.8 million barrels per day in 2035. Domestic crude oil production decreases to 3.2 million barrels per day in 2035 in the P&G projection.

Supply from renewable sources increases to about 1.1 million barrels per day in 2015, almost 1.5 million barrels per day in 2025 (38.5 percent higher than the 2015 level), and more than 2.3 million barrels per day in 2035 (120.2 percent higher than the 2015 level) in the AEO2012 Reference case. In the BP projection, supplies from renewable sources, on an energy-equivalent basis, increase by 49.5 percent from 2015 to 2025. BP does not report supplies from renewable sources in 2035, and it is not included in the projections by EVA, INFORUM, and P&G.

Prices for both transportation diesel fuel and gasoline increase through 2035 in the AEO2012 projection, with diesel prices higher than gasoline prices. INFORUM projects rising gasoline prices from 2015 levels but decreasing diesel prices, with the gasoline price consistently higher than the diesel price. The BP, EVA, and P&G projections do not include delivered fuel prices.

7. Coal

Projections from EVA, IHSGI, INFORUM, IEA, ExxonMobil, and BP offer some opportunity to compare other coal outlooks with the AEO2012 Reference case. Although many of the assumptions used in the other projections are unknown, ExxonMobil does assume a carbon tax, and EVA assumes some additional regulations affecting coal use that are not included in current laws. Such assumptions

Table 27. Comparison of liquids projections, 2015, 2025, and 2035 (million barrels per day, except where noted)

Projection	2010	AEO2012 Reference case	Other projections			
			BP ^a	EVA	INFORUM	P&G
2015						
Average U.S. imported RAC (2010 dollars per barrel)	75.87	113.97	--	--	91.78	--
Average WTI price (2010 dollars per barrel)	79.39	116.91	--	82.24	--	98.75
Domestic production	7.55	8.71	8.56	9.60	--	7.92
Crude oil	5.47	6.15	--	6.90	5.43	5.43
Alaska	0.60	0.46	--	0.40	--	0.54
NGL	2.07	2.56	--	2.70	--	2.49
Total net imports	9.56	8.27	8.20	--	9.81	--
Crude oil	9.17	8.52	--	--	8.59	9.69
Products	0.39	-0.25	--	--	1.22	--
Liquids consumption	19.17	19.10	18.26	--	20.04 ^b	17.69
Net petroleum import share of liquids supplied (percent)	50	43	45	--	--	--
Supply from renewable sources	0.90	1.05	1.24	--	--	--
Transportation product prices (2010 dollars per gallon)						
Gasoline	2.76	3.54	--	--	3.85	--
Diesel	3.00	3.78	--	--	3.60	--

-- = not reported

See notes at end of table

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Comparison with other projections

probably contribute to lower coal consumption levels compared with historical levels and the AEO2012 Reference case. BP, EVA, ExxonMobil, and IHSGI have the most pessimistic views of coal use, with consumption declining over their respective projection horizons. In contrast, both the AEO2012 and INFORUM projections show rising coal consumption after an initial decline. INFORUM's projection for coal consumption in 2035 is the highest—12 percent higher than in the AEO2012 Reference case (Table 28).

Because most coal consumed in the United States is used for electricity generation, the outlooks with the largest declines in total coal consumption also show similar declines in coal use for electric power generation. The AEO2012 Reference case has the most pessimistic outlook for coal consumption in the power sector in 2015; however, while coal use in the electric power sector recovers after 2015 in the AEO2012 Reference case, it continues to decline in the EVA, IHSGI, ExxonMobil, and BP projections. ExxonMobil—which includes a carbon tax—shows the largest decline in coal use for electricity generation compared with the other projections.

*Table 27. Comparison of liquids projections, 2015, 2025, and 2035 (million barrels per day, except where noted)
(continued)*

Projection	2010	AEO2012	Other projections			
		Reference case	BP ^a	EVA	INFORUM	P&G
2025						
Average U.S. imported RAC (2010 dollars per barrel)	75.87	121.21	--	--	113.35	--
Average WTI price (2010 dollars per barrel)	79.39	132.56	--	89.07	--	106.47
Domestic production	7.55	9.41	9.20	11.10	--	7.37
Crude oil	5.47	6.40	--	7.10	5.74	4.26
Alaska	0.60	0.40	--	0.00	--	0.45
NGL	2.07	3.01	--	4.00	--	3.11
Total net imports	9.56	7.12	5.87	--	9.89	--
Crude oil	9.17	7.24	--	--	8.31	10.71
Products	0.39	-0.12	--	--	1.58	--
Liquids consumption	19.17	19.20	17.30	--	20.38 ^b	17.39
Net petroleum import share of liquids supplied (percent)	50	37	34	--	--	--
Supply from renewable sources	0.90	1.45	1.85	--	--	--
Transportation product prices (2010 dollars per gallon)						
Gasoline	2.76	3.85	--	--	4.36	--
Diesel	3.00	4.17	--	--	3.46	--
2035						
Average U.S. imported RAC (2010 dollars per barrel)	75.87	132.95	--	--	116.76	--
Average WTI price (2010 dollars per barrel)	79.39	144.98	--	102.11	--	107.37
Domestic production	7.55	9.00	--	--	--	--
Crude oil	5.47	5.99	--	--	5.80	3.23
Alaska	0.60	0.27	--	--	--	0.41
NGL	2.07	3.01	--	--	--	--
Total net imports	9.56	7.18	--	--	10.36	--
Crude oil	9.17	7.52	--	--	8.49	11.68
Products	0.39	-0.34	--	--	1.88	--
Liquids consumption	19.17	19.90	--	--	21.31 ^b	17.38
Net petroleum import share of liquids supplied (percent)	50	36	--	--	--	--
Supply from renewable sources	0.90	2.31	--	--	--	--
Transportation product prices (2010 dollars per gallon)						
Gasoline	2.76	4.03	--	--	4.49	--
Diesel	3.00	4.44	--	--	3.30	--

-- = not reported

^aFor BP, liquids production data were converted from million metric tons to barrels at 8.067817 barrels per metric ton, and liquids demand data were converted at 8.162674 barrels per metric ton. One metric ton equals 1,000 kilograms.

^bFor INFORUM, liquids demand data were converted from quadrillion Btus to barrels at 187.84572 million barrels per quadrillion Btu.

and coal consumption in the BP outlook also declines from 2010 levels. The EVA projection for coal consumption in the electric power sector in 2030 is 13 percent lower than the 2010 level, whereas coal consumption returns to 2010 levels in 2030 in the AEO2012 Reference case. The IEA projection for coal consumption in the electric power sector in 2035, at 19.2 quadrillion Btu, is similar to the AEO2012 Reference case projection.

EVA, IHSGI, and the AEO2012 Reference case all project declining use of coal at coking plants through 2030, with EVA including the most pessimistic outlook. INFORUM's industrial coal consumption figure, which appears to include both coking coal consumption

Table 28. Comparison of coal projections, 2015, 2025, 2030, and 2035 (million short tons, except where noted)

Projection	AEO2012 Reference case			Other projections					
	2010	(million short tons)	(quadrillion Btu)	EVA ^a	IHSGI	INFORUM	IEA ^b	Exxon-Mobil ^c	BP ^b
	2015								
Production	1,084	993	20.24	1,017	1,144	970	--	--	22.00
East of the Mississippi	446	407	--	411	--	--	--	--	--
West of the Mississippi	638	586	--	606	--	--	--	--	--
Consumption									
Electric power	975	839	16.15	871	1,002	--	--	17.00	18.68
Coke plants	21	22	--	20	21	--	--	--	--
Coal-to-liquids	0	0	--	--	--	--	--	--	--
Other industrial/buildings	55	53	1.66 ^d	42	50	1.81 ^d	--	--	--
Total consumption (quadrillion Btu) ^e	20.76	--	17.80	--	--	--	--	19.00	20.53
Total consumption (million short tons)	1,051	914	--	933	1,073	916^f	--	--	--
Net coal exports	64	95	2.38	100	70	54	--	--	1.48
Exports	82	110	2.73	104	89	70	--	--	1.48
Imports	18	15	0.35	4	19	16	--	--	0.00 ^g
Minemouth price									
2010 dollars per ton	35.61	42.08	--	--	--	32.80	--	--	--
2010 dollars per Btu	1.76	2.08	--	--	--	--	--	--	--
Average delivered price to electricity generators									
2010 dollars per ton	44.27	45.17	--	--	--	42.72	--	--	--
2010 dollars per Btu	2.26	2.35	--	--	2.39	--	--	--	--
	2025								
Production	1,084	1,118	22.25	995	1,038	1,114	--	--	19.40
East of the Mississippi	446	383	--	403	--	--	--	--	--
West of the Mississippi	638	735	--	592	--	--	--	--	--
Consumption									
Electric power	975	952	18.06	847	927	--	--	15.00	16.16
Coke plants	21	19	--	17	19	--	--	--	--
Coal-to-liquids	0	38	--	--	--	--	--	--	--
Other industrial/buildings	55	55	1.63 ^d	33	39	2.07 ^d	--	--	--
Total consumption (quadrillion Btu) ^e	20.76	--	20.02	--	--	--	--	15.00	17.70
Total consumption (million short tons)	1,051	1,063	--	897	986	1,072^f	--	--	--
Net coal exports	64	71	1.79	113	53	42	--	--	1.70
Exports	82	115	2.82	118	73	75	--	--	1.70
Imports	18	44	1.03	4	20	33	--	--	0.00 ^g
Minemouth price									
2010 dollars per ton	35.61	44.05	--	--	--	33.43	--	--	--
2010 dollars per Btu	1.76	2.23	--	--	--	--	--	--	--
Average delivered price to electricity generators									
2010 dollars per ton	44.27	48.13	--	--	--	43.58	--	--	--
2010 dollars per Btu	2.26	2.54	--	--	2.48	--	--	--	--

-- = not reported.

See notes at end of table.

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Comparison with other projections

Table 28. Comparison of coal projections, 2015, 2025, 2030, and 2035 (million short tons, except where noted) (continued)

Projection	AEO2012 Reference case			Other projections					
	2010	(million short tons)	(quadrillion Btu)	EVA ^a	IHSGI	INFORUM	IEA ^b	Exxon-Mobil ^c	BP ^b
				(million short tons)					
				2030					
Production	1,084	1,166	23.22	992	984	1,177	--	--	17.99
East of the Mississippi	446	409	--	396	--	--	--	--	--
West of the Mississippi	638	757	--	596	--	--	--	--	--
Consumption									
Electric power	975	975	18.55	847	885	--	19.2	13.00	14.76
Coke plants	21	18	--	16	19	--	--	--	--
Coal-to-liquids	0	51	--	--	--	--	--	--	--
Other industrial/buildings	55	55	1.60 ^d	31	35	2.37 ^d	1.1 ^b	--	--
Total consumption (quadrillion Btu) ^e	20.76	--	20.59	--	--	--	--	13.00	16.18
Total consumption (million short tons)	1,051	1,099	--	894	938	1,156^f	--	--	--
Net coal exports	64	83	2.08	113	47	41	--	--	1.81
Exports	82	117	2.85	118	68	74	--	--	1.81
Imports	18	33	0.77	5	20	53	--	--	0.00 ^g
Minemouth price									
2010 dollars per ton	35.61	47.28	--	--	--	33.21	--	--	--
2010 dollars per Btu	1.76	2.39	--	--	--	--	--	--	--
Average delivered price to electricity generators									
2010 dollars per ton	44.27	50.56	--	--	--	43.31	--	--	--
2010 dollars per Btu	2.26	2.66	--	--	2.52	--	--	--	--
				2035					
Production	1,084	1,212	24.14	--	926	1,284	--	--	--
East of the Mississippi	446	431	--	--	--	--	--	--	--
West of the Mississippi	638	781	--	--	--	--	--	--	--
Consumption									
Electric power	975	998	19.03	--	837	--	19.2	11.00	--
Coke plants	21	17	--	--	18	--	--	--	--
Coal-to-liquids	0	67	--	--	--	--	--	--	--
Other industrial/buildings	55	56	1.58 ^d	--	31	2.70 ^d	1.1	--	--
Total consumption (quadrillion Btu) ^e	20.76	--	21.15	--	--	--	--	11.00	--
Total consumption (million short tons)	1,051	1,137	--	--	886	1,277^f	--	--	--
Net coal exports	64	94	2.31	--	42	8	--	--	--
Exports	82	129	3.13	--	63	71	--	--	--
Imports	18	36	0.82	--	20	64	--	--	--
Minemouth price									
2010 dollars per ton	35.61	50.52	--	--	--	33.06	--	--	--
2010 dollars per Btu	1.76	2.56	--	--	--	--	--	--	--
Average delivered price to electricity generators									
2010 dollars per ton	44.27	53.31	--	--	--	43.13	--	--	--
2010 dollars per Btu	2.26	2.80	--	--	2.54	--	--	--	--

-- = not reported.

^aRegulations known to be accounted for in the EVA projections include MATS, CSAPR, regulations for cooling-water intake structures under Section 316(b) of the Clean Water Act, and regulations for coal combustion residuals under authority of the Resource Conservation and Recovery Act.^bFor IEA and BP, data were converted from millions of tons oil equivalent (toe) at 39 683 million Btu per toe.^cExxonMobil projections include a carbon tax.^dCoal consumption in quadrillion Btu. INFORUM's value appears to include coal consumption at coke plants. To facilitate comparison the AEO2012 value also includes coal consumption at coke plants.^eFor AEO2012, excludes coal converted to coal-based synthetic liquids.^fCalculated as consumption = (production - exports + imports).^gCalculated as imports = (consumption - production + exports).

and coal use at industrial steam plants, is higher than projected in the *AEO2012* Reference case. EVA and IHSGI show declines in coal use in the industrial/buildings sector (excluding the coking sector), whereas the *AEO2012* outlook is more stable. According to ExxonMobil's projection, coal is consumed only for electricity generation after 2015, as implied consumption in all other sectors drops to zero. The *AEO2012* Reference case appears to be the only projection that includes coal use in CTL production.

Only EVA provides regional production information for comparison with the *AEO2012* Reference case. Despite much lower total coal consumption than in *AEO2012*, EVA's estimate of coal production east of the Mississippi is similar to that in the *AEO2012* Reference case. The differences in coal production are primarily in basins west of the Mississippi, where *AEO2012* projects 161 million more tons of coal production in 2030 than projected by EVA.

With respect to exports, two broad consensus groups are identifiable among the projections. The most optimistic projections are EVA and *AEO2012*, which show exports remaining above 100 million tons through 2030. However, EVA and *AEO2012* do differ, in that the *AEO2012* Reference case projects stronger growth for coking coal exports, and EVA projects stronger growth for thermal coal exports. The second group of projections, including BP, INFORUM, and IHSGI, shows a less optimistic outlook for U.S. coal exports. Coal exports in 2030 in the *AEO2012* Reference case are 1.0 quadrillion Btu higher than projected by BP. If BP's average heat rate for exports is assumed to be similar to that in *AEO2012*, BP's projected coal exports in 2030 are about 70 million tons, similar to the INFORUM and IHSGI projections for the same year. IHSGI's projection of exports is the lowest of this group, peaking in 2025 and then falling to 63 million tons in 2035.

The outlook for coal imports varies considerably across the projections, with little consensus. In the EVA projection, imports drop to a negligible 4 million tons early on and remain at that level for the balance of the projection, and in the BP projection, there are no coal imports to the United States after 2015. In the IHSGI projection, coal imports vary little through 2035. In 2035, coal imports in the *AEO2012* Reference case are just over one-half those in the INFORUM outlook.

Coal price comparisons can be made only for the *AEO2012*, IHSGI, and INFORUM projections. *AEO2012* includes the highest minemouth coal prices, which rise by 42 percent from 2010 to 2035. IHSGI and the *AEO2012* Reference case do project similar delivered coal prices to the electricity sector through 2020, but after 2020 IHSGI's prices change little, whereas prices in the *AEO2012* Reference case continue to rise. The difference may indicate that IHSGI's more pessimistic coal consumption outlook has less to do with high coal prices than with other factors. Similarly, INFORUM's delivered coal price to the electricity sector falls and then remains constant at around 2015 levels through 2035, lower than the price in 2010.

Comparison with other projections

Endnotes for Comparison with other projections

Links current as of June 2012

140. ExxonMobil's projection for residential consumption includes commercial consumption.

141. SEER's prices include a carbon tax.

List of acronyms

AB	Assembly Bill	IHSGI	IHS Global Insight
AB32	California Assembly Bill 32	INFORUM	Interindustry Forecasting Project at the University of Maryland
ACI	Activated carbon injection	IOU	Investor-owned utility
AEO	Annual Energy Outlook	IREC	Interstate Renewable Energy Council
AEO2012	Annual Energy Outlook 2012	ITC	Investment tax credit
ANWR	Arctic National Wildlife Refuge	LCFS	Low Carbon Fuel Standard
ARRA2009	American Recovery and Reinvestment Act of 2009	LDV	Light-duty vehicle
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers	LED	Light-emitting diode
Blue Chip	Blue Chip Consensus	LFMM	Liquid Fuels Market Module
BTL	Biomass-to-liquids	LNG	Liquefied natural gas
Btu	British thermal unit	MATS	Mercury and Air Toxics Standards
CAFE	Corporate average fuel economy	MAM	Macroeconomic Activity Module
CAIR	Clean Air Interstate Rule	mmt	Million metric tons
CARB	California Air Resources Board	MMTCO ₂ e	Million metric tons carbon dioxide equivalent
CBO	Congressional Budget Office	mpg	Miles per gallon
CBTL	Coal- and biomass-to-liquids	MSRP	Manufacturer's suggested retail price
CCS	Carbon capture and storage	MY	Model year
CHP	Combined heat and power	NAICS	North American Industry Classification System
CI	Carbon intensity	NEMS	National Energy Modeling System
CMM	Coal Market Module	NERC	North American Electric Reliability Corporation
CNG	Compressed natural gas	NGL	Natural gas liquids
CO ₂	Carbon dioxide	NGPL	Natural gas plant liquids
CO ₂ -EOR	Carbon dioxide-enhanced oil recovery	NGTDM	Natural Gas Transmission and Distribution Module
CSAPR	Cross-State Air Pollution Rule	NGV	Natural gas vehicle
CTL	Coal-to-liquids	NHTSA	National Highway Traffic Safety Administration
DG	Distributed generation	NO _x	Nitrogen oxides
dge	Diesel gallon equivalent	NRC	U. S. Nuclear Regulatory Commission
DOE	U.S. Department of Energy	OECD	Organization for Economic Cooperation and Development
DSI	Direct sorbent injection	OMB	Office of Management and Budget
E10	Motor gasoline blend containing up to 10 percent ethanol	OPEC	Organization of the Petroleum Exporting Countries
E15	Motor gasoline blend containing up to 15 percent ethanol	P&G	Purvin & Gertz
E85	Motor fuel containing up to 85 percent ethanol	PADD	Petroleum Administration for Defense District
EERE	Energy Efficiency and Renewable Energy	PCs	Personal computers
EIA	U.S. Energy Information Administration	PHEV	Plug-in hybrid electric vehicle
EIEA2008	Energy Improvement and Extension Act of 2008	PM	Particulate matter
EISA2007	Energy Independence and Security Act of 2007	PM _{2.5}	Particulate matter less than 2.5 microns diameter
EOR	Enhanced oil recovery	PMM	Petroleum Market Module
EPA	U.S. Environmental Protection Agency	PTC	Production tax credit
EPACT05	Energy Policy Act of 2005	PV	Solar photovoltaic
EUR	Estimated ultimate recovery	RAC	U.S. Refiner Acquisition Cost
EV	Electric vehicle	RECS	Residential Energy Consumption Survey
EVA	Energy Ventures Analysis	RFM	Renewable Fuels Module
FEMP	Federal Energy Management Program	RFS	Renewable fuel standard
FFV	Flex-fuel vehicle	RGGI	Regional Greenhouse Gas Initiative
FGD	Flue gas desulfurization	RPS	Renewable portfolio standard
GDP	Gross domestic product	SB	Senate Bill
GHG	Greenhouse gas	SCR	Selective catalytic reduction
GTL	Gas-to-liquids	SEER	Strategic Energy and Economic Research, Inc.
GVWR	Gross vehicle weight rating	SEIA	Solar Energy Industries Association
HAP	Hazardous air pollutant	SNCR	Selective noncatalytic reduction
HB	House Bill	SO ₂	Sulfur dioxide
HCl	Hydrogen chloride	STEO	Short-Term Energy Outlook
HD	Heavy-duty	TAPS	Trans-Alaska Pipeline System
HDV	Heavy-duty vehicle	TRR	Technically recoverable resource
HEV	Hybrid electric vehicle	UEC	Unit energy consumption
Hg	Mercury	UPS	Uninterruptible power supply
ICE	Internal combustion engine	USGS	United States Geological Survey
IDM	Industrial Demand Module	VIUS	Vehicle Inventory and Use Survey
IEA	International Energy Agency	VMT	Vehicle miles traveled
IECC2006	2006 International Energy Conversion Code	WTI	West Texas Intermediate
IEM	International Energy Module		

Notes and sources

Table notes and sources

Table 1. HD National Program vehicle regulatory categories: U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: Final Rule," *Federal Register*, Vol. 76, No. 179 (Washington, DC: September 15, 2011), pp 57106-57513, website <http://www.epa.gov/tdsys/pac/FR-2011-09-15/html/2011-20710.html>.

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Table 9. Vehicle types that do not rely solely on a gasoline internal combustion engine for motive and accessory power: U.S. Energy Information Administration, Office of Energy Analysis.

Table 10. Description of battery-powered electric vehicles: U.S. Energy Information Administration, Office of Energy Analysis.

Table 11. Comparison of operating and incremental costs of battery electric vehicles and conventional gasoline vehicles: U.S. Energy Information Administration, Office of Energy Analysis.

Table 12. Summary of key results from the Reference, High Nuclear, and Low Nuclear cases, 2010-2035: History: U.S. Energy Information Administration, *Annual Energy Review 2010*, DOE/EIA-0384 (Washington, DC, October 2011). Projections: AEO2012 National Energy Modeling System, runs REF2012.D020112C, HINUC12.D022312A and LOWNUC12.D022312b.

Table 13. Alaska North Slope wells completed during 2010 in selected oil fields: Alaska Oil and Gas Conservation Commission, Public Databases Website at doa.alaska.gov/ogc/publicdb.html. The North Slope well total includes exploration wells, water disposal wells, service wells, etc. The Alpine field is the primary field within the Colville River Unit.

Table 14. Unproved technically recoverable resource assumption by basin: U.S. Energy Information Administration, Office of Energy Analysis.

Table 15. AEO2012 unproved technically recoverable resources for selected shale gas plays as of January 1, 2010: U.S. Energy Information Administration, Office of Energy Analysis. Note: Average well spacing, percent of area untested, and percent of area with potential have been rounded to the nearest unit.

Table 16. AEO2012 unproved technically recoverable tight oil resources as of January 1, 2010: U.S. Energy Information Administration, Office of Energy Analysis. Note: Average well spacing, percent of area untested, and percent of area with potential have been rounded to the nearest unit.

Table 17. Estimated ultimate recovery for selected shale gas plays in three AEOs: Projections: AEO2012 National Energy Modeling System, runs REF2012.D020112C, AEO2011 National Energy Modeling System, runs REF2011.D0209A, and AEO2010 National Energy Modeling System, runs REF2010.D111809A.

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Table 20. Marcellus unproved technically recoverable resources in AEO2012 (as of January 1, 2010): U.S. Energy Information Administration, Office of Energy Analysis. Note: Average well spacing, percent of area untested, and percent of area with potential have been rounded to the nearest unit.

Table 21. Marcellus unproved technically recoverable resources: AEO2011, USGS 2011, and AEO2012: Projections: AEO2011: AEO2011 National Energy Modeling System, run REF2011.D0209A; USGS 2011: USGS 2011 Open-File Report 2011-1298, website pubs.usgs.gov/ofr/2011/1298/; and Fact Sheet 2011-3092, website pubs.usgs.gov/fs/2011/3092/; AEO2012: AEO2012 National Energy Modeling System, run REF2012.D020112C. Note: Average well spacing, percent of area untested, and percent of area with potential have been rounded to the nearest unit.

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Table 26. Comparison of natural gas projections, 2010, 2015, 2025, and 2035: AEO2012 (Reference case): AEO2012 National Energy Modeling System, run AEO2012.REF2012.D020112C. IHSGI: IHS Global Insight, *30-year U.S. and Regional Economic Forecast* (Lexington, MA, November 2011), website www.ihs.com/products/global-insight/index.aspx (subscription site). EVA: Energy Ventures Analysis, Inc., e-mail from Anthony Petruzzo (January 26, 2012). Deloitte: Deloitte LLP, e-mail from Tom Choi (January 26, 2012). SEER: Strategic Energy and Economic Research, Inc., e-mail from Ron Denhardt (February 21, 2012). ExxonMobil: ExxonMobil Corporation, *The Outlook for Energy: A View to 2040* (Irving, TX, 2012), website www.exxonmobil.com/Corporate/energy_outlook.aspx. INFORUM: "Inforum Lift (Long-term Interindustry Forecasting Tool) Model" (College Park, MD, February 2012), website forum.net.usd.edu/services/models/lift.html.

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Figure 2. U.S. production of tight oil in four cases, 2000-2035: History: U.S. Energy Information Administration, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). Projections: AEO2012 National Energy Modeling System, runs REF2012.D020112C, REF2012.LEUR12.D02212A, REF2012.HEUR12.D02212A, and REF2012.HTRR12.D050412A.

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Figure 10. Total combined requirements for State renewable portfolio standards, 2015-2035: Projections: AEO2012 National Energy Modeling System, runs REF2012.D020112C.

Figure 11. Total energy consumption in three cases, 2005-2035: History: U.S. Energy Information Administration, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). Projections: AEO2012 National Energy Modeling System, runs REF2012.D020112C, NOSUNSET.D032112A, and EXTENDED.D050612B.

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Figure 116. U.S. ethanol use in blended gasoline and E85, 2000-2035: History: U.S. Energy Information Administration, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). Projections: AEO2012 National Energy Modeling System, run REF2012.D020112C.

Figure 117. U.S. motor gasoline and diesel fuel consumption, 2000-2035: History: U.S. Energy Information Administration, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). Projections: AEO2012 National Energy Modeling System, run REF2012.D020112C.

Figure 118. Coal production by region, 1970-2035: History (short tons): 1970-1990: U.S. Energy Information Administration, *The U.S. Coal Industry, 1970-1990: Two Decades of Change*, DOE/EIA-0559 (Washington, DC, November 2002). 1991-2000: U.S. Energy Information Administration, *Coal Industry Annual*, DOE/EIA-0584 (various years). 2001-2010: U.S. Energy Information Administration, *Annual Coal Report 2010*, DOE/EIA-0584(2010) (Washington, DC, November 2011), and previous issues. History (conversion to quadrillion Btu): 1970-2010: Estimation Procedure: Estimates of average heat content by region and year are based on coal quality data collected through various energy surveys (see sources) and national-level estimates of U.S. coal production by year in units of quadrillion Btu, published in EIA's *Annual Energy Review*. Sources: U.S. Energy Information Administration, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011), Table 1.2; Form EIA-3, "Quarterly Coal Consumption and Quality Report, Manufacturing and Transformation/Processing Coal Plants and Commercial and Institutional Coal Users"; Form EIA-5, "Quarterly Coal Consumption and Quality Report, Coke Plants"; Form EIA-6A, "Coal Distribution Report"; Form EIA-7A, "Annual Coal Production and Preparation Report"; Form EIA-423, "Monthly Cost and Quality of Fuels for Electric Plants Report"; Form EIA-906, "Power Plant Report"; Form EIA-920, "Combined Heat and Power Plant Report"; Form EIA-923, "Power Plant Operations Report"; U.S. Department of Commerce, Bureau of the Census, "Monthly Report EM 545"; and Federal Energy Regulatory Commission, Form 423, "Monthly Report of Cost and Quality of Fuels for Electric Plants." Projections: AEO2012 National Energy Modeling System, run REF2012.D020112C. Note: For 1989-2035, coal production includes waste coal.

Figure 119. U.S. total coal production in six cases, 2010, 2020, and 2035: AEO2012 National Energy Modeling System, run REF2012.D020112C, LCCST12.D031312A, HP2012.D022112A, HM2012.D022412A, LM2012.D022412A, and CO2FEE15.D031312A. Note: Coal production includes waste coal.

Figure 120. Average annual minemouth coal prices by region, 1990-2035: History (dollars per short ton): 1990-2000: U.S. Energy Information Administration, *Coal Industry Annual*, DOE/EIA-0584 (various years). 2001-2010: U.S. Energy Information Administration, *Annual Coal Report 2010*, DOE/EIA-0584(2010) (Washington, DC, November 2011), and previous issues. History (conversion to dollars per million Btu): 1970-2009: Estimation Procedure: Estimates of average heat content by region and year based on coal quality data collected through various energy surveys (see sources) and national-level estimates of U.S. coal production by year in units of quadrillion Btu published in EIA's *Annual Energy Review*. Sources: U.S. Energy Information Administration, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011), Table 1.2; Form EIA-3, "Quarterly Coal Consumption and Quality Report, Manufacturing and Transformation/Processing Coal Plants and Commercial and Institutional Coal Users"; Form EIA-5, "Quarterly Coal Consumption and Quality Report, Coke Plants"; Form EIA-6A, "Coal Distribution Report"; Form EIA-7A, "Annual Coal Production and Preparation Report"; Form EIA-423, "Monthly Cost and Quality of Fuels for Electric Plants Report"; Form EIA-906, "Power Plant Report"; and Form EIA-920, "Combined Heat and Power Plant

Report"; Form EIA-923, "Power Plant Operations Report"; U.S. Department of Commerce, Bureau of the Census, "Monthly Report EM 545"; and Federal Energy Regulatory Commission, Form 423, "Monthly Report of Cost and Quality of Fuels for Electric Plants." Projections: AEO2012 National Energy Modeling System, run REF2012.D020112C. Note: Includes reported prices for both open-market and captive mines.

Figure 121. Cumulative coal-fired generating capacity additions by sector in two cases, 2011-2035: AEO2012 National Energy Modeling System, run REF2012.D020112C and NOGHGCONCERN.D031212A.

Figure 122. U.S. energy-related carbon dioxide emissions by sector and fuel, 2005 and 2035: AEO2012 National Energy Modeling System, run REF2012.D020112C.

Figure 123. Sulfur dioxide emissions from electricity generation, 1990-2035: 1990, 2000, 2005: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1990-1998*, EPA-454/R-00-002 (Washington, DC, March 2000); U.S. Environmental Protection Agency, *Acid Rain Program Preliminary Summary Emissions Report, Fourth Quarter 2004*, website ampd.epa.gov/ampd/, 2010 and Projections: AEO2012 National Energy Modeling System, run REF2012.D020112C.

Figure 124. Nitrogen oxide emissions from electricity generation, 1990-2035: History: 1990, 2000, 2005: U.S. Environmental Protection Agency, *National Air Pollutant Emissions Trends, 1990-1998*, EPA-454/R-00-002 (Washington, DC, March 2000); U.S. Environmental Protection Agency, *Acid Rain Program Preliminary Summary Emissions Report, Fourth Quarter 2004*, website ampd.epa.gov/ampd/, 2010 and Projections: AEO2012 National Energy Modeling System, run REF2012.D020112C.

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Appendix A

Reference case

Table A1. Total energy supply, disposition, and price summary
(quadrillion Btu per year, unless otherwise noted)

Supply, disposition, and prices	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Production								
Crude oil and lease condensate	11.35	11.59	13.23	14.40	13.77	13.71	12.89	0.4%
Natural gas plant liquids	2.57	2.78	3.33	3.79	3.93	3.98	3.94	1.4%
Dry natural gas	21.09	22.10	24.22	25.69	26.91	27.58	28.60	1.0%
Coal ¹	21.63	22.06	20.24	20.74	22.25	23.22	24.14	0.4%
Nuclear / uranium ²	8.36	8.44	8.68	9.28	9.60	9.56	9.28	0.4%
Hydropower	2.67	2.51	2.90	2.95	2.99	3.02	3.04	0.8%
Biomass ³	3.72	4.05	4.45	5.26	6.26	7.60	9.07	3.3%
Other renewable energy ⁴	1.11	1.34	1.99	2.04	2.22	2.41	2.81	3.0%
Other ⁵	0.47	0.64	0.60	0.64	0.69	0.79	0.91	1.4%
Total	72.97	75.50	79.64	84.80	88.61	91.87	94.67	0.9%
Imports								
Crude oil	19.70	20.14	18.87	16.00	16.23	16.04	16.90	-0.7%
Liquid fuels and other petroleum ⁶	5.40	5.02	4.32	4.03	4.08	4.04	4.14	-0.8%
Natural gas ⁷	3.85	3.81	3.73	3.49	2.75	3.00	2.84	-1.2%
Other imports ⁸	0.61	0.52	0.44	0.72	1.07	0.78	0.81	1.8%
Total	29.56	29.49	27.37	24.25	24.14	23.86	24.69	-0.7%
Exports								
Liquid fuels and other petroleum ⁹	4.20	4.81	5.00	4.39	4.46	4.67	4.95	0.1%
Natural gas ¹⁰	1.08	1.15	1.93	3.09	3.51	3.86	4.17	5.3%
Coal	1.51	2.10	2.73	2.36	2.82	2.85	3.13	1.6%
Total	6.79	8.06	9.66	9.84	10.79	11.38	12.25	1.7%
Discrepancy¹¹	1.04	-1.23	-0.08	-0.10	-0.03	0.04	0.18	--
Consumption								
Liquid fuels and other petroleum ¹²	36.50	37.25	36.72	36.38	36.58	36.99	37.70	0.0%
Natural gas	23.43	24.71	26.00	26.07	26.14	26.72	27.26	0.4%
Coal ¹³	19.62	20.76	17.80	18.73	20.02	20.59	21.15	0.1%
Nuclear / uranium ²	8.36	8.44	8.68	9.28	9.60	9.56	9.28	0.4%
Hydropower	2.67	2.51	2.90	2.95	2.99	3.02	3.04	0.8%
Biomass ¹⁴	2.72	2.88	3.04	3.58	4.17	4.78	5.44	2.6%
Other renewable energy ⁴	1.11	1.34	1.99	2.04	2.22	2.41	2.81	3.0%
Other ¹⁵	0.32	0.29	0.30	0.29	0.28	0.25	0.24	-0.6%
Total	94.71	98.16	97.43	99.32	101.99	104.32	106.93	0.3%
Prices (2010 dollars per unit)								
Petroleum (dollars per barrel)								
Low sulfur light crude oil	62.37	79.39	116.91	126.68	132.56	138.49	144.98	2.4%
Imported crude oil ¹⁶	59.72	75.87	113.97	115.74	121.21	126.51	132.95	2.3%
Natural gas (dollars per million Btu)								
at Henry hub	4.00	4.39	4.29	4.58	5.63	6.29	7.37	2.1%
at the wellhead ¹⁷	3.75	4.06	3.84	4.10	5.00	5.56	6.48	1.9%
Natural gas (dollars per thousand cubic feet)								
at the wellhead ¹⁷	3.85	4.16	3.94	4.19	5.12	5.69	6.64	1.9%
Coal (dollars per ton)								
at the minemouth ¹⁸	33.62	35.61	42.08	40.96	44.05	47.28	50.52	1.4%
Coal (dollars per million Btu)								
at the minemouth ¹⁸	1.68	1.76	2.08	2.06	2.23	2.39	2.56	1.5%
Average end-use ¹⁹	2.32	2.38	2.56	2.58	2.70	2.81	2.94	0.9%
Average electricity (cents per kilowatthour)	9.9	9.8	9.7	9.6	9.7	9.8	10.1	0.1%

Table A1. Total energy supply, disposition, and price summary (continued)
(quadrillion Btu per year, unless otherwise noted)

Supply, disposition, and prices	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Prices (nominal dollars per unit)								
Petroleum (dollars per barrel)								
Low sulfur light crude oil	61.65	79.39	125.97	148.87	170.09	197.10	229.55	4.3%
Imported crude oil ¹⁶	59.04	75.87	122.81	136.02	155.52	180.06	210.51	4.2%
Natural gas (dollars per million Btu)								
at Henry hub	3.95	4.39	4.62	5.39	7.23	8.95	11.67	4.0%
at the wellhead ¹⁷	3.71	4.06	4.14	4.81	6.42	7.92	10.26	3.8%
Natural gas (dollars per thousand cubic feet)								
at the wellhead ¹⁷	3.80	4.16	4.24	4.93	6.57	8.11	10.51	3.8%
Coal (dollars per ton)								
at the minemouth ¹⁸	33.24	35.61	45.34	48.13	56.52	67.28	80.00	3.3%
Coal (dollars per million Btu)								
at the minemouth ¹⁸	1.66	1.76	2.24	2.42	2.86	3.41	4.05	3.4%
Average end-use ¹⁹	2.30	2.38	2.76	3.03	3.47	4.01	4.66	2.7%
Average electricity (cents per kilowatthour)	9.8	9.8	10.4	11.3	12.5	13.9	16.0	2.0%

¹Includes waste coal.

²These values represent the energy obtained from uranium when it is used in light water reactors. The total energy content of uranium is much larger, but alternative processes are required to take advantage of it.

³Includes grid-connected electricity from wood and wood waste; biomass, such as corn, used for liquid fuels production; and non-electric energy demand from wood. Refer to Table A17 for details.

⁴Includes grid-connected electricity from landfill gas; biogenic municipal waste; wind; photovoltaic and solar thermal sources; and non-electric energy from renewable sources, such as active and passive solar systems. Excludes electricity imports using renewable sources and nonmarketed renewable energy. See Table A17 for selected nonmarketed residential and commercial renewable energy data.

⁵Includes non-biogenic municipal waste, liquid hydrogen, methanol, and some domestic inputs to refineries.

⁶Includes imports of finished petroleum products, unfinished oils, alcohols, ethers, blending components, and renewable fuels such as ethanol.

⁷Includes imports of liquefied natural gas that is later re-exported.

⁸Includes coal, coal coke (net), and electricity (net). Excludes imports of fuel used in nuclear power plants.

⁹Includes crude oil, petroleum products, ethanol, and biodiesel.

¹⁰Includes re-exported liquefied natural gas.

¹¹Balancing item. Includes unaccounted for supply, losses, gains, and net storage withdrawals.

¹²Includes petroleum-derived fuels and non-petroleum derived fuels, such as ethanol and biodiesel, and coal-based synthetic liquids. Petroleum coke, which is a solid, is included. Also included are natural gas plant liquids and crude oil consumed as a fuel. Refer to Table A17 for detailed renewable liquid fuels consumption.

¹³Excludes coal converted to coal-based synthetic liquids and natural gas.

¹⁴Includes grid-connected electricity from wood and wood waste, non-electric energy from wood, and biofuels heat and coproducts used in the production of liquid fuels, but excludes the energy content of the liquid fuels.

¹⁵Includes non-biogenic municipal waste, liquid hydrogen, and net electricity imports.

¹⁶Weighted average price delivered to U.S. refiners.

¹⁷Represents lower 48 onshore and offshore supplies.

¹⁸Includes reported prices for both open market and captive mines.

¹⁹Prices weighted by consumption; weighted average excludes residential and commercial prices, and export free-alongside-ship (f.a.s.) prices.

Btu = British thermal unit.

-- = Not applicable.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 natural gas supply values: U.S. Energy Information Administration (EIA), *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010). 2010 natural gas supply values and natural gas wellhead price: EIA, *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2009 natural gas wellhead price: U.S. Department of the Interior, Office of Natural Resources Revenue; and EIA, *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010). 2009 and 2010 coal minemouth and delivered coal prices: EIA, *Annual Coal Report 2010*, DOE/EIA-0584(2010) (Washington, DC, November 2011). 2010 petroleum supply values and 2009 crude oil and lease condensate production: EIA, *Petroleum Supply Annual 2010*, DOE/EIA-0340(2010)/1 (Washington, DC, July 2011). Other 2009 petroleum supply values: EIA, *Petroleum Supply Annual 2009*, DOE/EIA-0340(2009)/1 (Washington, DC, July 2010). 2009 and 2010 low sulfur light crude oil price: EIA, Form EIA-856, "Monthly Foreign Crude Oil Acquisition Report." Other 2009 and 2010 coal values: *Quarterly Coal Report, October-December 2010*, DOE/EIA-0121(2010/4Q) (Washington, DC, May 2011). Other 2009 and 2010 values: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Table A2. Energy consumption by sector and source
(quadrillion Btu per year, unless otherwise noted)

Sector and source	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Energy consumption								
Residential								
Liquefied petroleum gases	0.51	0.56	0.51	0.50	0.50	0.51	0.51	-0.4%
Kerosene	0.03	0.03	0.02	0.02	0.02	0.02	0.02	-1.7%
Distillate fuel oil	0.60	0.63	0.55	0.48	0.43	0.38	0.35	-2.3%
Liquid fuels and other petroleum subtotal	1.14	1.22	1.08	1.01	0.95	0.91	0.87	-1.3%
Natural gas	4.90	5.06	4.97	4.95	4.88	4.84	4.76	-0.2%
Coal	0.01	0.01	0.01	0.01	0.01	0.01	0.01	-1.1%
Renewable energy ¹	0.43	0.42	0.43	0.43	0.43	0.43	0.43	0.1%
Electricity	4.66	4.95	4.75	4.96	5.23	5.55	5.86	0.7%
Delivered energy	11.13	11.66	11.24	11.36	11.51	11.73	11.93	0.1%
Electricity related losses	9.80	10.39	9.58	10.01	10.52	10.95	11.35	0.4%
Total	20.93	22.05	20.81	21.36	22.02	22.68	23.28	0.2%
Commercial								
Liquefied petroleum gases	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.3%
Motor gasoline ²	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.4%
Kerosene	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.7%
Distillate fuel oil	0.41	0.43	0.35	0.34	0.33	0.33	0.32	-1.2%
Residual fuel oil	0.08	0.08	0.08	0.08	0.08	0.08	0.08	-0.0%
Liquid fuels and other petroleum subtotal	0.68	0.72	0.62	0.62	0.62	0.62	0.62	-0.5%
Natural gas	3.20	3.28	3.41	3.51	3.53	3.60	3.69	0.5%
Coal	0.07	0.06	0.06	0.06	0.06	0.06	0.06	-0.0%
Renewable energy ³	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.0%
Electricity	4.46	4.54	4.59	4.88	5.16	5.48	5.80	1.0%
Delivered energy	8.51	8.70	8.80	9.18	9.48	9.87	10.28	0.7%
Electricity related losses	9.39	9.52	9.27	9.85	10.38	10.82	11.23	0.7%
Total	17.90	18.22	18.06	19.03	19.86	20.69	21.50	0.7%
Industrial⁴								
Liquefied petroleum gases	2.00	2.00	1.83	2.06	2.17	2.18	2.15	0.3%
Motor gasoline ²	0.24	0.25	0.28	0.30	0.30	0.30	0.30	0.8%
Distillate fuel oil	1.11	1.16	1.25	1.18	1.19	1.17	1.18	0.1%
Residual fuel oil	0.11	0.12	0.09	0.08	0.08	0.08	0.08	-1.3%
Petrochemical feedstocks	0.90	0.94	1.01	1.20	1.29	1.31	1.30	1.3%
Other petroleum ⁵	3.57	3.59	3.44	3.18	3.11	3.09	3.19	-0.5%
Liquid fuels and other petroleum subtotal	7.93	8.05	7.89	7.99	8.13	8.13	8.21	0.1%
Natural gas	6.32	6.76	7.19	7.26	7.32	7.21	7.18	0.2%
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Lease and plant fuel ⁶	1.31	1.37	1.43	1.55	1.57	1.59	1.63	0.7%
Natural gas subtotal	7.63	8.14	8.62	8.80	8.89	8.80	8.81	0.3%
Metallurgical coal	0.40	0.55	0.57	0.48	0.49	0.46	0.43	-1.0%
Other industrial coal	0.94	1.01	1.03	1.04	1.08	1.08	1.08	0.3%
Coal-to-liquids heat and power	0.00	0.00	0.00	0.26	0.36	0.48	0.60	--
Net coal coke imports	-0.02	-0.01	-0.01	-0.02	-0.03	-0.04	-0.06	9.3%
Coal subtotal	1.32	1.56	1.59	1.76	1.90	1.98	2.06	1.1%
Biofuels heat and coproducts	0.82	0.84	0.81	0.96	1.27	1.92	2.57	4.6%
Renewable energy ⁷	1.37	1.50	1.61	1.67	1.82	1.87	1.95	1.1%
Electricity	3.13	3.28	3.44	3.46	3.52	3.44	3.33	0.1%
Delivered energy	22.20	23.37	23.96	24.64	25.53	26.14	26.94	0.6%
Electricity related losses	6.59	6.89	6.94	6.97	7.09	6.80	6.46	-0.3%
Total	28.79	30.26	30.90	31.61	32.61	32.93	33.39	0.4%

Table A2. Energy consumption by sector and source (continued)
(quadrillion Btu per year, unless otherwise noted)

Sector and source	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Transportation								
Liquefied petroleum gases	0.05	0.04	0.04	0.04	0.04	0.05	0.05	0.5%
E85 ⁸	0.00	0.00	0.01	0.13	0.30	0.72	1.22	27.0%
Motor gasoline ²	16.84	16.91	16.13	15.31	14.90	14.69	14.53	-0.6%
Jet fuel ⁹	2.98	3.07	3.03	3.09	3.19	3.27	3.33	0.3%
Distillate fuel oil ¹⁰	5.53	5.77	6.55	6.80	7.03	7.20	7.44	1.0%
Residual fuel oil	0.81	0.90	0.91	0.92	0.93	0.93	0.94	0.2%
Other petroleum ¹¹	0.16	0.17	0.17	0.17	0.17	0.17	0.17	0.0%
Liquid fuels and other petroleum subtotal	26.36	26.88	26.83	26.46	26.57	27.02	27.67	0.1%
Pipeline fuel natural gas	0.61	0.65	0.68	0.67	0.67	0.68	0.69	0.2%
Compressed / liquefied natural gas	0.04	0.04	0.06	0.09	0.11	0.14	0.16	5.7%
Liquid hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Electricity	0.02	0.02	0.03	0.03	0.04	0.06	0.07	4.8%
Delivered energy	27.04	27.59	27.60	27.25	27.40	27.90	28.60	0.1%
Electricity related losses	0.05	0.05	0.05	0.06	0.08	0.11	0.14	4.5%
Total	27.09	27.63	27.65	27.32	27.49	28.01	28.75	0.2%
Delivered energy consumption for all sectors								
Liquefied petroleum gases	2.69	2.75	2.51	2.74	2.86	2.88	2.86	0.2%
E85 ⁸	0.00	0.00	0.01	0.13	0.30	0.72	1.22	27.0%
Motor gasoline ²	17.13	17.21	16.46	15.66	15.25	15.04	14.88	-0.6%
Jet fuel ⁹	2.98	3.07	3.03	3.09	3.19	3.27	3.33	0.3%
Kerosene	0.04	0.04	0.03	0.03	0.03	0.03	0.03	-1.2%
Distillate fuel oil	7.65	7.99	8.69	8.81	8.99	9.08	9.29	0.6%
Residual fuel oil	0.99	1.11	1.08	1.08	1.09	1.09	1.11	0.0%
Petrochemical feedstocks	0.90	0.94	1.01	1.20	1.29	1.31	1.30	1.3%
Other petroleum ¹²	3.72	3.76	3.61	3.34	3.27	3.26	3.36	-0.4%
Liquid fuels and other petroleum subtotal	36.10	36.87	36.43	36.08	36.28	36.68	37.38	0.1%
Natural gas	14.46	15.15	15.64	15.81	15.85	15.79	15.79	0.2%
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Lease and plant fuel ⁶	1.31	1.37	1.43	1.55	1.57	1.59	1.63	0.7%
Pipeline natural gas	0.61	0.65	0.68	0.67	0.67	0.68	0.69	0.2%
Natural gas subtotal	16.38	17.17	17.75	18.03	18.09	18.06	18.11	0.2%
Metallurgical coal	0.40	0.55	0.57	0.48	0.49	0.46	0.43	-1.0%
Other coal	1.01	1.08	1.09	1.10	1.14	1.14	1.15	0.3%
Coal-to-liquids heat and power	0.00	0.00	0.00	0.26	0.36	0.48	0.60	--
Net coal coke imports	-0.02	-0.01	-0.01	-0.02	-0.03	-0.04	-0.06	9.3%
Coal subtotal	1.39	1.62	1.65	1.82	1.96	2.04	2.12	1.1%
Biofuels heat and coproducts	0.82	0.84	0.81	0.96	1.27	1.92	2.57	4.6%
Renewable energy ¹³	1.91	2.03	2.15	2.21	2.36	2.41	2.50	0.8%
Liquid hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Electricity	12.27	12.79	12.81	13.33	13.96	14.53	15.06	0.7%
Delivered energy	68.87	71.32	71.59	72.43	73.92	75.64	77.75	0.3%
Electricity related losses	25.83	26.84	25.84	26.89	28.07	28.67	29.18	0.3%
Total	94.71	98.16	97.43	99.32	101.99	104.32	106.93	0.3%
Electric power¹⁴								
Distillate fuel oil	0.07	0.08	0.08	0.09	0.09	0.09	0.09	0.5%
Residual fuel oil	0.32	0.30	0.21	0.21	0.22	0.22	0.23	-1.1%
Liquid fuels and other petroleum subtotal	0.39	0.38	0.29	0.30	0.31	0.31	0.32	-0.7%
Natural gas	7.04	7.54	8.25	8.05	8.04	8.66	9.16	0.8%
Steam coal	18.23	19.13	16.15	16.91	18.06	18.55	19.03	-0.0%
Nuclear / uranium ¹⁵	8.36	8.44	8.68	9.28	9.60	9.56	9.28	0.4%
Renewable energy ¹⁶	3.77	3.85	4.96	5.40	5.75	5.87	6.22	1.9%
Electricity imports	0.12	0.09	0.10	0.09	0.08	0.05	0.04	-2.9%
Total¹⁷	38.10	39.63	38.64	40.22	42.03	43.20	44.24	0.4%

2012-03-01

Table A2. Energy consumption by sector and source (continued)
(quadrillion Btu per year, unless otherwise noted)

Sector and source	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Total energy consumption								
Liquefied petroleum gases	2.69	2.75	2.51	2.74	2.86	2.88	2.86	0.2%
E85 ⁸	0.00	0.00	0.01	0.13	0.30	0.72	1.22	27.0%
Motor gasoline ²	17.13	17.21	16.46	15.66	15.25	15.04	14.88	-0.6%
Jet fuel ⁹	2.98	3.07	3.03	3.09	3.19	3.27	3.33	0.3%
Kerosene	0.04	0.04	0.03	0.03	0.03	0.03	0.03	-1.2%
Distillate fuel oil	7.72	8.07	8.78	8.89	9.07	9.17	9.38	0.6%
Residual fuel oil	1.32	1.41	1.29	1.29	1.31	1.32	1.34	-0.2%
Petrochemical feedstocks	0.90	0.94	1.01	1.20	1.29	1.31	1.30	1.3%
Other petroleum ¹²	3.72	3.76	3.61	3.34	3.27	3.26	3.36	-0.4%
Liquid fuels and other petroleum subtotal	36.50	37.25	36.72	36.38	36.58	36.99	37.70	0.0%
Natural gas	21.51	22.69	23.89	23.85	23.89	24.45	24.94	0.4%
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Lease and plant fuel ⁶	1.31	1.37	1.43	1.55	1.57	1.59	1.63	0.7%
Pipeline natural gas	0.61	0.65	0.68	0.67	0.67	0.68	0.69	0.2%
Natural gas subtotal	23.43	24.71	26.00	26.07	26.14	26.72	27.26	0.4%
Metallurgical coal	0.40	0.55	0.57	0.48	0.49	0.46	0.43	-1.0%
Other coal	19.23	20.21	17.24	18.01	19.20	19.69	20.18	-0.0%
Coal-to-liquids heat and power	0.00	0.00	0.00	0.26	0.36	0.48	0.60	--
Net coal coke imports	-0.02	-0.01	-0.01	-0.02	-0.03	-0.04	-0.06	9.3%
Coal subtotal	19.62	20.76	17.80	18.73	20.02	20.59	21.15	0.1%
Nuclear / uranium ¹⁵	8.36	8.44	8.68	9.28	9.60	9.56	9.28	0.4%
Biofuels heat and coproducts	0.82	0.84	0.81	0.96	1.27	1.92	2.57	4.6%
Renewable energy ^{1b}	5.68	5.88	7.11	7.61	8.11	8.29	8.71	1.6%
Liquid hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Electricity imports	0.12	0.09	0.10	0.09	0.08	0.05	0.04	-2.9%
Total	94.71	98.16	97.43	99.32	101.99	104.32	106.93	0.3%
Energy use and related statistics								
Delivered energy use	68.87	71.32	71.59	72.43	73.92	75.64	77.75	0.3%
Total energy use	94.71	98.16	97.43	99.32	101.99	104.32	106.93	0.3%
Ethanol consumed in motor gasoline and E85	0.96	1.11	1.22	1.35	1.55	1.82	2.15	2.7%
Population (millions)	307.84	310.83	326.16	342.01	358.06	374.09	390.09	0.9%
Gross domestic product (billion 2005 dollars)	12703	13088	14803	16740	19185	21725	24539	2.5%
Carbon dioxide emissions (million metric tons)	5424.8	5633.6	5407.2	5434.4	5552.5	5647.3	5757.9	0.1%

¹Includes wood used for residential heating. See Table A4 and/or Table A17 for estimates of nonmarketed renewable energy consumption for geothermal heat pumps, solar thermal water heating, and electricity generation from wind and solar photovoltaic sources.

²Includes ethanol (blends of 15 percent or less) and ethers blended into gasoline.

³Excludes ethanol. Includes commercial sector consumption of wood and wood waste, landfill gas, municipal waste, and other biomass for combined heat and power. See Table A5 and/or Table A17 for estimates of nonmarketed renewable energy consumption for solar thermal water heating and electricity generation from wind and solar photovoltaic sources.

⁴Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public.

⁵Includes petroleum coke, asphalt, road oil, lubricants, still gas, and miscellaneous petroleum products.

⁶Represents natural gas used in well, field, and lease operations, and in natural gas processing plant machinery.

⁷Includes consumption of energy produced from hydroelectric, wood and wood waste, municipal waste, and other biomass sources. Excludes ethanol blends (15 percent or less) in motor gasoline.

⁸E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.

⁹Includes only kerosene type.

¹⁰Diesel fuel for on- and off- road use.

¹¹Includes aviation gasoline and lubricants.

¹²Includes unfinished oils, natural gasoline, motor gasoline blending components, aviation gasoline, lubricants, still gas, asphalt, road oil, petroleum coke, and miscellaneous petroleum products.

¹³Includes electricity generated for sale to the grid and for own use from renewable sources, and non-electric energy from renewable sources. Excludes ethanol and nonmarketed renewable energy consumption for geothermal heat pumps, buildings photovoltaic systems, and solar thermal water heaters.

¹⁴Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

¹⁵These values represent the energy obtained from uranium when it is used in light water reactors. The total energy content of uranium is much larger, but alternative processes are required to take advantage of it.

¹⁶Includes conventional hydroelectric, geothermal, wood and wood waste, biogenic municipal waste, other biomass, wind, photovoltaic, and solar thermal sources. Excludes net electricity imports.

¹⁷Includes non-biogenic municipal waste not included above.

¹⁸Includes conventional hydroelectric, geothermal, wood and wood waste, biogenic municipal waste, other biomass, wind, photovoltaic, and solar thermal sources. Excludes ethanol, net electricity imports, and nonmarketed renewable energy consumption for geothermal heat pumps, buildings photovoltaic systems, and solar thermal water heaters.

Btu = British thermal unit.

-- = Not applicable.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 consumption based on: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2009 and 2010 population and gross domestic product: IHS Global Insight Industry and Employment models, August 2011. 2009 and 2010 carbon dioxide emissions: EIA, *Monthly Energy Review, October 2011* DOE/EIA-0035(2011/10) (Washington, DC, October 2011). Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Table A3. Energy prices by sector and source
(2010 dollars per million Btu, unless otherwise noted)

Sector and source	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Residential								
Liquefied petroleum gases	24.84	27.02	30.70	31.07	32.27	33.29	34.64	1.0%
Distillate fuel oil	18.35	21.21	27.26	28.81	30.15	31.42	32.73	1.8%
Natural gas	11.95	11.08	10.31	10.84	12.03	12.76	13.98	0.9%
Electricity	34.01	33.69	34.59	33.87	34.08	34.06	34.58	0.1%
Commercial								
Liquefied petroleum gases	21.76	23.52	27.42	27.78	28.97	29.96	31.30	1.1%
Distillate fuel oil	16.16	20.77	23.98	25.49	26.86	27.98	29.18	1.4%
Residual fuel oil	13.66	11.07	16.18	17.60	18.24	19.04	18.90	2.2%
Natural gas	9.82	9.10	8.60	8.98	10.02	10.60	11.64	1.0%
Electricity	30.06	29.73	29.03	28.69	29.00	28.68	29.48	-0.0%
Industrial¹								
Liquefied petroleum gases	20.05	21.80	27.43	27.76	29.24	30.48	32.18	1.6%
Distillate fuel oil	16.74	21.32	24.20	25.73	27.22	28.39	29.53	1.3%
Residual fuel oil	12.16	10.92	19.21	20.53	21.23	21.71	21.65	2.8%
Natural gas ²	5.33	5.51	4.88	5.12	6.04	6.57	7.54	1.3%
Metallurgical coal	5.49	5.84	7.22	7.58	8.11	8.61	9.11	1.8%
Other industrial coal	2.99	2.71	3.27	3.30	3.38	3.50	3.64	1.2%
Coal to liquids	--	--	1.26	2.05	2.08	2.22	2.38	--
Electricity	20.05	19.63	18.91	18.95	19.60	19.81	20.78	0.2%
Transportation								
Liquefied petroleum gases ³	25.84	26.88	31.93	32.21	33.38	34.37	35.74	1.1%
E85 ⁴	20.76	25.21	29.03	29.91	28.81	30.75	31.96	1.0%
Motor gasoline ⁵	19.52	22.70	29.26	30.77	32.10	33.03	33.61	1.6%
Jet fuel ⁶	12.75	16.22	23.74	25.26	26.45	27.58	29.13	2.4%
Diesel fuel (distillate fuel oil) ⁷	18.02	21.87	27.56	28.98	30.42	31.38	32.40	1.6%
Residual fuel oil	10.61	10.42	18.32	19.58	20.62	20.76	20.95	2.8%
Natural gas ⁸	14.17	13.20	12.40	12.50	13.29	13.68	14.51	0.4%
Electricity	35.71	32.99	30.50	29.74	31.53	32.54	33.82	0.1%
Electric power⁹								
Distillate fuel oil	14.54	18.73	22.77	24.18	25.35	26.43	27.80	1.6%
Residual fuel oil	8.98	11.89	23.00	24.38	25.40	25.55	25.72	3.1%
Natural gas	4.85	5.14	4.55	4.72	5.60	6.21	7.21	1.4%
Steam coal	2.22	2.26	2.35	2.41	2.54	2.66	2.80	0.9%
Average price to all users¹⁰								
Liquefied petroleum gases	16.13	17.28	22.99	23.06	24.19	25.23	26.63	1.7%
E85 ⁴	20.76	25.21	29.03	29.91	28.81	30.75	31.96	1.0%
Motor gasoline ⁵	19.47	22.59	29.26	30.77	32.10	33.03	33.61	1.6%
Jet fuel	12.75	16.22	23.74	25.26	26.45	27.58	29.13	2.4%
Distillate fuel oil	17.73	21.65	26.87	28.36	29.81	30.87	31.91	1.6%
Residual fuel oil	10.51	10.82	19.01	20.31	21.31	21.53	21.68	2.8%
Natural gas	7.37	7.16	6.45	6.77	7.74	8.30	9.30	1.1%
Metallurgical coal	5.49	5.84	7.22	7.58	8.11	8.61	9.11	1.8%
Other coal	2.26	2.29	2.41	2.47	2.59	2.71	2.85	0.9%
Coal to liquids	--	--	1.26	2.05	2.08	2.22	2.38	--
Electricity	29.02	28.68	28.38	28.09	28.54	28.65	29.56	0.1%
Non-renewable energy expenditures by sector (billion 2010 dollars)								
Residential	240.88	251.69	246.72	251.77	266.75	280.17	298.72	0.7%
Commercial	177.13	179.08	177.92	187.57	201.89	212.88	231.98	1.0%
Industrial	184.40	198.98	223.88	239.75	261.92	268.58	282.31	1.4%
Transportation	479.66	573.78	746.84	770.94	803.52	829.88	856.65	1.6%
Total non-renewable expenditures	1082.08	1203.54	1395.36	1450.04	1534.08	1591.52	1669.66	1.3%
Transportation renewable expenditures	0.07	0.08	0.25	3.77	8.74	22.00	38.86	28.2%
Total expenditures	1082.15	1203.62	1395.61	1453.81	1542.81	1613.52	1708.52	1.4%

Table A3. Energy prices by sector and source (continued)
(nominal dollars per million Btu, unless otherwise noted)

Sector and source	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Residential								
Liquefied petroleum gases	24.55	27.02	33.08	36.51	41.41	47.38	54.86	2.9%
Distillate fuel oil	18.14	21.21	29.38	33.86	38.68	44.72	51.82	3.6%
Natural gas	11.82	11.08	11.11	12.74	15.43	18.16	22.14	2.8%
Electricity	33.62	33.69	37.27	39.80	43.72	48.47	54.76	2.0%
Commercial								
Liquefied petroleum gases	21.51	23.52	29.54	32.65	37.17	42.65	49.56	3.0%
Distillate fuel oil	15.97	20.77	25.83	29.95	34.47	39.82	46.20	3.2%
Residual fuel oil	13.51	11.07	17.43	20.68	23.41	27.10	29.93	4.1%
Natural gas	9.70	9.10	9.27	10.56	12.86	15.08	18.43	2.9%
Electricity	29.71	29.73	31.28	33.71	37.21	40.82	46.67	1.8%
Industrial¹								
Liquefied petroleum gases	19.82	21.80	29.56	32.63	37.51	43.38	50.95	3.5%
Distillate fuel oil	16.55	21.32	26.08	30.24	34.93	40.40	46.76	3.2%
Residual fuel oil	12.02	10.92	20.70	24.13	27.24	30.89	34.28	4.7%
Natural gas ²	5.27	5.51	5.26	6.02	7.75	9.35	11.93	3.1%
Metallurgical coal	5.43	5.84	7.78	8.91	10.40	12.26	14.42	3.7%
Other industrial coal	2.96	2.71	3.52	3.87	4.34	4.98	5.77	3.1%
Coal to liquids	--	--	1.36	2.41	2.67	3.16	3.78	--
Electricity	19.83	19.63	20.38	22.27	25.15	28.20	32.90	2.1%
Transportation								
Liquefied petroleum gases ³	25.55	26.88	34.41	37.85	42.83	48.91	56.59	3.0%
E85 ⁴	20.52	25.21	31.28	35.15	36.97	43.77	50.61	2.8%
Motor gasoline ⁵	19.29	22.70	31.53	36.17	41.19	47.01	53.22	3.5%
Jet fuel ⁶	12.61	16.22	25.58	29.68	33.94	39.25	46.12	4.3%
Diesel fuel (distillate fuel oil) ⁷	17.82	21.87	29.69	34.06	39.03	44.66	51.29	3.5%
Residual fuel oil	10.49	10.42	19.74	23.01	26.45	29.55	33.18	4.7%
Natural gas ⁸	14.01	13.20	13.36	14.69	17.05	19.47	22.97	2.2%
Electricity	35.31	32.99	32.86	34.95	40.46	46.31	53.55	2.0%
Electric power⁹								
Distillate fuel oil	14.37	18.73	24.53	28.42	32.52	37.61	44.02	3.5%
Residual fuel oil	8.88	11.89	24.78	28.66	32.59	36.37	40.73	5.0%
Natural gas	4.80	5.14	4.90	5.55	7.19	8.84	11.42	3.2%
Steam coal	2.19	2.26	2.53	2.83	3.25	3.78	4.43	2.7%

Table A3. Energy prices by sector and source (continued)
(nominal dollars per million Btu, unless otherwise noted)

Sector and source	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Average price to all users¹⁰								
Liquefied petroleum gases	15.94	17.28	24.78	27.10	31.04	35.90	42.17	3.6%
E85 ⁴	20.52	25.21	31.28	35.15	36.97	43.77	50.61	2.8%
Motor gasoline ⁵	19.25	22.59	31.53	36.16	41.19	47.01	53.22	3.5%
Jet fuel	12.61	16.22	25.58	29.68	33.94	39.25	46.12	4.3%
Distillate fuel oil	17.53	21.65	28.96	33.33	38.24	43.94	50.52	3.4%
Residual fuel oil	10.39	10.82	20.48	23.87	27.34	30.64	34.33	4.7%
Natural gas	7.28	7.16	6.95	7.96	9.93	11.81	14.73	2.9%
Metallurgical coal	5.43	5.84	7.78	8.91	10.40	12.26	14.42	3.7%
Other coal	2.23	2.29	2.60	2.90	3.32	3.86	4.51	2.8%
Coal to liquids	--	--	1.36	2.41	2.67	3.16	3.78	--
Electricity	28.68	28.68	30.58	33.01	36.62	40.77	46.80	2.0%
Non-renewable energy expenditures by sector (billion nominal dollars)								
Residential	238.13	251.69	265.85	295.89	342.26	398.75	472.99	2.6%
Commercial	175.11	179.08	191.71	220.43	259.04	302.97	367.31	2.9%
Industrial	182.29	198.98	241.24	281.75	336.06	382.26	447.01	3.3%
Transportation	474.19	573.78	804.75	906.02	1030.98	1181.11	1356.41	3.5%
Total non-renewable expenditures	1069.72	1203.54	1503.55	1704.09	1968.35	2265.08	2643.72	3.2%
Transportation renewable expenditures	0.07	0.08	0.27	4.43	11.21	31.31	61.53	30.6%
Total expenditures	1069.78	1203.62	1503.82	1708.52	1979.56	2296.40	2705.26	3.3%

¹Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public.

²Excludes use for lease and plant fuel.

³Includes Federal and State taxes while excluding county and local taxes.

⁴E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.

⁵Sales weighted-average price for all grades. Includes Federal, State and local taxes.

⁶Kerosene-type jet fuel. Includes Federal and State taxes while excluding county and local taxes.

⁷Diesel fuel for on-road use. Includes Federal and State taxes while excluding county and local taxes.

⁸Natural gas used as a vehicle fuel. Includes estimated motor vehicle fuel taxes and estimated dispensing costs or charges.

⁹Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

¹⁰Weighted averages of end-use fuel prices are derived from the prices shown in each sector and the corresponding sectoral consumption.

Btu = British thermal unit.

-- = Not applicable.

Note: Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 prices for motor gasoline, distillate fuel oil, and jet fuel are based on prices in the U.S. Energy Information Administration (EIA), *Petroleum Marketing Annual 2009*, DOE/EIA-0487(2009) (Washington, DC, August 2010). 2009 residential and commercial natural gas delivered prices: EIA, *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010). 2010 residential and commercial natural gas delivered prices: EIA, *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2009 and 2010 industrial natural gas delivered prices are estimated based on: EIA, *Manufacturing Energy Consumption Survey* and industrial and wellhead prices from the *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010) and the *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2009 transportation sector natural gas delivered prices are based on: EIA, *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010) and estimated State taxes, Federal taxes, and dispensing costs or charges. 2010 transportation sector natural gas delivered prices are model results. 2009 and 2010 electric power sector distillate and residual fuel oil prices: EIA, *Monthly Energy Review*, DOE/EIA-0035(2010/09) (Washington, DC, September 2010). 2009 and 2010 electric power sector natural gas prices: EIA, *Electric Power Monthly*, DOE/EIA-0226, April 2010 and April 2011, Table 4.2, and EIA, *State Energy Data Report 2009*, DOE/EIA-0214(2009) (Washington, DC, June 2011). 2009 and 2010 coal prices based on: EIA, *Quarterly Coal Report, October-December 2010*, DOE/EIA-0121(2010/4Q) (Washington, DC, May 2011) and EIA, AEO2012 National Energy Modeling System run REF2012.D020112C. 2009 and 2010 electricity prices: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2009 and 2010 E85 prices derived from monthly prices in the Clean Cities Alternative Fuel Price Report. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Reference case

Table A4. Residential sector key indicators and consumption
(quadrillion Btu per year, unless otherwise noted)

Key indicators and consumption	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Key indicators								
Households (millions)								
Single-family	81.73	82.11	85.49	89.94	94.26	98.56	102.54	0.9%
Multifamily	25.41	25.52	26.98	29.31	31.47	33.70	35.96	1.4%
Mobile homes	6.65	6.56	6.25	6.56	6.86	7.04	7.14	0.3%
Total	113.78	114.19	118.73	125.82	132.60	139.30	145.64	1.0%
Average house square footage	1646	1653	1684	1705	1725	1743	1759	0.2%
Energy intensity								
(million Btu per household)								
Delivered energy consumption	97.8	102.1	94.6	90.3	86.8	84.2	81.9	-0.9%
Total energy consumption	184.0	193.1	175.3	169.8	166.1	162.8	159.9	-0.8%
(thousand Btu per square foot)								
Delivered energy consumption	59.4	61.8	56.2	52.9	50.3	48.3	46.6	-1.1%
Total energy consumption	111.8	116.8	104.1	99.6	96.3	93.4	90.9	-1.0%
Delivered energy consumption by fuel								
Electricity								
Space heating	0.28	0.30	0.28	0.30	0.31	0.33	0.34	0.5%
Space cooling	0.81	1.08	1.01	1.06	1.12	1.18	1.24	0.6%
Water heating	0.44	0.45	0.47	0.50	0.52	0.53	0.53	0.7%
Refrigeration	0.38	0.37	0.37	0.38	0.39	0.41	0.43	0.6%
Cooking	0.11	0.11	0.11	0.12	0.13	0.14	0.15	1.4%
Clothes dryers	0.19	0.19	0.19	0.18	0.18	0.17	0.18	-0.3%
Freezers	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.3%
Lighting	0.70	0.69	0.52	0.48	0.46	0.46	0.47	-1.5%
Clothes washers ¹	0.03	0.03	0.03	0.03	0.02	0.02	0.02	-1.2%
Dishwashers ¹	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.4%
Color televisions and set-top boxes	0.32	0.33	0.32	0.34	0.37	0.40	0.43	1.1%
Personal computers and related equipment	0.17	0.17	0.19	0.22	0.24	0.26	0.27	1.8%
Furnace fans and boiler circulation pumps	0.14	0.13	0.14	0.14	0.14	0.15	0.15	0.4%
Other uses ²	0.90	0.92	0.92	1.03	1.16	1.31	1.44	1.8%
Delivered energy	4.66	4.95	4.75	4.96	5.23	5.55	5.86	0.7%
Natural gas								
Space heating	3.31	3.50	3.39	3.34	3.27	3.24	3.19	-0.4%
Space cooling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.3%
Water heating	1.32	1.29	1.31	1.33	1.33	1.31	1.27	-0.1%
Cooking	0.22	0.22	0.22	0.22	0.22	0.23	0.23	0.3%
Clothes dryers	0.05	0.06	0.06	0.06	0.06	0.06	0.07	0.7%
Delivered energy	4.90	5.06	4.97	4.95	4.88	4.84	4.76	-0.2%
Distillate fuel oil								
Space heating	0.50	0.53	0.48	0.42	0.38	0.34	0.31	-2.1%
Water heating	0.10	0.10	0.07	0.06	0.05	0.04	0.04	-3.9%
Delivered energy	0.60	0.63	0.55	0.48	0.43	0.38	0.35	-2.3%
Liquefied petroleum gases								
Space heating	0.26	0.30	0.26	0.25	0.24	0.23	0.22	-1.1%
Water heating	0.08	0.07	0.05	0.04	0.04	0.04	0.03	-3.0%
Cooking	0.03	0.03	0.03	0.03	0.03	0.03	0.02	-0.9%
Other uses ³	0.14	0.16	0.17	0.18	0.20	0.21	0.22	1.3%
Delivered energy	0.51	0.56	0.51	0.50	0.50	0.51	0.51	-0.4%
Marketed renewables (wood) ⁴	0.43	0.42	0.43	0.43	0.43	0.43	0.43	0.1%
Other fuels ⁵	0.04	0.04	0.03	0.03	0.03	0.03	0.03	-1.6%

Table A4. Residential sector key indicators and consumption (continued)
(quadrillion Btu per year, unless otherwise noted)

Key indicators and consumption	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Delivered energy consumption by end use								
Space heating	4.81	5.08	4.86	4.78	4.67	4.60	4.52	-0.5%
Space cooling	0.81	1.08	1.01	1.06	1.12	1.18	1.24	0.6%
Water heating	1.94	1.91	1.90	1.92	1.94	1.91	1.88	-0.1%
Refrigeration	0.38	0.37	0.37	0.38	0.39	0.41	0.43	0.6%
Cooking	0.35	0.35	0.36	0.37	0.38	0.39	0.40	0.5%
Clothes dryers	0.25	0.25	0.25	0.25	0.24	0.24	0.25	-0.0%
Freezers	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.3%
Lighting	0.70	0.69	0.52	0.48	0.46	0.46	0.47	-1.5%
Clothes washers ¹	0.03	0.03	0.03	0.03	0.02	0.02	0.02	-1.2%
Dishwashers ¹	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.4%
Color televisions and set-top boxes	0.32	0.33	0.32	0.34	0.37	0.40	0.43	1.1%
Personal computers and related equipment	0.17	0.17	0.19	0.22	0.24	0.26	0.27	1.8%
Furnace fans and boiler circulation pumps	0.14	0.13	0.14	0.14	0.14	0.15	0.15	0.4%
Other uses ⁶	1.04	1.08	1.09	1.21	1.36	1.52	1.67	1.8%
Delivered energy	11.13	11.66	11.24	11.36	11.51	11.73	11.93	0.1%
Electricity related losses	9.80	10.39	9.58	10.01	10.52	10.95	11.35	0.4%
Total energy consumption by end use								
Space heating	5.41	5.70	5.42	5.37	5.29	5.24	5.17	-0.4%
Space cooling	2.52	3.34	3.06	3.19	3.36	3.51	3.65	0.4%
Water heating	2.87	2.85	2.85	2.93	2.98	2.96	2.90	0.1%
Refrigeration	1.17	1.15	1.11	1.14	1.18	1.23	1.28	0.4%
Cooking	0.58	0.58	0.59	0.61	0.64	0.67	0.69	0.7%
Clothes dryers	0.65	0.65	0.64	0.62	0.59	0.58	0.60	-0.4%
Freezers	0.26	0.26	0.25	0.26	0.26	0.26	0.26	0.1%
Lighting	2.18	2.13	1.58	1.45	1.39	1.37	1.37	-1.7%
Clothes washers ¹	0.10	0.10	0.10	0.08	0.07	0.07	0.07	-1.4%
Dishwashers ¹	0.31	0.31	0.30	0.30	0.30	0.31	0.33	0.2%
Color televisions and set-top boxes	1.00	1.02	0.98	1.03	1.10	1.18	1.26	0.9%
Personal computers and related equipment	0.53	0.53	0.57	0.65	0.72	0.76	0.79	1.6%
Furnace fans and boiler circulation pumps	0.42	0.42	0.42	0.43	0.44	0.44	0.44	0.2%
Other uses ⁶	2.94	3.01	2.96	3.29	3.70	4.10	4.47	1.6%
Total	20.93	22.05	20.81	21.36	22.02	22.68	23.28	0.2%
Nonmarketed renewables⁷								
Geothermal heat pumps	0.00	0.01	0.01	0.02	0.02	0.02	0.03	6.4%
Solar hot water heating	0.01	0.01	0.02	0.02	0.02	0.02	0.02	2.4%
Solar photovoltaic	0.00	0.00	0.04	0.05	0.05	0.06	0.06	10.7%
Wind	0.00	0.00	0.01	0.01	0.01	0.01	0.01	9.1%
Total	0.02	0.02	0.08	0.10	0.10	0.11	0.11	6.9%
Heating degree days⁸	4408	4382	4208	4172	4136	4101	4067	-0.3%
Cooling degree days⁸	1279	1498	1392	1409	1426	1443	1459	-0.1%

¹Does not include water heating portion of load.

²Includes small electric devices, heating elements, and motors not listed above. Electric vehicles are included in the transportation sector.

³Includes such appliances as outdoor grills and mosquito traps.

⁴Includes wood used for primary and secondary heating in wood stoves or fireplaces as reported in the *Residential Energy Consumption Survey 2005*.

⁵Includes kerosene and coal.

⁶Includes all other uses listed above.

⁷Represents delivered energy displaced.

⁸See Table A5 for regional detail.

Btu = British thermal unit.

-- = Not applicable.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 consumption based on: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2009 and 2010 degree days based on state-level data from the National Oceanic and Atmospheric Administration's Climatic Data Center and Climate Prediction Center. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Table A5. Commercial sector key indicators and consumption
(quadrillion Btu per year, unless otherwise noted)

Key indicators and consumption	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Key indicators								
Total floorspace (billion square feet)								
Surviving	78.0	79.3	82.4	87.0	91.9	96.2	100.7	1.0%
New additions	2.3	1.8	1.7	2.0	2.0	2.0	2.3	1.0%
Total	80.3	81.1	84.1	89.1	93.9	98.2	103.0	1.0%
Energy consumption intensity (thousand Btu per square foot)								
Delivered energy consumption	106.0	107.3	104.6	103.1	101.0	100.6	99.8	-0.3%
Electricity related losses	117.0	117.3	110.2	110.6	110.6	110.2	109.0	-0.3%
Total energy consumption	223.0	224.5	214.8	213.7	211.5	210.7	208.8	-0.3%
Delivered energy consumption by fuel								
Purchased electricity								
Space heating ¹	0.18	0.18	0.16	0.16	0.16	0.16	0.16	-0.6%
Space cooling ¹	0.47	0.56	0.50	0.50	0.51	0.52	0.53	-0.2%
Water heating ¹	0.09	0.09	0.09	0.09	0.09	0.09	0.08	-0.4%
Ventilation	0.50	0.51	0.53	0.56	0.58	0.61	0.63	0.9%
Cooking	0.02	0.02	0.02	0.02	0.02	0.02	0.02	-0.3%
Lighting	1.03	1.01	1.00	1.03	1.06	1.10	1.13	0.4%
Refrigeration	0.40	0.39	0.35	0.34	0.34	0.34	0.35	-0.4%
Office equipment (PC)	0.22	0.21	0.19	0.19	0.20	0.21	0.21	0.0%
Office equipment (non-PC)	0.25	0.26	0.31	0.37	0.40	0.44	0.46	2.3%
Other uses ²	1.29	1.30	1.43	1.62	1.80	2.00	2.22	2.2%
Delivered energy	4.46	4.54	4.59	4.88	5.16	5.48	5.80	1.0%
Natural gas								
Space heating ¹	1.61	1.65	1.69	1.73	1.70	1.68	1.64	-0.0%
Space cooling ¹	0.03	0.04	0.04	0.04	0.03	0.03	0.03	-1.1%
Water heating ¹	0.43	0.44	0.48	0.51	0.52	0.53	0.54	0.8%
Cooking	0.17	0.18	0.19	0.20	0.21	0.22	0.22	0.9%
Other uses ³	0.95	0.98	1.01	1.04	1.07	1.14	1.25	1.0%
Delivered energy	3.20	3.28	3.41	3.51	3.53	3.60	3.69	0.5%
Distillate fuel oil								
Space heating ¹	0.16	0.14	0.12	0.11	0.10	0.10	0.09	-1.7%
Water heating ¹	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.9%
Other uses ⁴	0.22	0.26	0.20	0.20	0.20	0.20	0.19	-1.2%
Delivered energy	0.41	0.43	0.35	0.34	0.33	0.33	0.32	-1.2%
Marketed renewables (biomass)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.0%
Other fuels ⁵	0.33	0.34	0.33	0.34	0.34	0.35	0.36	0.2%
Delivered energy consumption by end use								
Space heating ¹	1.95	1.97	1.98	2.00	1.96	1.93	1.89	-0.2%
Space cooling ¹	0.50	0.60	0.54	0.54	0.54	0.55	0.57	-0.2%
Water heating ¹	0.55	0.56	0.60	0.63	0.64	0.65	0.66	0.7%
Ventilation	0.50	0.51	0.53	0.56	0.58	0.61	0.63	0.9%
Cooking	0.20	0.20	0.21	0.23	0.23	0.24	0.24	0.8%
Lighting	1.03	1.01	1.00	1.03	1.06	1.10	1.13	0.4%
Refrigeration	0.40	0.39	0.35	0.34	0.34	0.34	0.35	-0.4%
Office equipment (PC)	0.22	0.21	0.19	0.19	0.20	0.21	0.21	0.0%
Office equipment (non-PC)	0.25	0.26	0.31	0.37	0.40	0.44	0.46	2.3%
Other uses ⁶	2.90	2.99	3.09	3.30	3.53	3.80	4.13	1.3%
Delivered energy	8.51	8.70	8.80	9.18	9.48	9.87	10.28	0.7%

Table A5. Commercial sector key indicators and consumption (continued)
(quadrillion Btu per year, unless otherwise noted)

Key indicators and consumption	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Electricity related losses	9.39	9.52	9.27	9.85	10.38	10.82	11.23	0.7%
Total energy consumption by end use								
Space heating ¹	2.34	2.35	2.31	2.33	2.28	2.24	2.19	-0.3%
Space cooling ¹	1.50	1.77	1.54	1.55	1.57	1.58	1.60	-0.4%
Water heating ¹	0.75	0.75	0.78	0.80	0.81	0.82	0.82	0.4%
Ventilation	1.56	1.57	1.60	1.69	1.75	1.81	1.84	0.6%
Cooking	0.25	0.25	0.26	0.27	0.27	0.28	0.29	0.5%
Lighting	3.21	3.14	3.01	3.12	3.21	3.27	3.32	0.2%
Refrigeration	1.24	1.21	1.06	1.02	1.02	1.02	1.04	-0.6%
Office equipment (PC)	0.67	0.66	0.57	0.58	0.59	0.61	0.63	-0.2%
Office equipment (non-PC)	0.77	0.81	0.95	1.10	1.21	1.30	1.36	2.1%
Other uses ⁶	5.62	5.71	5.98	6.56	7.15	7.75	8.42	1.6%
Total	17.90	18.22	18.06	19.03	19.86	20.69	21.50	0.7%
Nonmarketed renewable fuels⁷								
Solar thermal	0.03	0.03	0.03	0.03	0.03	0.04	0.04	1.4%
Solar photovoltaic	0.00	0.01	0.01	0.01	0.01	0.01	0.01	2.8%
Wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.3%
Total	0.03	0.03	0.04	0.04	0.04	0.05	0.05	1.7%
Heating Degree Days								
New England	6649	5944	6349	6351	6355	6358	6360	0.3%
Middle Atlantic	5798	5453	5588	5587	5586	5585	5583	0.1%
East North Central	6542	6209	6215	6215	6215	6215	6215	0.0%
West North Central	6837	6585	6456	6461	6463	6466	6468	-0.1%
South Atlantic	2839	3183	2728	2703	2677	2651	2625	-0.8%
East South Central	3599	4003	3474	3480	3485	3491	3496	-0.5%
West South Central	2198	2503	2156	2149	2143	2137	2131	-0.6%
Mountain	4852	4808	4780	4749	4713	4677	4641	-0.1%
Pacific	3188	3202	3130	3135	3138	3140	3143	-0.1%
United States	4408	4382	4208	4172	4136	4101	4067	-0.3%
Cooling Degree Days								
New England	363	655	518	518	517	517	516	-0.9%
Middle Atlantic	587	997	783	783	783	784	784	-1.0%
East North Central	547	978	779	780	780	781	781	-0.9%
West North Central	720	1123	976	975	974	973	973	-0.6%
South Atlantic	2047	2289	2103	2118	2134	2149	2165	-0.2%
East South Central	1491	1999	1668	1665	1662	1658	1655	-0.8%
West South Central	2582	2755	2602	2607	2611	2615	2619	-0.2%
Mountain	1551	1489	1578	1595	1617	1637	1658	0.4%
Pacific	967	746	891	888	887	885	883	0.7%
United States	1279	1498	1392	1409	1426	1443	1459	-0.1%

¹Includes fuel consumption for district services.

²Includes miscellaneous uses, such as service station equipment, automated teller machines, telecommunications equipment, and medical equipment.

³Includes miscellaneous uses, such as pumps, emergency generators, combined heat and power in commercial buildings, and manufacturing performed in commercial buildings.

⁴Includes miscellaneous uses, such as cooking, emergency generators, and combined heat and power in commercial buildings.

⁵Includes residual fuel oil, liquefied petroleum gases, coal, motor gasoline, and kerosene.

⁶Includes miscellaneous uses, such as service station equipment, automated teller machines, telecommunications equipment, medical equipment, pumps, emergency generators, combined heat and power in commercial buildings, manufacturing performed in commercial buildings, and cooking (distillate), plus residual fuel oil, liquefied petroleum gases, coal, motor gasoline, and kerosene.

⁷Represents delivered energy displaced.

Btu = British thermal unit.

PC = Personal computer.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 consumption based on: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2009 and 2010 degree days based on state-level data from the National Oceanic and Atmospheric Administration's Climatic Data Center and Climate Prediction Center. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Table A6. Industrial sector key indicators and consumption

Key indicators and consumption	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Key indicators								
Value of shipments (billion 2005 dollars)								
Manufacturing	4052	4260	4857	5260	5745	6023	6285	1.6%
Nonmanufacturing	1615	1578	1873	2103	2228	2305	2407	1.7%
Total	5667	5838	6730	7363	7973	8328	8692	1.6%
Energy prices								
(2010 dollars per million Btu)								
Liquefied petroleum gases	20.05	21.80	27.43	27.76	29.24	30.48	32.18	1.6%
Motor gasoline	16.79	16.77	29.20	30.72	32.06	33.01	33.55	2.8%
Distillate fuel oil	16.74	21.32	24.20	25.73	27.22	28.39	29.53	1.3%
Residual fuel oil	12.16	10.92	19.21	20.53	21.23	21.71	21.65	2.8%
Asphalt and road oil	6.59	5.59	9.30	9.94	10.37	10.45	10.69	2.6%
Natural gas heat and power	4.59	4.78	4.16	4.41	5.33	5.88	6.89	1.5%
Natural gas feedstocks	6.16	6.32	5.68	5.93	6.83	7.36	8.33	1.1%
Metallurgical coal	5.49	5.84	7.22	7.58	8.11	8.61	9.11	1.8%
Other industrial coal	2.99	2.71	3.27	3.30	3.38	3.50	3.64	1.2%
Coal for liquids	--	--	1.26	2.05	2.08	2.22	2.38	--
Electricity	20.05	19.63	18.91	18.95	19.60	19.81	20.78	0.2%
(nominal dollars per million Btu)								
Liquefied petroleum gases	19.82	21.80	29.56	32.63	37.51	43.38	50.95	3.5%
Motor gasoline	16.60	16.77	31.46	36.10	41.14	46.98	53.12	4.7%
Distillate fuel oil	16.55	21.32	26.08	30.24	34.93	40.40	46.76	3.2%
Residual fuel oil	12.02	10.92	20.70	24.13	27.24	30.89	34.28	4.7%
Asphalt and road oil	6.52	5.59	10.02	11.68	13.30	14.87	16.93	4.5%
Natural gas heat and power	4.54	4.78	4.49	5.19	6.84	8.37	10.91	3.4%
Natural gas feedstocks	6.09	6.32	6.12	6.96	8.77	10.48	13.18	3.0%
Metallurgical coal	5.43	5.84	7.78	8.91	10.40	12.26	14.42	3.7%
Other industrial coal	2.96	2.71	3.52	3.87	4.34	4.98	5.77	3.1%
Coal for liquids	--	--	1.36	2.41	2.67	3.16	3.78	--
Electricity	19.83	19.63	20.38	22.27	25.15	28.20	32.90	2.1%
Energy consumption (quadrillion Btu)¹								
Industrial consumption excluding refining								
Liquefied petroleum gases heat and power ..	0.45	0.41	0.36	0.39	0.41	0.41	0.40	-0.0%
Liquefied petroleum gases feedstocks	1.54	1.58	1.45	1.65	1.75	1.76	1.74	0.4%
Motor gasoline	0.24	0.25	0.28	0.30	0.30	0.30	0.30	0.8%
Distillate fuel oil	1.11	1.15	1.25	1.18	1.19	1.17	1.18	0.1%
Residual fuel oil	0.10	0.11	0.09	0.08	0.08	0.08	0.08	-1.1%
Petrochemical feedstocks	0.90	0.94	1.01	1.20	1.29	1.31	1.30	1.3%
Petroleum coke	0.28	0.16	0.20	0.19	0.15	0.12	0.13	-1.1%
Asphalt and road oil	0.87	0.88	1.00	1.00	0.98	0.94	0.94	0.3%
Miscellaneous petroleum ²	0.38	0.52	0.14	0.12	0.12	0.11	0.12	-5.8%
Petroleum subtotal	5.87	6.00	5.78	6.11	6.27	6.20	6.19	0.1%
Natural gas heat and power	4.48	4.84	5.23	5.22	5.27	5.23	5.23	0.3%
Natural gas feedstocks	0.47	0.48	0.48	0.51	0.50	0.47	0.44	-0.3%
Lease and plant fuel ³	1.31	1.37	1.43	1.55	1.57	1.59	1.63	0.7%
Natural gas subtotal	6.25	6.69	7.14	7.27	7.34	7.29	7.31	0.4%
Metallurgical coal and coke ⁴	0.38	0.55	0.56	0.46	0.46	0.42	0.38	-1.5%
Other industrial coal	0.88	0.95	0.97	0.98	1.02	1.02	1.02	0.3%
Coal subtotal	1.26	1.50	1.53	1.44	1.47	1.44	1.40	-0.3%
Renewables ⁵	1.37	1.50	1.61	1.67	1.82	1.87	1.95	1.1%
Purchased electricity	2.94	3.09	3.24	3.26	3.33	3.24	3.12	0.0%
Delivered energy	17.69	18.78	19.30	19.75	20.23	20.04	19.97	0.2%
Electricity related losses	6.19	6.47	6.55	6.58	6.69	6.39	6.04	-0.3%
Total	23.88	25.25	25.84	26.33	26.92	26.44	26.01	0.1%

Table A6. Industrial sector key indicators and consumption (continued)

Key indicators and consumption	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Refining consumption								
Liquefied petroleum gases heat and power . . .	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.4%
Distillate fuel oil	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Residual fuel oil	0.01	0.01	0.00	0.00	0.00	0.00	0.00	--
Petroleum coke	0.52	0.52	0.53	0.49	0.49	0.51	0.53	0.1%
Still gas	1.50	1.50	1.55	1.36	1.34	1.39	1.45	-0.1%
Miscellaneous petroleum ²	0.02	0.02	0.02	0.02	0.02	0.02	0.02	1.2%
Petroleum subtotal	2.05	2.05	2.11	1.89	1.86	1.93	2.02	-0.1%
Natural gas heat and power	1.38	1.44	1.48	1.53	1.55	1.51	1.51	0.2%
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Natural gas subtotal	1.38	1.44	1.48	1.53	1.55	1.51	1.51	0.2%
Other industrial coal	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.0%
Coal-to-liquids heat and power	0.00	0.00	0.00	0.26	0.36	0.48	0.60	--
Coal subtotal	0.06	0.06	0.06	0.32	0.42	0.54	0.66	10.0%
Biofuels heat and coproducts	0.82	0.84	0.81	0.96	1.27	1.92	2.57	4.6%
Purchased electricity	0.19	0.20	0.20	0.20	0.19	0.20	0.21	0.3%
Delivered energy	4.51	4.60	4.66	4.89	5.30	6.10	6.97	1.7%
Electricity related losses	0.40	0.41	0.39	0.39	0.39	0.40	0.41	0.0%
Total	4.91	5.01	5.05	5.28	5.69	6.50	7.39	1.6%
Total industrial sector consumption								
Liquefied petroleum gases heat and power . . .	0.46	0.42	0.38	0.41	0.42	0.42	0.41	-0.0%
Liquefied petroleum gases feedstocks	1.54	1.58	1.45	1.65	1.75	1.76	1.74	0.4%
Motor gasoline	0.24	0.25	0.28	0.30	0.30	0.30	0.30	0.8%
Distillate fuel oil	1.11	1.16	1.25	1.18	1.19	1.17	1.18	0.1%
Residual fuel oil	0.11	0.12	0.09	0.08	0.08	0.08	0.08	-1.3%
Petrochemical feedstocks	0.90	0.94	1.01	1.20	1.29	1.31	1.30	1.3%
Petroleum coke	0.80	0.68	0.73	0.68	0.64	0.63	0.66	-0.1%
Asphalt and road oil	0.87	0.88	1.00	1.00	0.98	0.94	0.94	0.3%
Still gas	1.50	1.50	1.55	1.36	1.34	1.39	1.45	-0.1%
Miscellaneous petroleum ²	0.40	0.54	0.17	0.14	0.14	0.13	0.14	-5.3%
Petroleum subtotal	7.93	8.05	7.89	7.99	8.13	8.13	8.21	0.1%
Natural gas heat and power	5.86	6.28	6.71	6.75	6.82	6.74	6.74	0.3%
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Natural gas feedstocks	0.47	0.48	0.48	0.51	0.50	0.47	0.44	-0.3%
Lease and plant fuel ³	1.31	1.37	1.43	1.55	1.57	1.59	1.63	0.7%
Natural gas subtotal	7.63	8.14	8.62	8.80	8.89	8.80	8.81	0.3%
Metallurgical coal and coke ⁴	0.38	0.55	0.56	0.46	0.46	0.42	0.38	-1.5%
Other industrial coal	0.94	1.01	1.03	1.04	1.08	1.08	1.08	0.3%
Coal-to-liquids heat and power	0.00	0.00	0.00	0.26	0.36	0.48	0.60	--
Coal subtotal	1.32	1.56	1.59	1.76	1.90	1.98	2.06	1.1%
Biofuels heat and coproducts	0.82	0.84	0.81	0.96	1.27	1.92	2.57	4.6%
Renewables ⁵	1.37	1.50	1.61	1.67	1.82	1.87	1.95	1.1%
Purchased electricity	3.13	3.28	3.44	3.46	3.52	3.44	3.33	0.1%
Delivered energy	22.20	23.37	23.96	24.64	25.53	26.14	26.94	0.6%
Electricity related losses	6.59	6.89	6.94	6.97	7.09	6.80	6.46	-0.3%
Total	28.79	30.26	30.90	31.61	32.61	32.93	33.39	0.4%

Table A6. Industrial sector key indicators and consumption (continued)

Key indicators and consumption	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Energy consumption per dollar of shipments (thousand Btu per 2005 dollar)								
Liquid fuels and other petroleum	1.40	1.38	1.17	1.09	1.02	0.98	0.94	-1.5%
Natural gas	1.35	1.39	1.28	1.20	1.11	1.06	1.01	-1.3%
Coal	0.23	0.27	0.24	0.24	0.24	0.24	0.24	-0.5%
Renewable fuels ⁵	0.39	0.40	0.36	0.36	0.39	0.45	0.52	1.0%
Purchased electricity	0.55	0.56	0.51	0.47	0.44	0.41	0.38	-1.5%
Delivered energy	3.92	4.00	3.56	3.35	3.20	3.14	3.10	-1.0%
Industrial combined heat and power								
Capacity (gigawatts)	25.08	25.64	30.38	35.48	40.71	48.10	55.79	3.2%
Generation (billion kilowatthours)	130.57	141.07	168.00	201.40	235.62	287.62	341.40	3.6%

¹Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public.

²Includes lubricants and miscellaneous petroleum products.

³Represents natural gas used in well, field, and lease operations, and in natural gas processing plant machinery.

⁴Includes net coal coke imports.

⁵Includes consumption of energy produced from hydroelectric, wood and wood waste, municipal waste, and other biomass sources.

Btu = British thermal unit.

-- = Not applicable.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 prices for motor gasoline and distillate fuel oil are based on: U.S. Energy Information Administration (EIA), *Petroleum Marketing Annual 2009*, DOE/EIA-0487(2009) (Washington, DC, August 2010). 2009 and 2010 petrochemical feedstock and asphalt and road oil prices are based on: EIA, *State Energy Data Report 2009*, DOE/EIA-0214(2009) (Washington, DC, June 2011). 2009 and 2010 coal prices are based on: EIA, *Quarterly Coal Report, October-December 2010*, DOE/EIA-0121(2010/4Q) (Washington, DC, May 2011) and EIA, AEO2012 National Energy Modeling System run REF2012.D020112C. 2009 and 2010 electricity prices: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2009 and 2010 natural gas prices are based on: EIA, *Manufacturing Energy Consumption Survey* and industrial and wellhead prices from the *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010) and the *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2009 refining consumption values are based on: *Petroleum Supply Annual 2009*, DOE/EIA-0340(2009)/1 (Washington, DC, July 2010). 2010 refining consumption based on: *Petroleum Supply Annual 2010*, DOE/EIA-0340(2010)/1 (Washington, DC, July 2011). Other 2009 and 2010 consumption values are based on: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2009 and 2010 shipments: IHS Global Insight, Global Insight Industry model, August 2011. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Table A7. Transportation sector key indicators and delivered energy consumption

Key indicators and consumption	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Key indicators								
Travel indicators								
(billion vehicle miles traveled)								
Light-duty vehicles less than 8,501 pounds	2625	2662	2710	2881	3111	3363	3583	1.2%
Commercial light trucks ¹	58	64	70	76	83	88	92	1.5%
Freight trucks greater than 10,000 pounds	240	234	273	297	317	330	345	1.6%
(billion seat miles available)								
Air	964	999	1028	1075	1120	1164	1208	0.8%
(billion ton miles traveled)								
Rail	1532	1559	1503	1662	1782	1826	1871	0.7%
Domestic shipping	477	522	549	587	604	617	627	0.7%
Energy efficiency indicators								
(miles per gallon)								
New light-duty vehicle CAFE standard ²	25.4	25.7	32.4	35.0	35.2	35.3	35.3	1.3%
New car ²	28.2	28.2	37.0	39.9	39.9	39.9	39.9	1.4%
New light truck ²	23.0	23.4	27.9	29.2	29.2	29.2	29.2	0.9%
Compliance new light-duty vehicle ³	29.3	29.2	32.5	35.9	36.8	37.4	37.9	1.0%
New car ³	34.0	33.8	37.4	40.3	41.3	42.2	42.9	1.0%
New light truck ³	25.4	25.5	27.7	30.6	31.0	31.2	31.5	0.8%
Tested new light-duty vehicle ⁴	28.2	28.3	31.5	35.9	36.8	37.4	37.9	1.2%
New car ⁴	33.2	33.3	36.4	40.3	41.2	42.2	42.8	1.0%
New light truck ⁴	24.2	24.3	26.7	30.6	31.0	31.2	31.5	1.0%
On-road new light-duty vehicle ⁵	23.0	22.9	25.6	29.2	30.0	30.5	30.9	1.2%
New car ⁵	27.4	27.3	29.9	33.1	33.9	34.7	35.2	1.0%
New light truck ⁵	19.5	19.6	21.6	24.7	24.9	25.2	25.4	1.0%
Light-duty stock ⁶	20.4	20.4	21.5	23.6	25.6	27.1	28.2	1.3%
New commercial light truck ¹	15.6	15.7	16.7	18.8	18.9	19.0	19.1	0.8%
Stock commercial light truck ¹	14.3	14.4	15.2	16.7	18.0	18.7	19.0	1.1%
Freight truck	6.7	6.7	6.8	7.3	7.7	8.0	8.1	0.8%
(seat miles per gallon)								
Aircraft	62.0	62.3	62.8	63.8	65.2	67.0	69.3	0.4%
(ton miles per thousand Btu)								
Rail	3.4	3.4	3.5	3.5	3.5	3.5	3.5	0.1%
Domestic shipping	2.4	2.4	2.4	2.5	2.5	2.5	2.5	0.2%
Energy use by mode								
(quadrillion Btu)								
Light-duty vehicles	15.89	16.06	15.39	14.84	14.73	15.05	15.46	-0.2%
Commercial light trucks ¹	0.51	0.55	0.58	0.57	0.58	0.59	0.61	0.4%
Bus transportation	0.21	0.25	0.26	0.27	0.29	0.30	0.31	0.9%
Freight trucks	4.95	4.82	5.51	5.57	5.66	5.69	5.84	0.8%
Rail, passenger	0.04	0.05	0.05	0.06	0.06	0.06	0.06	1.2%
Rail, freight	0.36	0.45	0.43	0.48	0.51	0.52	0.53	0.6%
Shipping, domestic	0.17	0.22	0.23	0.24	0.25	0.25	0.25	0.5%
Shipping, international	0.77	0.86	0.87	0.87	0.88	0.88	0.89	0.1%
Recreational boats	0.24	0.25	0.26	0.26	0.27	0.28	0.29	0.5%
Air	2.44	2.52	2.55	2.63	2.71	2.76	2.79	0.4%
Military use	0.71	0.77	0.66	0.64	0.66	0.70	0.74	-0.1%
Lubricants	0.13	0.14	0.13	0.14	0.14	0.14	0.14	0.1%
Pipeline fuel	0.61	0.65	0.68	0.67	0.67	0.68	0.69	0.2%
Total	27.04	27.59	27.60	27.25	27.40	27.90	28.60	0.1%

Table A7. Transportation sector key indicators and delivered energy consumption (continued)

Key indicators and consumption	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Energy use by mode (million barrels per day oil equivalent)								
Light-duty vehicles	8.50	8.63	8.30	8.05	8.05	8.31	8.64	0.0%
Commercial light trucks ¹	0.26	0.28	0.30	0.29	0.30	0.30	0.31	0.4%
Bus transportation	0.10	0.12	0.13	0.13	0.14	0.14	0.15	0.9%
Freight trucks	2.39	2.32	2.65	2.68	2.72	2.74	2.81	0.8%
Rail, passenger	0.02	0.02	0.02	0.03	0.03	0.03	0.03	1.2%
Rail, freight	0.17	0.22	0.21	0.23	0.24	0.25	0.25	0.6%
Shipping, domestic	0.08	0.10	0.11	0.11	0.11	0.11	0.12	0.5%
Shipping, international	0.34	0.38	0.38	0.38	0.38	0.39	0.39	0.1%
Recreational boats	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.5%
Air	1.18	1.22	1.23	1.27	1.31	1.33	1.35	0.4%
Military use	-0.34	0.37	0.32	0.31	0.32	0.34	0.36	-0.1%
Lubricants	0.06	0.07	0.06	0.06	0.07	0.07	0.07	0.1%
Pipeline fuel	0.29	0.31	0.32	0.32	0.32	0.32	0.32	0.2%
Total	13.87	14.17	14.17	14.01	14.14	14.48	14.95	0.2%

¹Commercial trucks 8,501 to 10,000 pounds gross vehicle weight rating.

²CAFE standard based on projected new vehicle sales.

³Includes CAFE credits for alternative fueled vehicle sales and credit banking.

⁴Environmental Protection Agency rated miles per gallon.

⁵Tested new vehicle efficiency revised for on-road performance.

⁶Combined "on-the-road" estimate for all cars and light trucks.

CAFE = Corporate average fuel economy.

Btu = British thermal unit.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010: U.S. Energy Information Administration (EIA), *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010); EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011); Federal Highway Administration, *Highway Statistics 2009* (Washington, DC, April 2011); Oak Ridge National Laboratory, *Transportation Energy Data Book Edition 30 and Annual* (Oak Ridge, TN, 2011); National Highway Traffic and Safety Administration, *Summary of Fuel Economy Performance* (Washington, DC, October 28, 2010); U.S. Department of Commerce, Bureau of the Census, "Vehicle Inventory and Use Survey," EC02TV (Washington, DC, December 2004); EIA, *Alternatives to Traditional Transportation Fuels 2008 (Part II - User and Fuel Data)*, April 2010; EIA, *State Energy Data Report 2009*, DOE/EIA-0214(2009) (Washington, DC, June 2011); U.S. Department of Transportation, Research and Special Programs Administration, *Air Carrier Statistics Monthly, December 2010/2009* (Washington, DC, December 2010); EIA, *Fuel Oil and Kerosene Sales 2009*, DOE/EIA-0535(2009) (Washington, DC, February 2011); and United States Department of Defense, Defense Fuel Supply Center, *Fact Book* (January, 2010). Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Electricity

Table A8. Electricity supply, disposition, prices, and emissions
(billion kilowatthours, unless otherwise noted)

Supply, disposition, prices, and emissions	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Generation by fuel type								
Electric power sector¹								
Power only²								
Coal	1712	1799	1531	1604	1710	1757	1803	0.0%
Petroleum	32	32	25	26	26	27	27	-0.6%
Natural gas ³	723	776	903	874	882	983	1074	1.3%
Nuclear power	799	807	830	887	917	914	887	0.4%
Pumped storage/other ⁴	2	2	2	2	2	2	2	-1.2%
Renewable sources ⁵	384	390	504	544	579	594	630	1.9%
Distributed generation (natural gas)	0	0	0	1	2	3	4	--
Total	3651	3806	3796	3937	4118	4279	4427	0.6%
Combined heat and power⁶								
Coal	29	32	30	30	31	31	31	-0.1%
Petroleum	4	3	1	1	1	1	1	-5.2%
Natural gas	118	122	126	124	124	124	123	0.0%
Renewable sources	5	5	4	5	5	5	4	-0.7%
Total	159	165	160	160	161	160	159	-0.1%
Total electric power sector generation	3810	3971	3956	4097	4279	4439	4586	0.6%
Less direct use	14	16	13	13	13	13	13	-0.7%
Net available to the grid	3796	3955	3942	4084	4265	4426	4572	0.6%
End-use sector⁷								
Coal	15	20	20	38	46	54	63	4.7%
Petroleum	3	3	2	2	2	2	2	-0.7%
Natural gas	80	84	101	113	132	160	198	3.5%
Other gaseous fuels ⁸	10	11	16	16	15	15	15	1.2%
Renewable sources ⁹	31	34	55	65	78	103	125	5.4%
Other ¹⁰	4	4	3	3	3	3	3	-0.8%
Total end-use sector generation	143	155	197	237	277	338	406	3.9%
Less direct use	107	112	149	180	208	243	288	3.8%
Total sales to the grid	36	43	48	57	69	95	118	4.1%
Total electricity generation by fuel								
Coal	1756	1851	1581	1671	1786	1841	1897	0.1%
Petroleum	39	37	28	28	29	29	30	-0.8%
Natural gas	921	982	1130	1113	1140	1270	1398	1.4%
Nuclear power	799	807	830	887	917	914	887	0.4%
Renewable sources ^{5,9}	420	429	562	614	662	702	760	2.3%
Other ¹¹	19	21	21	21	21	21	21	-0.0%
Total electricity generation	3953	4126	4152	4334	4556	4777	4992	0.8%
Net generation to the grid	3832	3998	3990	4141	4335	4521	4691	0.6%
Net imports	34	26	29	26	22	14	12	-2.9%
Electricity sales by sector								
Residential	1364	1451	1392	1454	1533	1626	1718	0.7%
Commercial	1307	1329	1346	1431	1513	1607	1699	1.0%
Industrial	917	962	1008	1013	1032	1009	977	0.1%
Transportation	7	7	8	9	12	16	22	4.8%
Total	3596	3749	3753	3907	4090	4258	4415	0.7%
Direct use	121	128	162	193	221	256	302	3.5%
Total electricity use	3717	3877	3915	4100	4311	4514	4716	0.8%

Table A8. Electricity supply, disposition, prices, and emissions (continued)
(billion kilowatthours, unless otherwise noted)

Supply, disposition, prices, and emissions	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
End-use prices								
(2010 cents per kilowatthour)								
Residential	11.6	11.5	11.8	11.6	11.6	11.6	11.8	0.1%
Commercial	10.3	10.1	9.9	9.8	9.9	9.8	10.1	-0.0%
Industrial	6.8	6.7	6.5	6.5	6.7	6.8	7.1	0.2%
Transportation	12.2	11.3	10.4	10.1	10.8	11.1	11.5	0.1%
All sectors average	9.9	9.8	9.7	9.6	9.7	9.8	10.1	0.1%
(nominal cents per kilowatthour)								
Residential	11.5	11.5	12.7	13.6	14.9	16.5	18.7	2.0%
Commercial	10.1	10.1	10.7	11.5	12.7	13.9	15.9	1.8%
Industrial	6.8	6.7	7.0	7.6	8.6	9.6	11.2	2.1%
Transportation	12.0	11.3	11.2	11.9	13.8	15.8	18.3	2.0%
All sectors average	9.8	9.8	10.4	11.3	12.5	13.9	16.0	2.0%
Prices by service category								
(2010 cents per kilowatthour)								
Generation	6.1	5.9	5.6	5.7	6.0	6.1	6.4	0.3%
Transmission	1.0	1.0	1.1	1.1	1.1	1.1	1.1	0.3%
Distribution	2.9	2.9	3.0	2.8	2.7	2.6	2.6	-0.5%
(nominal cents per kilowatthour)								
Generation	6.0	5.9	6.0	6.7	7.7	8.7	10.2	2.2%
Transmission	1.0	1.0	1.2	1.3	1.4	1.6	1.8	2.2%
Distribution	2.8	2.9	3.3	3.3	3.4	3.7	4.1	1.4%
Electric power sector emissions¹								
Sulfur dioxide (million short tons)	5.72	5.11	1.26	1.31	1.55	1.62	1.71	-4.3%
Nitrogen oxide (million short tons)	1.99	2.06	1.79	1.87	1.92	1.94	1.96	-0.2%
Mercury (short tons)	36.25	34.70	6.44	6.74	7.24	7.51	7.86	-5.8%

¹Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

²Includes plants that only produce electricity.

³Includes electricity generation from fuel cells.

⁴Includes non-biogenic municipal waste. The U.S. Energy Information Administration estimates that in 2010 approximately 6 billion kilowatthours of electricity were generated from a municipal waste stream containing petroleum-derived plastics and other non-renewable sources. See U.S. Energy Information Administration, *Methodology for Allocating Municipal Solid Waste to Biogenic and Non-Biogenic Energy*, (Washington, DC, May 2007).

⁵Includes conventional hydroelectric, geothermal, wood, wood waste, biogenic municipal waste, landfill gas, other biomass, solar, and wind power.

⁶Includes combined heat and power plants whose primary business is to sell electricity and heat to the public (i.e., those that report North American Industry Classification System code 22).

⁷Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.

⁸Includes refinery gas and still gas.

⁹Includes conventional hydroelectric, geothermal, wood, wood waste, all municipal waste, landfill gas, other biomass, solar, and wind power.

¹⁰Includes batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

¹¹Includes pumped storage, non-biogenic municipal waste, refinery gas, still gas, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

- - = Not applicable.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 electric power sector generation; sales to the grid; net imports; electricity sales; and electricity end-use prices: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011), and supporting databases. 2009 and 2010 emissions: U.S. Environmental Protection Agency, Clean Air Markets Database. 2009 and 2010 electricity prices by service category: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Reference case

Table A9. Electricity generating capacity
(gigawatts)

Net summer capacity ¹	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Electric power sector²								
Power only³								
Coal	305.9	308.1	276.7	269.8	269.8	269.9	270.4	-0.5%
Oil and natural gas steam ⁴	109.1	107.4	90.0	89.4	88.9	88.0	87.2	-0.8%
Combined cycle	167.7	171.7	187.4	187.7	197.6	218.3	246.0	1.4%
Combustion turbine/diesel	133.1	134.8	138.7	145.6	152.7	158.6	169.0	0.9%
Nuclear power ⁵	101.1	101.2	103.6	111.2	114.7	114.3	110.9	0.4%
Pumped storage	22.2	22.2	22.2	22.2	22.2	22.2	22.2	0.0%
Fuel cells	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.7%
Renewable sources ⁶	120.3	125.2	144.4	145.8	151.2	156.1	169.3	1.2%
Distributed generation ⁷	0.0	0.0	0.2	0.5	0.8	1.3	2.1	--
Total	959.5	970.6	963.2	972.1	997.8	1028.7	1077.0	0.4%
Combined heat and power⁸								
Coal	5.3	5.2	4.8	4.8	4.8	4.8	4.8	-0.3%
Oil and natural gas steam ⁴	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.0%
Combined cycle	25.8	26.3	26.3	26.3	26.3	26.3	26.3	-0.0%
Combustion turbine/diesel	2.8	2.8	2.8	2.8	2.8	2.8	2.8	-0.0%
Renewable sources ⁶	0.8	0.9	0.9	0.9	0.9	0.9	0.9	0.2%
Total	35.4	35.9	35.5	35.5	35.5	35.5	35.5	-0.0%
Cumulative planned additions⁹								
Coal	0.0	0.0	9.3	9.3	9.3	9.3	9.3	--
Oil and natural gas steam ⁴	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Combined cycle	0.0	0.0	14.3	14.3	14.3	14.3	14.3	--
Combustion turbine/diesel	0.0	0.0	5.0	5.0	5.0	5.0	5.0	--
Nuclear power	0.0	0.0	1.1	6.8	6.8	6.8	6.8	--
Pumped storage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Fuel cells	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Renewable sources ⁶	0.0	0.0	14.0	14.0	14.0	14.0	14.0	--
Distributed generation ⁷	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Total	0.0	0.0	43.7	49.3	49.3	49.3	49.3	--
Cumulative unplanned additions⁹								
Coal	0.0	0.0	0.0	0.9	0.9	1.0	1.7	--
Oil and natural gas steam ⁴	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Combined cycle	0.0	0.0	1.4	1.9	11.8	32.5	60.2	--
Combustion turbine/diesel	0.0	0.0	5.2	12.9	23.2	30.2	41.5	--
Nuclear power	0.0	0.0	0.0	0.0	0.0	0.1	1.8	--
Pumped storage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Fuel cells	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Renewable sources ⁶	0.0	0.0	5.7	7.0	12.4	17.4	30.5	--
Distributed generation ⁷	0.0	0.0	0.2	0.5	0.8	1.3	2.1	--
Total	0.0	0.0	12.4	23.2	49.1	82.5	137.8	--
Cumulative electric power sector additions	0.0	0.0	56.1	72.5	98.5	131.8	187.1	--
Cumulative retirements¹⁰								
Coal	0.0	0.0	41.0	48.9	48.9	48.9	49.0	--
Oil and natural gas steam ⁴	0.0	0.0	17.4	18.0	18.5	19.4	20.3	--
Combined cycle	0.0	0.0	0.0	0.2	0.2	0.2	0.2	--
Combustion turbine/diesel	0.0	0.0	6.4	7.2	10.4	11.4	12.4	--
Nuclear power	0.0	0.0	0.0	0.6	0.6	1.1	6.1	--
Pumped storage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Fuel cells	0.0	0.0	0.0	0.0	0.0	0.0	0.0	--
Renewable sources ⁶	0.0	0.0	0.4	0.4	0.4	0.4	0.4	--
Total	0.0	0.0	65.2	75.2	78.9	81.4	88.4	--
Total electric power sector capacity	994.9	1006.5	998.7	1007.6	1033.3	1064.2	1112.5	0.4%

Table A9. Electricity generating capacity (continued)
(gigawatts)

Net summer capacity ¹	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
End-use generators¹¹								
Coal	3.6	4.3	4.2	6.6	7.7	8.8	9.9	3.4%
Petroleum	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.3%
Natural gas	14.7	14.7	17.7	19.8	22.9	27.4	33.2	3.3%
Other gaseous fuels ¹²	1.8	1.7	2.5	2.5	2.5	2.5	2.5	1.5%
Renewable sources ⁶	6.7	7.6	17.6	21.1	23.4	27.1	30.6	5.7%
Other ¹³	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.0%
Total	28.0	29.6	43.3	51.3	57.8	67.1	77.5	3.9%
Cumulative capacity additions⁹	0.0	0.0	13.7	21.7	28.2	37.4	47.9	--

¹Net summer capacity is the steady hourly output that generating equipment is expected to supply to system load (exclusive of auxiliary power), as demonstrated by tests during summer peak demand.

²Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

³Includes plants that only produce electricity. Includes capacity increases (uprates) at existing units.

⁴Includes oil-, gas-, and dual-fired capacity.

⁵Nuclear capacity includes 7.3 gigawatts of uprates through 2035.

⁶Includes conventional hydroelectric, geothermal, wood, wood waste, all municipal waste, landfill gas, other biomass, solar, and wind power. Facilities co-firing biomass and coal are classified as coal.

⁷Primarily peak load capacity fueled by natural gas.

⁸Includes combined heat and power plants whose primary business is to sell electricity and heat to the public (i.e., those that report North American Industry Classification System code 22).

⁹Cumulative additions after December 31, 2010.

¹⁰Cumulative retirements after December 31, 2010.

¹¹Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.

¹²Includes refinery gas and still gas.

¹³Includes batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

-- = Not applicable

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 capacity and projected planned additions: U.S. Energy Information Administration (EIA), Form EIA-860, "Annual Electric Generator Report" (preliminary). Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Electricity Trade

Table A10. Electricity trade
(billion kilowatthours, unless otherwise noted)

Electricity trade	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Interregional electricity trade								
Gross domestic sales								
Firm power	232.1	237.5	139.1	104.4	47.1	24.2	24.2	-8.7%
Economy	231.9	137.0	206.3	211.9	235.4	230.1	235.8	2.2%
Total	464.0	374.4	345.3	316.3	282.5	254.3	260.0	-1.4%
Gross domestic sales (million 2010 dollars)								
Firm power	13923.7	14244.9	8341.5	6259.9	2824.5	1450.4	1450.4	-8.7%
Economy	9065.6	6611.0	8320.2	10576.4	14143.6	13529.2	14541.9	3.2%
Total	22989.2	20855.9	16661.8	16836.3	16968.1	14979.5	15992.2	-1.1%
International electricity trade								
Imports from Canada and Mexico								
Firm power	19.3	13.7	24.3	17.1	5.2	0.4	0.4	-13.3%
Economy	33.1	31.4	24.7	27.7	34.7	31.0	28.2	-0.4%
Total	52.4	45.1	49.0	44.8	39.9	31.4	28.6	-1.8%
Exports to Canada and Mexico								
Firm power	3.3	3.7	3.0	2.1	0.6	0.0	0.0	--
Economy	14.7	15.7	16.9	16.7	17.0	17.0	16.5	0.2%
Total	18.1	19.4	19.9	18.8	17.6	17.0	16.5	-0.7%

-- = Not applicable.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports. Firm power sales are capacity sales, meaning the delivery of the power is scheduled as part of the normal operating conditions of the affected electric systems. Economy sales are subject to curtailment or cessation of delivery by the supplier in accordance with prior agreements or under specified conditions.

Sources: 2009 and 2010 interregional firm electricity trade data: North American Electric Reliability Council (NERC), Electricity Sales and Demand Database 2007; NERC, 2011 Summer Reliability Assessment (May 2011); and NERC, Winter Reliability Assessment 2011/2012 (November 2011). 2009 and 2010 Mexican electricity trade data: U.S. Energy Information Administration (EIA), *Electric Power Annual 2010* DOE/EIA-0348(2010) (Washington, DC, November 2011). 2009 Canadian international electricity trade data: National Energy Board, *Electricity Exports and Imports Statistics, 2009*. 2010 Canadian international electricity trade data: National Energy Board, *Electricity Exports and Imports Statistics, 2010*. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Reference case

Table A11. Liquid fuels supply and disposition
(million barrels per day, unless otherwise noted)

Supply and disposition	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Crude oil								
Domestic crude production ¹	5.36	5.47	6.15	6.70	6.40	6.37	5.99	0.4%
Alaska	0.65	0.60	0.46	0.49	0.40	0.44	0.27	-3.2%
Lower 48 states	4.72	4.87	5.69	6.21	6.00	5.94	5.72	0.6%
Net imports	8.97	9.17	8.52	7.15	7.24	7.14	7.52	-0.8%
Gross imports	9.01	9.21	8.56	7.19	7.27	7.17	7.55	-0.8%
Exports	0.04	0.04	0.03	0.04	0.03	0.03	0.03	-1.1%
Other crude supply ²	0.01	0.08	0.00	0.00	0.00	0.00	0.00	--
Total crude supply	14.34	14.72	14.67	13.85	13.64	13.52	13.51	-0.3%
Other petroleum supply								
Natural gas plant liquids	1.91	2.07	2.56	2.91	3.01	3.05	3.01	1.5%
Net product imports	0.75	0.39	-0.25	-0.12	-0.12	-0.25	-0.34	--
Gross refined product imports ³	1.27	1.23	0.78	0.73	0.79	0.78	0.82	-1.6%
Unfinished oil imports	0.68	0.61	0.64	0.54	0.51	0.50	0.50	-0.8%
Blending component imports	0.72	0.74	0.66	0.64	0.65	0.65	0.66	-0.5%
Exports	1.92	2.19	2.32	2.03	2.07	2.17	2.31	0.2%
Refinery processing gain ⁴	0.98	1.07	0.95	0.94	0.91	0.89	0.85	-0.9%
Product stock withdrawal	-0.04	-0.03	0.00	0.00	0.00	0.00	0.00	--
Other non-petroleum supply	0.81	1.00	1.22	1.52	1.86	2.36	2.96	4.4%
Supply from renewable sources	0.75	0.87	1.05	1.22	1.48	1.89	2.37	4.1%
Ethanol	0.73	0.85	0.94	1.04	1.19	1.40	1.65	2.7%
Domestic production	0.72	0.88	0.94	1.04	1.17	1.37	1.59	2.4%
Net imports	0.01	-0.02	0.00	0.00	0.02	0.03	0.06	--
Biodiesel	0.02	0.01	0.09	0.12	0.12	0.13	0.13	9.2%
Domestic production	0.03	0.02	0.09	0.12	0.12	0.13	0.13	7.9%
Net imports	-0.01	-0.01	0.00	0.00	0.00	0.00	-0.00	--
Other biomass-derived liquids ⁵	0.00	0.00	0.03	0.06	0.16	0.36	0.59	23.2%
Liquids from gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Liquids from coal	0.00	0.00	0.00	0.12	0.17	0.22	0.28	--
Other ⁶	0.05	0.13	0.17	0.19	0.21	0.25	0.31	3.6%
Total primary supply⁷	18.74	19.22	19.14	19.10	19.29	19.57	19.99	0.2%
Liquid fuels consumption								
by fuel								
Liquefied petroleum gases	2.13	2.27	1.94	2.11	2.21	2.22	2.21	-0.1%
E85 ⁸	0.00	0.00	0.01	0.09	0.21	0.49	0.83	27.0%
Motor gasoline ⁹	9.00	8.99	8.88	8.48	8.29	8.17	8.09	-0.4%
Jet fuel ¹⁰	1.39	1.43	1.46	1.49	1.54	1.58	1.61	0.5%
Distillate fuel oil ¹¹	3.63	3.80	4.19	4.24	4.33	4.38	4.48	0.7%
Diesel	3.18	3.32	3.71	3.81	3.92	3.99	4.11	0.9%
Residual fuel oil	0.51	0.54	0.56	0.56	0.57	0.57	0.58	0.3%
Other ¹²	2.15	2.14	2.06	2.04	2.06	2.06	2.10	-0.1%
by sector								
Residential and commercial	1.05	1.12	1.00	0.96	0.94	0.92	0.91	-0.9%
Industrial ¹³	4.24	4.31	4.17	4.31	4.41	4.41	4.44	0.1%
Transportation	13.54	13.82	13.80	13.62	13.71	14.00	14.41	0.2%
Electric power ¹⁴	0.17	0.17	0.13	0.13	0.14	0.14	0.14	-0.7%
Total	18.81	19.17	19.10	19.02	19.20	19.47	19.90	0.1%
Discrepancy¹⁵	-0.07	0.05	0.05	0.09	0.10	0.10	0.09	--

Reference case

Table A11. Liquid fuels supply and disposition (continued)
(million barrels per day, unless otherwise noted)

Supply and disposition	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Domestic refinery distillation capacity ¹⁶	17.7	17.6	17.5	15.8	15.5	15.4	15.2	-0.6%
Capacity utilization rate (percent) ¹⁷	83.0	86.0	85.9	89.8	90.1	89.6	90.8	0.2%
Net import share of product supplied (percent)	51.9	49.6	43.2	36.8	37.0	35.4	36.2	-1.2%
Net expenditures for imported crude oil and petroleum products (billion 2010 dollars)	206.18	243.07	373.00	322.55	344.58	353.03	389.97	1.9%

¹Includes lease condensate.

²Strategic petroleum reserve stock additions plus unaccounted for crude oil and crude stock withdrawals minus crude product supplied.

³Includes other hydrocarbons and alcohols.

⁴The volumetric amount by which total output is greater than input due to the processing of crude oil into products which, in total, have a lower specific gravity than the crude oil processed.

⁵Includes pyrolysis oils, biomass-derived Fischer-Tropsch liquids, and renewable feedstocks used for the on-site production of diesel and gasoline.

⁶Includes domestic sources of other blending components, other hydrocarbons, and ethers.

⁷Total crude supply plus other petroleum supply plus other non-petroleum supply.

⁸E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.

⁹Includes ethanol and ethers blended into gasoline.

¹⁰Includes only kerosene type.

¹¹Includes distillate fuel oil and kerosene from petroleum and biomass feedstocks.

¹²Includes aviation gasoline, petrochemical feedstocks, lubricants, waxes, asphalt, road oil, still gas, special naphthas, petroleum coke, crude oil product supplied, methanol, and miscellaneous petroleum products.

¹³Includes consumption for combined heat and power, which produces electricity and other useful thermal energy.

¹⁴Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

¹⁵Balancing item. Includes unaccounted for supply, losses, and gains.

¹⁶End-of-year operable capacity.

¹⁷Rate is calculated by dividing the gross annual input to atmospheric crude oil distillation units by their operable refining capacity in barrels per calendar day.

-- = Not applicable

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 product supplied based on: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). Other 2009 data: EIA, *Petroleum Supply Annual 2009*, DOE/EIA-0340(2009)/1 (Washington, DC, July 2010). Other 2010 data: EIA, *Petroleum Supply Annual 2010*, DOE/EIA-0340(2010)/1 (Washington, DC, July 2011). Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Table A12. Petroleum product prices
(2010 dollars per gallon, unless otherwise noted)

Sector and fuel	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Crude oil prices (2010 dollars per barrel)								
Low sulfur light	62.37	79.39	116.91	126.68	132.56	138.49	144.98	2.4%
Imported crude oil ¹	59.72	75.87	113.97	115.74	121.21	126.51	132.95	2.3%
Delivered sector product prices								
Residential								
Liquefied petroleum gases	2.10	2.29	2.60	2.63	2.73	2.82	2.93	1.0%
Distillate fuel oil	2.54	2.94	3.78	4.00	4.18	4.36	4.54	1.8%
Commercial								
Distillate fuel oil	2.23	2.87	3.30	3.51	3.70	3.85	4.02	1.4%
Residual fuel oil	2.04	1.66	2.42	2.63	2.73	2.85	2.83	2.2%
Residual fuel oil (2010 dollars per barrel) ...	85.89	69.58	101.70	110.65	114.70	119.73	118.85	2.2%
Industrial²								
Liquefied petroleum gases	1.70	1.85	2.32	2.35	2.48	2.58	2.73	1.6%
Distillate fuel oil	2.31	2.93	3.32	3.53	3.74	3.90	4.05	1.3%
Residual fuel oil	1.82	1.63	2.88	3.07	3.18	3.25	3.24	2.8%
Residual fuel oil (2010 dollars per barrel) ...	76.47	68.62	120.80	129.07	133.47	136.47	136.12	2.8%
Transportation								
Liquefied petroleum gases	2.19	2.28	2.70	2.73	2.83	2.91	3.03	1.1%
Ethanol (E85) ³	1.98	2.40	2.77	2.85	2.75	2.93	3.05	1.0%
Ethanol wholesale price	1.59	1.71	2.23	2.54	2.33	2.29	2.16	0.9%
Motor gasoline ⁴	2.38	2.76	3.54	3.71	3.86	3.97	4.03	1.5%
Jet fuel ⁵	1.72	2.19	3.21	3.41	3.57	3.72	3.93	2.4%
Diesel fuel (distillate fuel oil) ⁶	2.47	3.00	3.78	3.97	4.17	4.30	4.44	1.6%
Residual fuel oil	1.59	1.56	2.74	2.93	3.09	3.11	3.14	2.8%
Residual fuel oil (2010 dollars per barrel) ...	66.71	65.53	115.15	123.09	129.62	130.52	131.73	2.8%
Electric power⁷								
Distillate fuel oil	2.02	2.60	3.16	3.35	3.52	3.67	3.86	1.6%
Residual fuel oil	1.34	1.78	3.44	3.65	3.80	3.83	3.85	3.1%
Residual fuel oil (2010 dollars per barrel) ...	56.46	74.77	144.60	153.30	159.70	160.65	161.71	3.1%
Refined petroleum product prices⁸								
Liquefied petroleum gases	1.37	1.46	1.95	1.95	2.05	2.14	2.26	1.7%
Motor gasoline ⁴	2.37	2.74	3.54	3.71	3.85	3.97	4.03	1.6%
Jet fuel ⁵	1.72	2.19	3.21	3.41	3.57	3.72	3.93	2.4%
Distillate fuel oil	2.44	2.97	3.69	3.89	4.09	4.23	4.38	1.6%
Residual fuel oil	1.57	1.62	2.85	3.04	3.19	3.22	3.25	2.8%
Residual fuel oil (2010 dollars per barrel) ...	66.10	68.00	119.50	127.68	133.95	135.33	136.32	2.8%
Average	2.17	2.53	3.32	3.46	3.60	3.72	3.83	1.7%

Petroleum prices

Table A12. Petroleum product prices (continued)
(nominal dollars per gallon, unless otherwise noted)

Sector and fuel	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Crude oil prices (nominal dollars per barrel)								
Low sulfur light	61.65	79.39	125.97	148.87	170.09	197.10	229.55	4.3%
Imported crude oil ¹	59.04	75.87	122.81	136.02	155.52	180.06	210.51	4.2%
Delivered sector product prices								
Residential								
Liquefied petroleum gases	2.08	2.29	2.80	3.09	3.51	4.01	4.65	2.9%
Distillate fuel oil	2.52	2.94	4.07	4.70	5.36	6.20	7.19	3.6%
Commercial								
Distillate fuel oil	2.20	2.87	3.56	4.12	4.75	5.48	6.36	3.2%
Residual fuel oil	2.02	1.66	2.61	3.10	3.50	4.06	4.48	4.1%
Residual fuel oil (nominal dollars per barrel)	84.91	69.58	109.59	130.04	147.17	170.40	188.19	4.1%
Industrial²								
Liquefied petroleum gases	1.68	1.85	2.50	2.76	3.18	3.67	4.31	3.5%
Distillate fuel oil	2.28	2.93	3.58	4.15	4.80	5.55	6.42	3.2%
Residual fuel oil	1.80	1.63	3.10	3.61	4.08	4.62	5.13	4.7%
Residual fuel oil (nominal dollars per barrel)	75.59	68.62	130.16	151.68	171.25	194.23	215.53	4.7%
Transportation								
Liquefied petroleum gases	2.16	2.28	2.91	3.21	3.63	4.14	4.79	3.0%
Ethanol (E85) ³	1.96	2.40	2.98	3.35	3.52	4.17	4.82	2.8%
Ethanol wholesale price	1.57	1.71	2.40	2.98	2.99	3.25	3.42	2.8%
Motor gasoline ⁴	2.35	2.76	3.81	4.36	4.95	5.64	6.39	3.4%
Jet fuel ⁵	1.70	2.19	3.45	4.01	4.58	5.30	6.23	4.3%
Diesel fuel (distillate fuel oil) ⁶	2.44	3.00	4.07	4.67	5.35	6.12	7.03	3.5%
Residual fuel oil	1.57	1.56	2.95	3.44	3.96	4.42	4.97	4.7%
Residual fuel oil (nominal dollars per barrel)	65.95	65.53	124.07	144.66	166.32	185.76	208.57	4.7%
Electric power⁷								
Distillate fuel oil	1.99	2.60	3.40	3.94	4.51	5.22	6.11	3.5%
Residual fuel oil	1.33	1.78	3.71	4.29	4.88	5.44	6.10	5.0%
Residual fuel oil (nominal dollars per barrel)	55.81	74.77	155.81	180.16	204.91	228.64	256.05	5.0%
Refined petroleum product prices⁸								
Liquefied petroleum gases	1.35	1.46	2.10	2.30	2.63	3.04	3.57	3.6%
Motor gasoline ⁴	2.35	2.74	3.81	4.36	4.95	5.64	6.39	3.4%
Jet fuel ⁵	1.70	2.19	3.45	4.01	4.58	5.30	6.23	4.3%
Distillate fuel oil	2.41	2.97	3.97	4.57	5.25	6.03	6.93	3.4%
Residual fuel oil	1.56	1.62	3.07	3.57	4.09	4.59	5.14	4.7%
Residual fuel oil (nominal dollars per barrel)	65.34	68.00	128.77	150.05	171.87	192.61	215.84	4.7%
Average	2.14	2.53	3.57	4.06	4.62	5.29	6.06	3.6%

¹Weighted average price delivered to U.S. refiners.

²Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public.

³E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.

⁴Sales weighted-average price for all grades. Includes Federal, State and local taxes.

⁵Includes only kerosene type.

⁶Diesel fuel for on-road use. Includes Federal and State taxes while excluding county and local taxes.

⁷Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

⁸Weighted averages of end-use fuel prices are derived from the prices in each sector and the corresponding sectoral consumption.

Note: Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 low sulfur light crude oil price: U.S. Energy Information Administration (EIA), Form EIA-856, "Monthly Foreign Crude Oil Acquisition Report." 2009 and 2010 imported crude oil price: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2009 and 2010 prices for motor gasoline, distillate fuel oil, and jet fuel are based on: EIA, *Petroleum Marketing Annual 2009*, DOE/EIA-0487(2009) (Washington, DC, August 2010). 2009 and 2010 residential, commercial, industrial, and transportation sector petroleum product prices are derived from: EIA, Form EIA-782A, "Refiners'/Gas Plant Operators' Monthly Petroleum Product Sales Report." 2009 and 2010 electric power prices based on: EIA, *Monthly Energy Review*, DOE/EIA-0035(2011/09) (Washington, DC, September 2011). 2009 and 2010 E85 prices derived from monthly prices in the Clean Cities Alternative Fuel Price Report. 2009 and 2010 wholesale ethanol prices derived from Bloomberg U.S. average rack price. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Table A13. Natural gas supply, disposition, and prices
(trillion cubic feet per year, unless otherwise noted)

Supply, disposition, and prices	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Production								
Dry gas production ¹	20.58	21.58	23.65	25.09	26.28	26.94	27.93	1.0%
Supplemental natural gas ²	0.07	0.07	0.06	0.06	0.06	0.06	0.06	-0.2%
Net imports								
Pipeline ³	2.68	2.58	1.73	0.35	-0.79	-0.89	-1.36	--
Liquefied natural gas	2.26	2.21	1.56	1.01	-0.13	-0.27	-0.70	--
Liquefied natural gas	0.42	0.37	0.16	-0.66	-0.66	-0.62	-0.66	--
Total supply								
	23.32	24.22	25.45	25.50	25.55	26.11	26.63	0.4%
Consumption by sector								
Residential	4.78	4.94	4.85	4.83	4.76	4.72	4.64	-0.2%
Commercial	3.12	3.20	3.33	3.43	3.44	3.52	3.60	0.5%
Industrial ⁴	6.17	6.60	7.01	7.08	7.14	7.03	7.00	0.2%
Natural-gas-to-liquids heat and power ⁵	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Natural gas to liquids production ⁶	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Electric power ⁷	6.87	7.38	8.08	7.87	7.87	8.47	8.96	0.8%
Transportation ⁸	0.04	0.04	0.06	0.08	0.11	0.14	0.16	5.9%
Pipeline fuel	0.60	0.63	0.67	0.66	0.66	0.66	0.67	0.2%
Lease and plant fuel ⁹	1.28	1.34	1.39	1.51	1.53	1.55	1.60	0.7%
Total	22.85	24.13	25.39	25.47	25.53	26.10	26.63	0.4%
Discrepancy¹⁰								
	0.47	0.10	0.05	0.04	0.02	0.01	-0.00	--
Natural gas prices								
(2010 dollars per million Btu)								
Henry hub spot price	4.00	4.39	4.29	4.58	5.63	6.29	7.37	2.1%
Average lower 48 wellhead price ¹¹	3.75	4.06	3.84	4.10	5.00	5.56	6.48	1.9%
(2010 dollars per thousand cubic feet)								
Average lower 48 wellhead price ¹¹	3.85	4.16	3.94	4.19	5.12	5.69	6.64	1.9%
Delivered prices								
(2010 dollars per thousand cubic feet)								
Residential	12.25	11.36	10.56	11.11	12.33	13.08	14.33	0.9%
Commercial	10.06	9.32	8.82	9.21	10.27	10.86	11.93	1.0%
Industrial ⁴	5.47	5.65	5.00	5.25	6.19	6.73	7.73	1.3%
Electric power ⁷	4.97	5.25	4.65	4.83	5.73	6.35	7.37	1.4%
Transportation ¹²	14.52	13.53	12.71	12.81	13.62	14.02	14.87	0.4%
Average¹³	7.55	7.33	6.60	6.93	7.93	8.50	9.52	1.1%

(AEP 2012 011)

Table A13. Natural gas supply, disposition, and prices (continued)
(trillion cubic feet per year, unless otherwise noted)

Supply, disposition, and prices	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Natural gas prices								
(nominal dollars per million Btu)								
Henry hub spot price	3.95	4.39	4.62	5.39	7.23	8.95	11.67	4.0%
Average lower 48 wellhead price ¹¹	3.71	4.06	4.14	4.81	6.42	7.92	10.26	3.8%
(nominal dollars per thousand cubic feet)								
Average lower 48 wellhead price ¹¹	3.80	4.16	4.24	4.93	6.57	8.11	10.51	3.8%
Delivered prices								
(nominal dollars per thousand cubic feet)								
Residential	12.11	11.36	11.38	13.06	15.82	18.61	22.69	2.8%
Commercial	9.95	9.32	9.50	10.82	13.18	15.46	18.89	2.9%
Industrial ⁴	5.40	5.65	5.39	6.17	7.94	9.58	12.23	3.1%
Electric power ⁷	4.92	5.25	5.01	5.67	7.35	9.03	11.67	3.2%
Transportation ¹²	14.36	13.53	13.70	15.06	17.48	19.95	23.54	2.2%
Average¹³	7.46	7.33	7.11	8.15	10.17	12.10	15.08	2.9%

¹Marketed production (wet) minus extraction losses.

²Synthetic natural gas, propane air, coke oven gas, refinery gas, biomass gas, air injected for Btu stabilization, and manufactured gas commingled and distributed with natural gas.

³Includes any natural gas regasified in the Bahamas and transported via pipeline to Florida, as well as gas from Canada and Mexico.

⁴Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public.

⁵Includes any natural gas used in the process of converting natural gas to liquid fuel that is not actually converted.

⁶Includes any natural gas converted into liquid fuel.

⁷Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

⁸Natural gas used as vehicle fuel.

⁹Represents natural gas used in well, field, and lease operations, and in natural gas processing plant machinery.

¹⁰Balancing item. Natural gas lost as a result of converting flow data measured at varying temperatures and pressures to a standard temperature and pressure and the merger of different data reporting systems which vary in scope, format, definition, and respondent type. In addition, 2009 and 2010 values include net storage injections.

¹¹Represents lower 48 onshore and offshore supplies.

¹²Natural gas used as a vehicle fuel. Price includes estimated motor vehicle fuel taxes and estimated dispensing costs or charges.

¹³Weighted average prices. Weights used are the sectoral consumption values excluding lease, plant, and pipeline fuel.

-- = Not applicable

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 supply values; and lease, plant, and pipeline fuel consumption: U.S. Energy Information Administration (EIA), *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010). 2010 supply values; lease, plant, and pipeline fuel consumption; and wellhead price: EIA, *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). Other 2009 and 2010 consumption based on: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2009 wellhead price: U.S. Department of the Interior, Office of Natural Resources Revenue; and EIA, *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010). 2009 residential and commercial delivered prices: EIA, *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010). 2010 residential and commercial delivered prices: EIA, *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2009 and 2010 electric power prices: EIA, *Electric Power Monthly*, DOE/EIA-0226, April 2010 and April 2011, Table 4.2, and EIA, *State Energy Data Report 2009*, DOE/EIA-0214(2009) (Washington, DC, June 2011). 2009 and 2010 industrial delivered prices are estimated based on: EIA, *Manufacturing Energy Consumption Survey* and industrial and wellhead prices from the *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010) and the *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2009 transportation sector delivered prices are based on: EIA, *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010) and estimated state taxes, federal taxes, and dispensing costs or charges. 2010 transportation sector delivered prices are model results. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Table A14. Oil and gas supply

Production and supply	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Crude oil								
Lower 48 average wellhead price¹ (2010 dollars per barrel)	57.46	80.46	117.84	124.44	130.30	130.74	137.55	2.2%
Production (million barrels per day)²								
United States total	5.36	5.47	6.15	6.70	6.40	6.37	5.99	0.4%
Lower 48 onshore	3.04	3.21	4.09	4.38	4.43	4.29	3.99	0.9%
Tight oil ³	0.25	0.37	0.97	1.20	1.29	1.32	1.23	4.9%
Carbon dioxide enhanced oil recovery	0.27	0.28	0.26	0.33	0.49	0.61	0.66	3.5%
Other	2.52	2.55	2.86	2.85	2.66	2.36	2.10	-0.8%
Lower 48 offshore	1.68	1.67	1.60	1.83	1.57	1.65	1.74	0.2%
Alaska	0.65	0.60	0.46	0.49	0.40	0.44	0.27	-3.2%
Lower 48 end of year reserves² (billion barrels)	18.75	18.33	20.55	23.02	23.64	24.34	24.23	1.1%
Natural gas								
Lower 48 average wellhead price¹ (2010 dollars per million Btu)								
Henry hub spot price	4.00	4.39	4.29	4.58	5.63	6.29	7.37	2.1%
Average lower 48 wellhead price ¹	3.75	4.06	3.84	4.10	5.00	5.56	6.48	1.9%
(2010 dollars per thousand cubic feet)								
Average lower 48 wellhead price ¹	3.85	4.16	3.94	4.19	5.12	5.69	6.64	1.9%
Dry production (trillion cubic feet)⁴								
United States total	20.58	21.58	23.65	25.09	26.28	26.94	27.93	1.0%
Lower 48 onshore	17.50	18.66	21.48	22.48	23.64	24.11	24.97	1.2%
Associated-dissolved ⁵	1.40	1.40	1.52	1.54	1.41	1.18	1.00	-1.3%
Non-associated	16.10	17.26	19.96	20.94	22.23	22.93	23.97	1.3%
Tight gas	6.40	5.68	6.08	6.06	6.17	6.07	6.14	0.3%
Shale gas	2.91	4.99	8.24	9.69	11.26	12.42	13.63	4.1%
Coalbed methane	1.99	1.99	1.83	1.79	1.77	1.74	1.76	-0.5%
Other	4.80	4.59	3.82	3.40	3.03	2.70	2.44	-2.5%
Lower 48 offshore	2.70	2.56	1.88	2.34	2.38	2.58	2.72	0.3%
Associated-dissolved ⁵	0.70	0.71	0.55	0.75	0.67	0.70	0.73	0.1%
Non-associated	2.00	1.85	1.33	1.59	1.71	1.88	2.00	0.3%
Alaska	0.37	0.36	0.29	0.27	0.25	0.25	0.23	-1.8%
Lower 48 end of year dry reserves⁴ (trillion cubic feet)	263.40	260.50	274.79	290.32	299.77	307.17	311.58	0.7%
Supplemental gas supplies (trillion cubic feet)⁶	0.07	0.07	0.06	0.06	0.06	0.06	0.06	-0.2%
Total lower 48 wells drilled (thousands)	34.31	43.19	49.79	53.80	59.42	60.21	65.59	1.7%

¹Represents lower 48 onshore and offshore supplies.

²Includes lease condensate.

³Tight oil represents resources in low-permeability reservoirs, including shale and chalk formations. The specific plays included in the tight oil category are Bakken/Three Forks/Sanish, Eagle Ford, Woodford, Austin Chalk, Spraberry, Niobrara, Avalon/Bone Springs, and Monterey.

⁴Marketed production (wet) minus extraction losses.

⁵Gas which occurs in crude oil reservoirs either as free gas (associated) or as gas in solution with crude oil (dissolved).

⁶Synthetic natural gas, propane air, coke oven gas, refinery gas, biomass gas, air injected for Btu stabilization, and manufactured gas commingled and distributed with natural gas.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 crude oil lower 48 average wellhead price: U.S. Energy Information Administration (EIA), *Petroleum Marketing Annual 2009*, DOE/EIA-0487(2009) (Washington, DC, August 2010). 2009 and 2010 lower 48 onshore, lower 48 offshore, and Alaska crude oil production: EIA, *Petroleum Supply Annual 2010*, DOE/EIA-0340(2010)/1 (Washington, DC, July 2011). 2009 U.S. crude oil and natural gas reserves: EIA, *U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves*, DOE/EIA-0216(2009) (Washington, DC, November 2010). 2009 Alaska and total natural gas production, and supplemental gas supplies: EIA, *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010). 2009 natural gas lower 48 average wellhead price: U.S. Department of the Interior, Office of Natural Resources Revenue; and EIA, *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010). 2010 natural gas lower 48 average wellhead price, Alaska and total natural gas production, and supplemental gas supplies: EIA, *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). Other 2009 and 2010 values: EIA, Office of Energy Analysis. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Reference case

Table A15. Coal supply, disposition, and prices
(million short tons per year, unless otherwise noted)

Supply, disposition, and prices	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Production¹								
Appalachia	343	336	300	262	271	282	291	-0.6%
Interior	147	156	151	159	163	181	198	1.0%
West	585	592	542	613	684	703	722	0.8%
East of the Mississippi	450	446	407	377	383	409	431	-0.1%
West of the Mississippi	625	638	586	657	735	757	781	0.8%
Total	1075	1084	993	1034	1118	1166	1212	0.4%
Waste coal supplied²	14	14	15	15	16	17	19	1.4%
Net imports								
Imports ³	21	18	15	28	44	33	36	2.8%
Exports	59	82	110	95	115	117	129	1.8%
Total	-38	-64	-95	-67	-71	-83	-94	--
Total supply⁴	1050	1034	914	982	1064	1100	1138	0.4%
Consumption by sector								
Residential and commercial	3	3	3	3	3	3	3	-0.3%
Coke plants	15	21	22	18	19	18	17	-1.0%
Other industrial ⁵	45	52	50	51	52	52	53	0.0%
Coal-to-liquids heat and power	0	0	0	13	19	26	34	--
Coal to liquids production	0	0	0	12	18	25	32	--
Electric power ⁶	934	975	839	885	952	975	998	0.1%
Total	997	1051	914	982	1063	1099	1137	0.3%
Discrepancy and stock change⁷	53	-17	-0	-0	1	0	0	--
Average minemouth price⁸								
(2010 dollars per short ton)	33.62	35.61	42.08	40.96	44.05	47.28	50.52	1.4%
(2010 dollars per million Btu)	1.68	1.76	2.08	2.06	2.23	2.39	2.56	1.5%
Delivered prices (2010 dollars per short ton)⁹								
Coke plants	144.66	153.59	189.11	198.45	212.18	225.36	238.32	1.8%
Other industrial ⁵	65.62	59.28	70.14	70.89	72.77	75.43	78.53	1.1%
Coal to liquids	--	--	18.65	40.67	39.03	40.20	41.54	--
Electric power								
(2010 dollars per short ton)	43.83	44.27	45.17	45.98	48.13	50.56	53.31	0.7%
(2010 dollars per million Btu)	2.22	2.26	2.35	2.41	2.54	2.66	2.80	0.9%
Average	46.41	47.17	49.95	49.99	51.90	54.09	56.48	0.7%
Exports ¹⁰	102.61	120.41	140.89	155.03	163.43	172.39	177.66	1.6%

Table A15. Coal supply, disposition, and prices (continued)
(million short tons per year, unless otherwise noted)

Supply, disposition, and prices	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Average minemouth price⁶								
(nominal dollars per short ton)	33.24	35.61	45.34	48.13	56.52	67.28	80.00	3.3%
(nominal dollars per million Btu)	1.66	1.76	2.24	2.42	2.86	3.41	4.05	3.4%
Delivered prices (nominal dollars per short ton)⁹								
Coke plants	143.01	153.59	203.77	233.22	272.25	320.74	377.36	3.7%
Other industrial ⁵	64.87	59.28	75.58	83.31	93.37	107.35	124.34	3.0%
Coal to liquids	--	--	20.09	47.80	50.08	57.22	65.77	--
Electric power								
(nominal dollars per short ton)	43.33	44.27	48.68	54.03	61.76	71.96	84.40	2.6%
(nominal dollars per million Btu)	2.19	2.26	2.53	2.83	3.25	3.78	4.43	2.7%
Average	45.88	47.17	53.83	58.74	66.60	76.98	89.43	2.6%
Exports ¹⁰	101.44	120.41	151.81	182.19	209.70	245.35	281.30	3.5%

¹Includes anthracite, bituminous coal, subbituminous coal, and lignite.

²Includes waste coal consumed by the electric power and industrial sectors. Waste coal supplied is counted as a supply-side item to balance the same amount of waste coal included in the consumption data.

³Excludes imports to Puerto Rico and the U.S. Virgin Islands.

⁴Production plus waste coal supplied plus net imports.

⁵Includes consumption for combined heat and power plants, except those plants whose primary business is to sell electricity, or electricity and heat, to the public. Excludes all coal use in the coal-to-liquids process.

⁶Includes all electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

⁷Balancing item: the sum of production, net imports, and waste coal supplied minus total consumption.

⁸Includes reported prices for both open market and captive mines.

⁹Prices weighted by consumption; weighted average excludes residential and commercial prices, and export free-alongside-ship (f a s.) prices.

¹⁰F.a.s. price at U.S. port of exit.

-- = Not applicable.

Btu = British thermal unit.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 data based on: U.S. Energy Information Administration (EIA), *Annual Coal Report 2010*, DOE/EIA-0584(2010) (Washington, DC, November 2011); EIA, *Quarterly Coal Report, October-December 2010*, DOE/EIA-0121(2010/4Q) (Washington, DC, May 2011); and EIA, AEO2012 National Energy Modeling System run REF2012.D020112C. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

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Table A16. Renewable energy generating capacity and generation
(gigawatts, unless otherwise noted)

Net summer capacity and generation	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Electric power sector¹								
Net summer capacity								
Conventional hydropower	78.01	78.03	78.55	79.13	80.14	80.66	81.25	0.2%
Geothermal ²	2.37	2.37	2.86	3.57	4.45	5.48	6.30	4.0%
Municipal waste ³	3.20	3.30	3.36	3.36	3.36	3.36	3.36	0.1%
Wood and other biomass ⁴	2.43	2.45	2.72	2.72	2.72	2.72	2.89	0.7%
Solar thermal	0.47	0.47	1.36	1.36	1.36	1.36	1.36	4.3%
Solar photovoltaic ⁵	0.15	0.38	2.02	2.03	2.30	2.97	8.18	13.0%
Wind	34.52	39.05	54.26	54.31	57.57	60.29	66.65	2.2%
Offshore wind	0.00	0.00	0.20	0.20	0.20	0.20	0.20	--
Total electric power sector capacity	121.16	126.06	145.34	146.68	152.10	157.05	170.19	1.2%
Generation (billion kilowatthours)								
Conventional hydropower	271.50	255.32	295.43	300.54	305.00	307.40	310.08	0.8%
Geothermal ²	15.01	15.67	18.68	24.41	31.53	39.89	46.54	4.5%
Biogenic municipal waste ⁶	16.10	16.56	14.66	14.67	14.67	14.67	14.67	-0.5%
Wood and other biomass	10.74	11.51	21.28	51.60	63.90	57.08	49.28	6.0%
Dedicated plants	9.68	10.15	10.13	13.16	13.30	11.81	10.37	0.1%
Cofiring	1.06	1.36	11.15	38.44	50.60	45.27	38.92	14.4%
Solar thermal	0.74	0.82	2.86	2.86	2.86	2.86	2.86	5.1%
Solar photovoltaic ⁵	0.16	0.46	3.61	3.62	4.37	6.16	20.19	16.4%
Wind	73.88	94.49	150.22	150.34	160.73	169.64	189.92	2.8%
Offshore wind	0.00	0.00	0.75	0.75	0.75	0.75	0.75	--
Total electric power sector generation	388.11	394.82	507.49	548.78	583.81	598.46	634.30	1.9%
End-use sectors⁷								
Net summer capacity								
Conventional hydropower ⁸	0.34	0.33	0.33	0.33	0.33	0.33	0.33	0.0%
Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Municipal waste ⁹	0.36	0.35	0.35	0.35	0.35	0.35	0.35	0.0%
Biomass	4.56	4.56	5.73	6.68	8.44	11.31	13.81	4.5%
Solar photovoltaic ⁵	1.22	2.05	8.98	11.19	11.69	12.41	13.33	7.8%
Wind	0.18	0.36	2.25	2.57	2.60	2.65	2.74	8.5%
Total end-use sector capacity	6.66	7.65	17.64	21.12	23.41	27.05	30.57	5.7%
Generation (billion kilowatthours)								
Conventional hydropower ⁸	1.94	1.76	1.75	1.75	1.75	1.75	1.75	-0.0%
Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	--
Municipal waste ⁹	2.07	2.02	2.79	2.79	2.79	2.79	2.79	1.3%
Biomass	25.31	26.10	33.30	39.53	52.34	76.03	96.17	5.4%
Solar photovoltaic ⁵	1.93	3.21	13.88	17.40	18.22	19.40	20.91	7.8%
Wind	0.24	0.47	2.88	3.31	3.36	3.44	3.56	8.5%
Total end-use sector generation	31.48	33.56	54.59	64.77	78.45	103.40	125.17	5.4%

Table A16. Renewable energy generating capacity and generation (continued)
(gigawatts, unless otherwise noted)

Net summer capacity and generation	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Total, all sectors								
Net summer capacity								
Conventional hydropower	78.35	78.36	78.88	79.46	80.47	80.99	81.58	0.2%
Geothermal	2.37	2.37	2.86	3.57	4.45	5.48	6.30	4.0%
Municipal waste	3.57	3.65	3.71	3.71	3.71	3.71	3.71	0.1%
Wood and other biomass ⁴	6.99	7.00	8.45	9.40	11.16	14.03	16.71	3.5%
Solar ⁵	1.85	2.90	12.37	14.58	15.35	16.74	22.87	8.6%
Wind	34.70	39.41	56.72	57.07	60.37	63.15	69.59	2.3%
Total capacity, all sectors	127.83	133.70	162.98	167.80	175.51	184.10	200.76	1.6%
Generation (billion kilowatthours)								
Conventional hydropower	273.44	257.08	297.18	302.28	306.75	309.15	311.83	0.8%
Geothermal	15.01	15.67	18.68	24.41	31.53	39.89	46.54	4.5%
Municipal waste	18.16	18.59	17.45	17.46	17.46	17.46	17.46	-0.3%
Wood and other biomass	36.05	37.61	54.58	91.13	116.24	133.11	145.45	5.6%
Solar ⁵	2.82	4.48	20.35	23.87	25.44	28.42	43.96	9.6%
Wind	74.12	94.95	153.85	154.40	164.84	173.83	194.23	2.9%
Total generation, all sectors	419.59	428.38	562.08	613.55	662.25	701.85	759.46	2.3%

¹Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

²Includes both hydrothermal resources (hot water and steam) and near-field enhanced geothermal systems (EGS). Near-field EGS potential occurs on known hydrothermal sites, however this potential requires the addition of external fluids for electricity generation and is only available after 2025.

³Includes municipal waste, landfill gas, and municipal sewage sludge. Incremental growth is assumed to be for landfill gas facilities. All municipal waste is included, although a portion of the municipal waste stream contains petroleum-derived plastics and other non-renewable sources.

⁴Facilities co-firing biomass and coal are classified as coal.

⁵Does not include off-grid photovoltaics (PV). Based on annual PV shipments from 1989 through 2009, EIA estimates that as much as 245 megawatts of remote electricity generation PV applications (i.e., off-grid power systems) were in service in 2009, plus an additional 558 megawatts in communications, transportation, and assorted other non-grid-connected, specialized applications. See U.S. Energy Information Administration, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011), Table 10.9 (annual PV shipments, 1989-2009). The approach used to develop the estimate, based on shipment data, provides an upper estimate of the size of the PV stock, including both grid-based and off-grid PV. It will overestimate the size of the stock, because shipments include a substantial number of units that are exported, and each year some of the PV units installed earlier will be retired from service or abandoned.

⁶Includes biogenic municipal waste, landfill gas, and municipal sewage sludge. Incremental growth is assumed to be for landfill gas facilities. Only biogenic municipal waste is included. The U.S. Energy Information Administration estimates that in 2010 approximately 6 billion kilowatthours of electricity were generated from a municipal waste stream containing petroleum-derived plastics and other non-renewable sources. See U.S. Energy Information Administration, *Methodology for Allocating Municipal Solid Waste to Biogenic and Non-Biogenic Energy* (Washington, DC, May 2007).

⁷Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.

⁸Represents own-use industrial hydroelectric power.

⁹Includes municipal waste, landfill gas, and municipal sewage sludge. All municipal waste is included, although a portion of the municipal waste stream contains petroleum-derived plastics and other non-renewable sources.

-- = Not applicable.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 capacity: U.S. Energy Information Administration (EIA), Form EIA-860, "Annual Electric Generator Report" (preliminary) 2009 and 2010 generation: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Reference case

Table A17. Renewable energy consumption by sector and source
(quadrillion Btu per year)

Sector and source	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Marketed renewable energy¹								
Residential (wood)	0.43	0.42	0.43	0.43	0.43	0.43	0.43	0.1%
Commercial (biomass)	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.0%
Industrial²	2.19	2.34	2.42	2.63	3.09	3.79	4.52	2.7%
Conventional hydroelectric	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.0%
Municipal waste ³	0.16	0.17	0.18	0.18	0.18	0.18	0.18	0.1%
Biomass	1.19	1.31	1.42	1.48	1.62	1.68	1.76	1.2%
Biofuels heat and coproducts	0.82	0.84	0.81	0.96	1.27	1.92	2.57	4.6%
Transportation	0.99	1.14	1.45	1.72	2.16	2.88	3.75	4.9%
Ethanol used in E85 ⁴	0.00	0.00	0.01	0.08	0.20	0.47	0.80	27.0%
Ethanol used in gasoline blending	0.95	1.10	1.21	1.27	1.35	1.35	1.34	0.8%
Biodiesel used in distillate blending	0.04	0.03	0.18	0.23	0.24	0.25	0.26	9.2%
Liquids from biomass	0.00	0.00	0.03	0.11	0.33	0.78	1.31	--
Renewable diesel and gasoline ⁵	0.00	0.01	0.03	0.03	0.03	0.03	0.03	6.2%
Electric power⁶	3.77	3.85	4.96	5.40	5.75	5.87	6.22	1.9%
Conventional hydroelectric	2.65	2.49	2.88	2.93	2.98	3.00	3.03	0.8%
Geothermal	0.15	0.15	0.18	0.24	0.31	0.39	0.45	4.5%
Biogenic municipal waste ⁷	0.07	0.08	0.09	0.09	0.09	0.09	0.09	0.6%
Biomass	0.17	0.19	0.27	0.60	0.73	0.64	0.56	4.4%
Dedicated plants	0.16	0.17	0.16	0.21	0.22	0.18	0.16	-0.1%
Cofiring	0.01	0.02	0.11	0.39	0.52	0.46	0.40	11.8%
Solar thermal	0.01	0.01	0.03	0.03	0.03	0.03	0.03	5.1%
Solar photovoltaic	0.00	0.00	0.04	0.04	0.04	0.06	0.20	16.4%
Wind	0.72	0.92	1.47	1.47	1.58	1.66	1.86	2.8%
Total marketed renewable energy	7.49	7.87	9.37	10.29	11.54	13.09	15.03	2.6%
Sources of ethanol								
from corn and other starch	0.94	1.14	1.20	1.32	1.39	1.39	1.46	1.0%
from cellulose	0.00	0.00	0.01	0.03	0.13	0.40	0.61	56.6%
Net imports	0.02	-0.03	0.00	0.00	0.03	0.04	0.08	--
Total	0.95	1.11	1.22	1.35	1.55	1.82	2.15	2.7%

Table A17. Renewable energy consumption by sector and source (continued)
(quadrillion Btu per year)

Sector and source	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Nonmarketed renewable energy^a								
Selected consumption								
Residential	0.02	0.02	0.08	0.10	0.10	0.11	0.11	6.9%
Solar hot water heating	0.01	0.01	0.02	0.02	0.02	0.02	0.02	2.4%
Geothermal heat pumps	0.00	0.01	0.01	0.02	0.02	0.02	0.03	6.4%
Solar photovoltaic	0.00	0.00	0.04	0.05	0.05	0.06	0.06	10.7%
Wind	0.00	0.00	0.01	0.01	0.01	0.01	0.01	9.1%
Commercial	0.03	0.03	0.04	0.04	0.04	0.05	0.05	1.7%
Solar thermal	0.03	0.03	0.03	0.03	0.03	0.04	0.04	1.4%
Solar photovoltaic	0.00	0.01	0.01	0.01	0.01	0.01	0.01	2.8%
Wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.3%

¹Includes nonelectric renewable energy groups for which the energy source is bought and sold in the marketplace, although all transactions may not necessarily be marketed, and marketed renewable energy inputs for electricity entering the marketplace on the electric power grid. Excludes electricity imports; see Table A2.

²Includes all electricity production by industrial and other combined heat and power for the grid and for own use.

³Includes municipal waste, landfill gas, and municipal sewage sludge. All municipal waste is included, although a portion of the municipal waste stream contains petroleum-derived plastics and other non-renewable sources.

⁴Excludes motor gasoline component of E85.

⁵Renewable feedstocks for the on-site production of diesel and gasoline.

⁶Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Actual heat rates used to determine fuel consumption for all renewable fuels except hydropower, geothermal, solar, and wind. Consumption at hydroelectric, geothermal, solar, and wind facilities determined by using the fossil fuel equivalent of 9,760 Btu per kilowatt-hour.

⁷Includes biogenic municipal waste, landfill gas, and municipal sewage sludge. Incremental growth is assumed to be for landfill gas facilities. Only biogenic municipal waste is included. The U.S. Energy Information Administration estimates that in 2010 approximately 0.3 quadrillion Btus were consumed from a municipal waste stream containing petroleum-derived plastics and other non-renewable sources. See U.S. Energy Information Administration, *Methodology for Allocating Municipal Solid Waste to Biogenic and Non-Biogenic Energy* (Washington, DC, May 2007).

⁸Includes selected renewable energy consumption data for which the energy is not bought or sold, either directly or indirectly as an input to marketed energy. The U.S. Energy Information Administration does not estimate or project total consumption of nonmarketed renewable energy.

-- = Not applicable.

Btu = British thermal unit.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 ethanol: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011); 2009 and 2010 electric power sector: EIA, Form EIA-860, "Annual Electric Generator Report" (preliminary). Other 2009 and 2010 values: EIA, Office of Energy Analysis. Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Reference case

Table A18. Energy-related carbon dioxide emissions by sector and source
(million metric tons, unless otherwise noted)

Sector and source	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Residential								
Petroleum	81	85	74	69	65	61	59	-1.5%
Natural gas	259	267	264	263	259	257	252	-0.2%
Coal	1	1	1	1	1	1	1	-1.3%
Electricity ¹	819	879	746	769	816	862	907	0.1%
Total residential	1159	1232	1084	1101	1141	1181	1218	-0.0%
Commercial								
Petroleum	49	51	44	44	44	44	44	-0.6%
Natural gas	169	173	181	186	187	191	196	0.5%
Coal	6	6	6	6	6	6	6	0.0%
Electricity ¹	785	805	721	757	806	852	897	0.4%
Total commercial	1009	1035	952	993	1043	1093	1142	0.4%
Industrial²								
Petroleum	339	344	364	350	351	351	358	0.2%
Natural gas ³	383	408	445	454	459	455	456	0.4%
Coal	128	157	154	170	183	190	197	0.9%
Electricity ¹	551	583	540	536	550	535	516	-0.5%
Total industrial	1401	1492	1503	1509	1542	1531	1527	0.1%
Transportation								
Petroleum ⁴	1818	1836	1825	1785	1778	1791	1814	-0.0%
Natural gas ⁵	34	36	39	40	42	44	45	0.9%
Electricity ¹	4	4	4	5	7	9	12	4.2%
Total transportation	1856	1876	1868	1831	1827	1843	1871	-0.0%
Electric power⁶								
Petroleum	34	33	23	23	24	24	25	-1.1%
Natural gas	373	399	438	427	427	459	485	0.8%
Coal	1741	1828	1539	1606	1717	1763	1809	-0.0%
Other ⁷	12	12	12	12	12	12	12	0.0%
Total electric power	2159	2271	2011	2067	2179	2258	2330	0.1%
Total by fuel								
Petroleum ³	2320	2349	2329	2271	2261	2271	2300	-0.1%
Natural gas	1218	1283	1367	1370	1374	1405	1435	0.4%
Coal	1876	1990	1699	1781	1906	1959	2012	0.0%
Other ⁷	12	12	12	12	12	12	12	0.0%
Total	5425	5634	5407	5434	5552	5647	5758	0.1%
Carbon dioxide emissions								
(tons per person)	17.6	18.1	16.6	15.9	15.5	15.1	14.8	-0.8%

¹Emissions from the electric power sector are distributed to the end-use sectors

²Fuel consumption includes energy for combined heat and power plants, except those plants whose primary business is to sell electricity, or electricity and heat, to the public

³Includes lease and plant fuel

⁴This includes carbon dioxide from international bunker fuels, both civilian and military, which are excluded from the accounting of carbon dioxide emissions under the United Nations convention. From 1990 through 2009, international bunker fuels accounted for 90 to 126 million metric tons annually

⁵Includes pipeline fuel natural gas and natural gas used as vehicle fuel

⁶Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public

⁷Includes emissions from geothermal power and nonbiogenic emissions from municipal waste

Note: By convention, the direct emissions from biogenic energy sources are excluded from energy-related carbon dioxide emissions. The release of carbon from these sources is assumed to be balanced by the uptake of carbon when the feedstock is grown, resulting in zero net emissions over some period of time. If, however, increased use of biomass energy results in a decline in terrestrial carbon stocks, a net positive release of carbon may occur. See "Energy-Related Carbon Dioxide Emissions by End Use" for the emissions from biogenic energy sources as an indication of the potential net release of carbon dioxide in the absence of offsetting sequestration. Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports

Sources: 2009 and 2010 emissions and emission factors: U.S. Energy Information Administration (EIA), *Monthly Energy Review, October 2011* DOE/EIA-0035(2011/10) (Washington, DC, October 2011). Projections: EIA, AEO2012 National Energy Modeling System run REF2012 D020112C

Table A19. Energy-related carbon dioxide emissions by end use
(million metric tons)

Sector and end use	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Residential								
Space heating	280.90	298.51	277.05	272.48	267.41	264.17	259.97	-0.6%
Space cooling	142.72	191.18	159.32	164.10	174.13	183.61	192.21	0.0%
Water heating	160.15	159.68	151.53	154.46	157.58	156.73	154.55	-0.1%
Refrigeration	66.17	66.06	57.91	58.63	61.36	64.38	67.24	0.1%
Cooking	32.01	32.25	30.98	32.26	33.88	35.40	36.82	0.5%
Clothes dryers	36.78	37.23	33.43	31.76	30.86	30.58	31.50	-0.7%
Freezers	14.50	14.62	13.14	13.17	13.46	13.61	13.81	-0.2%
Lighting	123.36	122.27	81.97	74.77	72.02	71.52	72.33	-2.1%
Clothes washers ¹	5.87	5.79	4.96	4.18	3.86	3.64	3.74	-1.7%
Dishwashers ¹	17.70	17.75	15.48	15.32	15.33	16.16	17.28	-0.1%
Color televisions and set-top boxes	56.62	58.20	50.98	53.06	57.14	61.62	66.45	0.5%
Personal computers and related equipment	29.75	30.47	29.70	33.59	37.07	39.80	41.67	1.3%
Furnace fans and boiler circulation pumps	23.80	23.93	21.88	22.19	22.63	22.80	23.00	-0.2%
Other uses	167.37	173.46	155.66	171.03	194.05	216.69	237.60	1.3%
Discrepancy ²	1.73	0.16	0.00	-0.00	0.00	0.00	0.00	--
Total residential	1159.44	1231.57	1083.99	1101.00	1140.80	1180.73	1218.17	-0.0%
Commercial								
Space heating ³	129.16	129.68	124.70	124.97	122.24	120.61	118.00	-0.4%
Space cooling ³	84.66	101.34	80.33	79.94	81.20	82.60	84.17	-0.7%
Water heating ³	41.32	41.44	41.47	42.83	43.45	44.00	44.04	0.2%
Ventilation	88.64	90.04	83.19	86.87	90.94	94.43	97.04	0.3%
Cooking	13.27	13.58	13.68	14.20	14.47	14.84	15.13	0.4%
Lighting	181.96	180.09	156.69	160.17	166.24	171.06	174.62	-0.1%
Refrigeration	70.13	69.16	55.15	52.64	52.71	53.53	54.79	-0.9%
Office equipment (PC)	38.00	37.69	29.68	29.85	30.75	32.11	33.19	-0.5%
Office equipment (non-PC)	43.86	46.44	49.41	56.62	62.87	67.77	71.49	1.7%
Other uses ⁴	317.61	325.18	317.95	345.09	378.20	411.92	449.71	1.3%
Total commercial	1008.62	1034.63	952.26	993.16	1043.07	1092.87	1142.18	0.4%
Industrial								
Manufacturing								
Refining	261.44	265.88	268.04	278.94	288.94	303.58	322.94	0.8%
Food products	100.97	105.04	98.92	104.00	108.26	111.71	113.98	0.3%
Paper products	77.15	76.70	71.83	71.82	73.13	71.21	69.81	-0.4%
Bulk chemicals	221.74	234.55	213.65	229.11	233.13	225.47	215.77	-0.3%
Glass	18.92	18.59	19.05	20.00	21.33	21.21	20.50	0.4%
Cement manufacturing	25.91	25.67	33.19	35.70	37.08	36.48	37.41	1.5%
Iron and steel	91.87	116.74	117.01	110.23	114.88	107.91	99.25	-0.6%
Aluminum	27.63	30.89	28.68	27.66	26.37	24.89	23.14	-1.1%
Fabricated metal products	36.69	36.14	36.43	36.81	37.90	35.62	33.25	-0.3%
Machinery	22.80	23.76	24.75	24.32	26.46	25.49	23.73	-0.0%
Computers and electronics	30.67	33.07	32.16	33.69	36.48	36.57	36.74	0.4%
Transportation equipment	43.77	45.62	56.18	54.82	54.85	57.23	58.87	1.0%
Electrical equipment	7.86	8.17	8.23	8.25	9.10	8.85	8.55	0.2%
Wood products	16.74	16.90	19.68	19.99	20.46	19.14	18.50	0.4%
Plastics	37.47	38.26	34.96	35.35	34.86	34.29	33.32	-0.6%
Balance of manufacturing	142.01	142.62	133.94	136.85	138.25	133.50	129.25	-0.4%
Total manufacturing	1163.64	1218.60	1196.68	1227.54	1261.49	1253.14	1245.00	0.1%
Nonmanufacturing								
Agriculture	73.84	73.82	69.73	68.13	68.31	67.95	68.29	-0.3%
Construction	76.16	69.67	83.15	91.08	92.27	91.23	91.95	1.1%
Mining	43.45	46.03	44.37	44.16	43.79	43.23	42.83	-0.3%
Total nonmanufacturing	193.45	189.52	197.25	203.37	204.37	202.41	203.08	0.3%
Discrepancy ²	43.83	83.41	108.76	78.58	76.09	74.99	78.94	-0.2%
Total industrial	1400.92	1491.53	1502.69	1509.48	1541.94	1530.55	1527.02	0.1%

Table A19. Energy-related carbon dioxide emissions by end use (continued)
(million metric tons)

Sector and end use	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Transportation								
Light-duty vehicles	1068.20	1060.96	1014.74	966.95	945.91	950.30	957.76	-0.4%
Commercial light trucks ⁵	35.27	38.02	39.58	38.75	38.76	39.51	40.97	0.3%
Bus transportation	14.85	17.67	17.32	17.17	17.13	17.18	17.32	-0.1%
Freight trucks	356.16	348.09	389.50	391.24	396.52	398.85	409.21	0.6%
Rail, passenger	5.41	5.84	5.76	6.02	6.39	6.70	6.98	0.7%
Rail, freight	26.27	32.99	30.95	33.83	36.05	36.73	37.43	0.5%
Shipping, domestic	13.03	16.31	16.75	17.65	17.97	18.15	18.27	0.5%
Shipping, international	60.55	67.51	67.87	68.23	68.70	69.13	69.55	0.1%
Recreational boats	16.45	17.12	17.27	17.53	17.90	18.42	18.94	0.4%
Air	172.79	178.28	180.48	186.23	192.08	195.53	197.54	0.4%
Military use	50.94	54.70	47.05	45.77	47.13	49.65	52.56	-0.2%
Lubricants	4.71	5.19	5.00	5.10	5.19	5.24	5.28	0.1%
Pipeline fuel	32.53	34.34	36.23	35.81	35.79	35.99	36.36	0.2%
Discrepancy ²	-1.34	-1.15	-0.21	0.45	1.14	1.81	2.39	--
Total transportation	1855.81	1875.88	1868.28	1830.73	1826.65	1843.20	1870.57	-0.0%
Biogenic energy combustion⁶								
Biomass	178.16	190.68	208.91	245.80	271.80	268.87	268.81	1.4%
Electric power sector	15.83	18.00	25.42	56.39	68.61	60.49	52.72	4.4%
Other sectors	162.33	172.68	183.49	189.41	203.18	208.37	216.10	0.9%
Biogenic waste	6.56	7.10	8.20	8.21	8.21	8.21	8.21	0.6%
Biofuels heat and coproducts	77.06	79.11	75.91	89.81	119.14	179.75	241.23	4.6%
Ethanol	65.18	75.71	83.37	92.41	106.14	124.29	146.78	2.7%
Biodiesel	3.07	2.11	12.76	16.51	17.69	18.42	19.18	9.2%
Liquids from biomass	0.00	0.00	2.01	7.99	24.22	57.28	95.80	--
Renewable diesel and gasoline	0.00	0.50	2.23	2.23	2.23	2.23	2.21	6.2%
Total	330.03	355.21	393.39	462.96	549.43	659.05	782.23	3.2%

¹Does not include water heating portion of load.

²Represents differences between total emissions by end-use and total emissions by fuel as reported in Table A18. Emissions by fuel may reflect benchmarking and other modeling adjustments to energy use and the associated emissions that are not assigned to specific end uses.

³Includes emissions related to fuel consumption for district services.

⁴Includes miscellaneous uses, such as service station equipment, automated teller machines, telecommunications equipment, medical equipment, pumps, emergency generators, combined heat and power in commercial buildings, manufacturing performed in commercial buildings, and cooking (distillate), plus emissions from residual fuel oil, liquefied petroleum gases, coal, motor gasoline, and kerosene.

⁵Commercial trucks 8,501 to 10,000 pounds gross vehicle weight rating.

⁶By convention, the direct emissions from biogenic energy sources are excluded from energy-related carbon dioxide emissions. The release of carbon from these sources is assumed to be balanced by the uptake of carbon when the feedstock is grown, resulting in zero net emissions over some period of time. If, however, increased use of biomass energy results in a decline in terrestrial carbon stocks, a net positive release of carbon may occur. Accordingly, the emissions from biogenic energy sources are reported here as an indication of the potential net release of carbon dioxide in the absence of offsetting sequestration.

-- = Not applicable.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 emissions and emission factors: U.S. Energy Information Administration (EIA), *Monthly Energy Review, October 2011* DOE/EIA-0035(2011/10) (Washington, DC, October 2011). Projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C.

Table A20. Macroeconomic indicators
(billion 2005 chain-weighted dollars, unless otherwise noted)

Indicators	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Real gross domestic product	12703	13088	14803	16740	19185	21725	24539	2.5%
Components of real gross domestic product								
Real consumption	9037	9221	10218	11250	12697	14359	16220	2.3%
Real investment	1454	1715	2457	2888	3472	4063	4836	4.2%
Real government spending	2540	2557	2355	2407	2525	2667	2818	0.4%
Real exports	1494	1663	2289	3096	4235	5484	6953	5.9%
Real imports	1853	2085	2463	2800	3516	4461	5690	4.1%
Energy intensity (thousand Btu per 2005 dollar of GDP)								
Delivered energy	5.42	5.45	4.84	4.33	3.85	3.48	3.17	-2.1%
Total energy	7.46	7.50	6.58	5.93	5.32	4.80	4.36	-2.1%
Price indices								
GDP chain-type price index (2005=1.000)	1.097	1.110	1.196	1.304	1.424	1.580	1.758	1.9%
Consumer price index (1982-4=1.00)								
All-urban	2.15	2.18	2.42	2.67	2.95	3.30	3.72	2.2%
Energy commodities and services	1.93	2.12	2.62	2.94	3.36	3.86	4.37	2.9%
Wholesale price index (1982=1.00)								
All commodities	1.73	1.85	2.10	2.23	2.39	2.58	2.81	1.7%
Fuel and power	1.59	1.86	2.29	2.57	3.01	3.50	4.12	3.2%
Metals and metal products	1.87	2.08	2.43	2.50	2.57	2.61	2.64	1.0%
Industrial commodities excluding energy	1.76	1.83	2.04	2.13	2.22	2.32	2.43	1.1%
Interest rates (percent, nominal)								
Federal funds rate	0.16	0.18	3.26	4.07	4.29	4.52	4.30	--
10-year treasury note	3.26	3.21	4.67	5.10	5.06	5.26	5.18	--
AA utility bond rate	5.75	5.24	6.74	7.41	7.17	7.48	7.56	--
Value of shipments (billion 2005 dollars)								
Service sectors	19996	20602	22469	24967	28029	30911	33430	2.0%
Total industrial	5667	5838	6730	7363	7973	8328	8692	1.6%
Nonmanufacturing	1615	1578	1873	2103	2228	2305	2407	1.7%
Manufacturing	4052	4260	4857	5260	5745	6023	6285	1.6%
Energy-intensive	1509	1595	1664	1786	1901	1973	2034	1.0%
Non-energy-intensive	2543	2664	3194	3474	3844	4050	4251	1.9%
Total shipments	25664	26440	29199	32329	36002	39239	42122	1.9%
Population and employment (millions)								
Population, with armed forces overseas	307.8	310.8	326.2	342.0	358.1	374.1	390.1	0.9%
Population, aged 16 and over	241.8	244.3	256.5	269.4	282.6	296.2	309.6	1.0%
Population, over age 65	39.7	40.4	47.1	55.1	64.2	72.3	77.7	2.6%
Employment, nonfarm	130.7	129.8	139.4	147.3	154.2	162.0	166.8	1.0%
Employment, manufacturing	11.8	11.5	12.1	11.9	11.4	10.3	9.2	-0.9%
Key labor indicators								
Labor force (millions)	154.2	153.9	158.0	163.6	168.6	174.5	181.7	0.7%
Nonfarm labor productivity (1992=1.00)	1.06	1.10	1.16	1.26	1.42	1.57	1.75	1.9%
Unemployment rate (percent)	9.28	9.63	7.51	6.47	5.54	5.40	5.54	--
Key indicators for energy demand								
Real disposable personal income	9883	10062	11035	12472	14286	16268	18217	2.4%
Housing starts (millions)	0.60	0.63	1.75	1.92	1.96	1.90	1.89	4.5%
Commercial floorspace (billion square feet)	80.3	81.1	84.1	89.1	93.9	98.2	103.0	1.0%
Unit sales of light-duty vehicles (millions)	10.40	11.55	16.16	16.40	17.79	18.11	18.64	1.9%

GDP = Gross domestic product.

Btu = British thermal unit.

-- = Not applicable.

Sources: 2009 and 2010: IHS Global Insight, Global Insight Industry and Employment models, August 2011. Projections: U.S. Energy Information Administration, AEO2012 National Energy Modeling System run REF2012.D020112C.

Reference case

Table A21. International liquids supply and disposition summary
(million barrels per day, unless otherwise noted)

Supply and disposition	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Crude oil prices (2010 dollars per barrel)								
Low sulfur light	62.37	79.39	116.91	126.68	132.56	138.49	144.98	2.4%
Imported crude oil ¹	59.72	75.87	113.97	115.74	121.21	126.51	132.95	2.3%
Crude oil prices (nominal dollars per barrel)								
Low sulfur light	61.65	79.39	125.97	148.87	170.09	197.10	229.55	4.3%
Imported crude oil ¹	59.04	75.87	122.81	136.02	155.52	180.06	210.51	4.2%
Petroleum liquids production²								
OPEC ³								
Middle East	22.30	23.43	25.46	27.16	29.77	32.07	33.94	1.5%
North Africa	3.92	3.89	3.62	3.42	3.37	3.31	3.27	-0.7%
West Africa	4.16	4.45	5.09	5.35	5.40	5.31	5.26	0.7%
South America	2.43	2.29	2.13	1.97	1.92	1.79	1.72	-1.1%
Total OPEC petroleum production	32.80	34.05	36.30	37.91	40.46	42.48	44.19	1.0%
Non-OPEC								
OECD								
United States (50 states)	8.27	8.79	9.82	10.73	10.53	10.57	10.15	0.6%
Canada	1.96	1.91	1.79	1.82	1.82	1.81	1.78	-0.3%
Mexico and Chile	3.00	2.98	2.65	1.97	1.58	1.65	1.68	-2.3%
OECD Europe ⁴	4.70	4.36	3.70	3.33	3.15	3.00	2.83	-1.7%
Japan	0.13	0.13	0.14	0.15	0.15	0.15	0.16	0.7%
Australia and New Zealand	0.65	0.62	0.55	0.54	0.54	0.53	0.53	-0.6%
Total OECD petroleum production	18.71	18.80	18.65	18.54	17.78	17.72	17.14	-0.4%
Non-OECD								
Russia	9.93	10.14	10.04	10.54	11.06	11.62	12.16	0.7%
Other Europe and Eurasia ⁵	3.12	3.22	3.67	4.01	4.37	4.52	4.54	1.4%
China	3.99	4.27	4.29	4.46	4.79	4.93	4.70	0.4%
Other Asia ⁶	3.67	3.77	3.79	3.55	3.38	3.17	3.00	-0.9%
Middle East	1.56	1.58	1.43	1.31	1.18	1.06	0.97	-1.9%
Africa	2.44	2.41	2.40	2.54	2.68	2.70	2.68	0.4%
Brazil	2.08	2.19	2.72	3.34	3.87	4.21	4.45	2.9%
Other Central and South America	1.90	2.01	2.29	2.32	2.47	2.67	2.65	1.1%
Total non-OECD petroleum production	28.69	29.59	30.63	32.07	33.80	34.88	35.15	0.7%
Total petroleum liquids production	80.21	82.44	85.58	88.52	92.04	95.08	96.47	0.6%
Other liquids production⁷								
United States (50 states)	0.75	0.90	1.05	1.34	1.62	2.08	2.59	4.3%
Other North America	1.69	1.93	2.51	3.08	3.75	4.46	5.16	4.0%
OECD Europe ⁴	0.22	0.22	0.23	0.24	0.26	0.27	0.28	1.0%
Middle East	0.01	0.01	0.17	0.21	0.24	0.24	0.24	14.5%
Africa	0.21	0.21	0.28	0.37	0.38	0.39	0.40	2.6%
Central and South America	1.14	1.20	1.78	2.31	2.61	2.90	3.17	3.9%
Other	0.12	0.13	0.16	0.28	0.61	0.92	1.18	9.1%
Total other liquids production	4.14	4.61	6.18	7.82	9.47	11.27	13.02	4.2%
Total production	84.35	87.05	91.76	96.33	101.51	106.34	109.50	0.9%

Table A21. International liquids supply and disposition summary (continued)
(million barrels per day, unless otherwise noted)

Supply and disposition	Reference case							Annual growth 2010-2035 (percent)
	2009	2010	2015	2020	2025	2030	2035	
Liquids consumption⁸								
OECD								
United States (50 states)	18.81	19.17	19.10	19.02	19.20	19.47	19.90	0.1%
United States territories	0.27	0.28	0.31	0.32	0.34	0.36	0.36	1.0%
Canada	2.16	2.21	2.15	2.21	2.25	2.29	2.35	0.2%
Mexico and Chile	2.35	2.34	2.39	2.43	2.50	2.60	2.68	0.5%
OECD Europe ⁴	14.66	14.58	14.14	14.43	14.65	14.76	14.74	0.0%
Japan	4.39	4.45	4.51	4.60	4.62	4.51	4.42	-0.0%
South Korea	2.15	2.24	2.25	2.35	2.46	2.53	2.56	0.5%
Australia and New Zealand	1.16	1.13	1.11	1.14	1.17	1.21	1.23	0.3%
Total OECD consumption	45.94	46.40	45.95	46.50	47.19	47.72	48.24	0.2%
Non-OECD								
Russia	2.73	2.93	3.02	2.94	2.91	2.94	2.97	0.1%
Other Europe and Eurasia ⁵	2.15	2.08	2.30	2.35	2.45	2.55	2.63	0.9%
China	8.33	9.19	12.10	14.36	16.03	17.65	18.50	2.8%
India	3.11	3.18	3.70	4.58	5.40	5.79	5.80	2.4%
Other non-OECD Asia ⁶	6.43	6.73	7.28	7.95	8.85	9.40	9.89	1.5%
Middle East	6.84	7.35	7.78	7.69	8.16	8.98	9.49	1.0%
Africa	3.23	3.34	3.30	3.37	3.57	3.80	4.09	0.8%
Brazil	2.52	2.65	2.84	2.94	3.15	3.47	3.80	1.5%
Other Central and South America	3.07	3.19	3.49	3.66	3.81	4.05	4.09	1.0%
Total non-OECD consumption	38.41	40.65	45.82	49.83	54.32	58.62	61.26	1.7%
Total liquids consumption	84.35	87.05	91.76	96.33	101.51	106.35	109.50	0.9%
OPEC production ⁹	33.34	34.58	37.30	39.23	41.91	44.05	45.89	1.1%
Non-OPEC production ⁹	51.01	52.47	54.46	57.10	59.60	62.30	63.61	0.8%
Net Eurasia exports	10.25	10.53	11.11	12.60	13.94	14.85	15.54	1.6%
OPEC market share (percent)	39.5	39.7	40.7	40.7	41.3	41.4	41.9	--

¹Weighted average price delivered to U.S. refiners.

²Includes production of crude oil (including lease condensate and shale oil/tight oil), natural gas plant liquids, other hydrogen and hydrocarbons for refinery feedstocks, and refinery gains.

³OPEC = Organization of Petroleum Exporting Countries - Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.

⁴OECD Europe = Organization for Economic Cooperation and Development - Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.

⁵Other Europe and Eurasia = Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Macedonia, Malta, Moldova, Montenegro, Romania, Serbia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

⁶Other Asia = Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia (Kampuchea), Fiji, French Polynesia, Guam, Hong Kong, Indonesia, Kiribati, Laos, Malaysia, Macau, Maldives, Mongolia, Myanmar (Burma), Nauru, Nepal, New Caledonia, Niue, North Korea, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Taiwan, Thailand, Tonga, Vanuatu, and Vietnam.

⁷Includes liquids produced from energy crops, natural gas, coal, extra-heavy oil, bitumen (oil sands), and kerogen (oil shale, not to be confused with shale oil/tight oil). Includes both OPEC and non-OPEC producers in the regional breakdown.

⁸Includes both OPEC and non-OPEC consumers in the regional breakdown.

⁹Includes both petroleum and other liquids production.

-- = Not applicable.

Note: Totals may not equal sum of components due to independent rounding. Data for 2009 and 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2009 and 2010 low sulfur light crude oil price: U.S. Energy Information Administration (EIA), Form EIA-856, "Monthly Foreign Crude Oil Acquisition Report." 2009 and 2010 imported crude oil price: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2009 quantities derived from: EIA, International Energy Statistics database as of November 2009. 2010 quantities and projections: EIA, AEO2012 National Energy Modeling System run REF2012.D020112C and EIA, Generate World Oil Balance Model.

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Appendix B

Economic growth case comparisons

Table B1. Total energy supply, disposition, and price summary
(quadrillion Btu per year, unless otherwise noted)

Supply, disposition, and prices	2010	Projections								
		2015			2025			2035		
		Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth
Production										
Crude oil and lease condensate	11 59	13 23	13 23	13 25	13 53	13 77	13 79	12 86	12 89	13 12
Natural gas plant liquids	2 78	3 33	3 33	3 33	3 91	3 93	3 93	3 93	3 94	3 95
Dry natural gas	22 10	24 02	24 22	24 28	26 17	26 91	27 64	27 48	28 60	30 05
Coal ¹	22.06	19 71	20 24	20 79	20 27	22 25	23 65	21 91	24 14	25 33
Nuclear / uranium ²	8.44	8 68	8 68	8 68	9 60	9 60	9 60	9 14	9 28	10 13
Hydropower	2.51	2 89	2 90	2 90	2 95	2 99	3 02	3 00	3 04	3 10
Biomass ³	4.05	4 41	4 45	4 49	6 04	6 26	6 30	8 37	9 07	9 58
Other renewable energy ⁴	1.34	2 08	1 99	2 18	2 21	2 22	2 42	2 44	2 81	3 64
Other ⁵	0.64	0 60	0 60	0 60	0 68	0 69	0 71	0 83	0 91	0 93
Total	75.50	78.96	79.64	80.50	85.36	88.61	91.06	89.95	94.67	99.83
Imports										
Crude oil	20.14	18 34	18 87	19 43	15 20	16 23	17 55	15 30	16 90	18 50
Liquid fuels and other petroleum ⁶	5 02	4 19	4 32	4 45	3 72	4 08	4 40	3 63	4 14	4 75
Natural gas ⁷	3 81	3 67	3 73	3 76	2 61	2 75	2 89	2 74	2 84	2 86
Other imports ⁸	0 52	0 34	0 44	0 47	0 97	1 07	0 95	0 73	0 81	0 96
Total	29.49	26.54	27.37	28.11	22.50	24.14	25.79	22.40	24.69	27.07
Exports										
Liquid fuels and other petroleum ⁹	4 81	4 90	5 00	5 08	4 32	4 46	4 57	4 68	4 95	5 11
Natural gas ¹⁰	1 15	1 93	1 93	1 92	3 55	3 51	3 48	4 29	4 17	4 07
Coal	2 10	2 73	2 73	2 73	2 78	2 82	2 82	3 09	3 13	3 18
Total	8.06	9.57	9.66	9.74	10.66	10.79	10.87	12.06	12.25	12.37
Discrepancy¹¹	-1.23	-0.03	-0.08	-0.09	-0.01	-0.03	-0.06	0.25	0.18	0.15
Consumption										
Liquid fuels and other petroleum ¹²	37 25	36 09	36 72	37 38	34 78	36 58	38 19	35 17	37 70	40 23
Natural gas	24 71	25 73	26 00	26 09	25 21	26 14	27 04	25 93	27 26	28 83
Coal ¹³	20 76	17 17	17 80	18 36	18 23	20 02	21 30	19 16	21 15	22 43
Nuclear / uranium ²	8.44	8 68	8 68	8 68	9 60	9 60	9 60	9 14	9 28	10 13
Hydropower	2.51	2 89	2 90	2 90	2 95	2 99	3 02	3 00	3 04	3 10
Biomass ¹⁴	2.88	3 01	3 04	3 06	3 95	4 17	4 21	4 96	5 44	5 78
Other renewable energy ⁴	1 34	2 08	1 99	2 18	2 21	2 22	2 42	2 44	2 81	3 64
Other ¹⁵	0.29	0 30	0 30	0 30	0 28	0 28	0 28	0 24	0 24	0 25
Total	98.16	95.96	97.43	98.96	97.20	101.99	106.05	100.04	106.93	114.38
Prices (2010 dollars per unit)										
Petroleum (dollars per barrel)										
Low sulfur light crude oil ¹⁶	79 39	116 06	116 91	117 83	130 58	132 56	134 77	142 51	144 98	147 82
Imported crude oil ¹⁶	75 87	113 12	113 97	114 90	118 61	121 21	124 15	130 33	132 95	136 68
Natural gas (dollars per million Btu)										
at Henry hub	4 39	4 06	4 29	4 36	5 10	5 63	6 17	6 60	7 37	7 58
at the wellhead ¹⁷	4 06	3 64	3 84	3 91	4 54	5 00	5 46	5 83	6 48	6 66
Natural gas (dollars per thousand cubic feet)										
at the wellhead ¹⁷	4 16	3 73	3 94	4 00	4 65	5 12	5 59	5 97	6 64	6 82
Coal (dollars per ton)										
at the minemouth ¹⁸	35 61	42 70	42 08	41 92	44 24	44 05	44 48	50 92	50 52	51 36
Coal (dollars per million Btu)										
at the minemouth ¹⁸	1 76	2 11	2 08	2 08	2 24	2 23	2 25	2 57	2 56	2 60
Average end-use ¹⁹	2 38	2 55	2 56	2 57	2 68	2 70	2 73	2 90	2 94	3 03
Average electricity (cents per kilowatt-hour)	9 8	9 9	9 7	9 6	9 7	9 7	9 9	9 8	10 1	10 5

Table B1. Total energy supply, disposition, and price summary (continued)
(quadrillion Btu per year, unless otherwise noted)

Supply, disposition, and prices	2010	Projections								
		2015			2025			2035		
		Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth
Prices (nominal dollars per unit)										
Petroleum (dollars per barrel)										
Low sulfur light crude oil ¹⁵	79.39	127.20	125.97	125.10	197.32	170.09	163.70	313.58	229.55	212.97
Imported crude oil ¹⁶	75.87	123.98	122.81	121.98	179.23	155.52	150.79	286.76	210.51	196.92
Natural gas (dollars per million Btu)										
at Henry hub	4.39	4.45	4.62	4.63	7.70	7.23	7.50	14.52	11.67	10.92
at the wellhead ¹⁷	4.06	3.99	4.14	4.15	6.86	6.42	6.63	12.82	10.26	9.59
Natural gas (dollars per thousand cubic feet)										
at the wellhead ¹⁷	4.16	4.09	4.24	4.25	7.02	6.57	6.79	13.13	10.51	9.82
Coal (dollars per ton)										
at the minemouth ¹⁸	35.61	46.80	45.34	44.50	66.85	56.52	54.03	112.04	80.00	74.00
Coal (dollars per million Btu)										
at the minemouth ¹⁸	1.76	2.31	2.24	2.21	3.39	2.86	2.73	5.64	4.05	3.74
Average end-use ¹⁹	2.38	2.79	2.76	2.73	4.05	3.47	3.32	6.37	4.66	4.36
Average electricity (cents per kilowatthour)	9.8	10.9	10.4	10.2	14.7	12.5	12.0	21.6	16.0	15.1

¹Includes waste coal
²These values represent the energy obtained from uranium when it is used in light water reactors. The total energy content of uranium is much larger, but alternative processes are required to take advantage of it
³Includes grid-connected electricity from wood and wood waste; biomass, such as corn, used for liquid fuels production; and non-electric energy demand from wood. Refer to Table A17 for details
⁴Includes grid-connected electricity from landfill gas; biogenic municipal waste; wind; photovoltaic and solar thermal sources; and non-electric energy from renewable sources, such as active and passive solar systems. Excludes electricity imports using renewable sources and nonmarketed renewable energy. See Table A17 for selected nonmarketed residential and commercial renewable energy data
⁵Includes non-biogenic municipal waste, liquid hydrogen, methanol, and some domestic inputs to refineries
⁶Includes imports of finished petroleum products, unfinished oils, alcohols, ethers, blending components, and renewable fuels such as ethanol
⁷Includes imports of liquefied natural gas that is later re-exported
⁸Includes coal, coal coke (net), and electricity (net). Excludes imports of fuel used in nuclear power plants
⁹Includes crude oil, petroleum products, ethanol, and biodiesel
¹⁰Includes re-exported liquefied natural gas and natural gas used for liquefaction at export terminals
¹¹Balancing item. Includes unaccounted for supply, losses, gains, and net storage withdrawals
¹²Includes petroleum-derived fuels and non-petroleum derived fuels, such as ethanol and biodiesel, and coal-based synthetic liquids. Petroleum coke, which is a solid, is included. Also included are natural gas plant liquids and crude oil consumed as a fuel. Refer to Table A17 for detailed renewable liquid fuels consumption.
¹³Excludes coal converted to coal-based synthetic liquids and natural gas
¹⁴Includes grid-connected electricity from wood and wood waste, non-electric energy from wood, and biofuels heat and coproducts used in the production of liquid fuels, but excludes the energy content of the liquid fuels
¹⁵Includes non-biogenic municipal waste, liquid hydrogen, and net electricity imports
¹⁶Weighted average price delivered to U.S. refiners
¹⁷Represents lower 48 onshore and offshore supplies
¹⁸Includes reported prices for both open market and captive mines
¹⁹Prices weighted by consumption; weighted average excludes residential and commercial prices, and export free-alongside-ship (f a s) prices
 Btu = British thermal unit
 Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports
 Sources: 2010 natural gas supply values and natural gas wellhead price: U.S. Energy Information Administration (EIA), *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2010 coal minemouth and delivered coal prices: EIA, *Annual Coal Report 2010*, DOE/EIA-0584(2010) (Washington, DC, November 2011). 2010 petroleum supply values: EIA, *Petroleum Supply Annual 2010*, DOE/EIA-0340(2010)/1 (Washington, DC, July 2011). 2010 low sulfur light crude oil price: EIA, Form EIA-856, "Monthly Foreign Crude Oil Acquisition Report." Other 2010 coal values: *Quarterly Coal Report, October-December 2010*, DOE/EIA-0121(2010/4Q) (Washington, DC, May 2011). Other 2010 values: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). Projections: EIA, AEO2012 National Energy Modeling System runs LM2012 D022412A, REF2012 D020112C, and HM2012 D022412A

Table B2. Energy consumption by sector and source
(quadrillion Btu per year, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth
Energy consumption										
Residential										
Liquefied petroleum gases	0.56	0.51	0.51	0.51	0.49	0.50	0.52	0.48	0.51	0.54
Kerosene	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Distillate fuel oil	0.63	0.55	0.55	0.55	0.43	0.43	0.43	0.35	0.35	0.35
Liquid fuels and other petroleum subtotal	1.22	1.08	1.08	1.08	0.94	0.95	0.97	0.85	0.87	0.91
Natural gas	5.06	4.96	4.97	5.00	4.77	4.88	5.04	4.50	4.76	5.08
Coal	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Renewable energy ¹	0.42	0.42	0.43	0.43	0.42	0.43	0.45	0.41	0.43	0.47
Electricity	4.95	4.68	4.75	4.82	4.97	5.23	5.58	5.35	5.86	6.57
Delivered energy	11.66	11.15	11.24	11.34	11.11	11.51	12.05	11.12	11.93	13.04
Electricity related losses	10.39	9.43	9.58	9.75	10.03	10.52	11.17	10.47	11.35	12.72
Total	22.05	20.59	20.81	21.09	21.13	22.02	23.22	21.59	23.28	25.76
Commercial										
Liquefied petroleum gases	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16
Motor gasoline ²	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06
Kerosene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01
Distillate fuel oil	0.43	0.35	0.35	0.35	0.33	0.33	0.33	0.32	0.32	0.32
Residual fuel oil	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Liquid fuels and other petroleum subtotal	0.72	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.63
Natural gas	3.28	3.43	3.41	3.42	3.56	3.53	3.51	3.70	3.69	3.71
Coal	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Renewable energy ³	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Electricity	4.54	4.57	4.59	4.61	5.11	5.16	5.22	5.70	5.80	5.89
Delivered energy	8.70	8.79	8.80	8.81	9.46	9.48	9.53	10.19	10.28	10.39
Electricity related losses	9.52	9.21	9.27	9.32	10.30	10.38	10.44	11.15	11.23	11.40
Total	18.22	18.00	18.06	18.13	19.76	19.86	19.97	21.34	21.50	21.79
Industrial⁴										
Liquefied petroleum gases	2.00	1.80	1.83	1.83	2.06	2.17	2.18	2.01	2.15	2.20
Motor gasoline ²	0.25	0.27	0.28	0.29	0.27	0.30	0.33	0.26	0.30	0.33
Distillate fuel oil	1.16	1.16	1.25	1.33	1.04	1.19	1.33	1.01	1.18	1.35
Residual fuel oil	0.12	0.09	0.09	0.09	0.08	0.08	0.09	0.08	0.08	0.09
Petrochemical feedstocks	0.94	1.00	1.01	1.01	1.22	1.29	1.29	1.21	1.30	1.33
Other petroleum ⁵	3.59	3.29	3.44	3.60	2.81	3.11	3.45	2.80	3.19	3.60
Liquid fuels and other petroleum subtotal	8.05	7.61	7.89	8.15	7.48	8.13	8.68	7.36	8.21	8.89
Natural gas	6.76	7.04	7.19	7.34	6.81	7.32	7.62	6.49	7.18	7.84
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lease and plant fuel ⁶	1.37	1.42	1.43	1.43	1.54	1.57	1.60	1.57	1.63	1.71
Natural gas subtotal	8.14	8.46	8.62	8.77	8.35	8.89	9.22	8.06	8.81	9.55
Metallurgical coal	0.55	0.55	0.57	0.59	0.41	0.49	0.54	0.34	0.43	0.53
Other industrial coal	1.01	1.01	1.03	1.05	1.02	1.08	1.12	1.01	1.08	1.14
Coal-to-liquids heat and power	0.00	0.00	0.00	0.00	0.11	0.36	0.37	0.31	0.60	0.61
Net coal coke imports	-0.01	-0.01	-0.01	-0.00	-0.03	-0.03	-0.03	-0.05	-0.06	-0.07
Coal subtotal	1.56	1.55	1.59	1.63	1.52	1.90	2.00	1.60	2.06	2.21
Biofuels heat and coproducts	0.84	0.80	0.81	0.82	1.26	1.27	1.27	2.39	2.57	2.69
Renewable energy ⁷	1.50	1.59	1.61	1.63	1.67	1.82	1.91	1.74	1.95	2.10
Electricity	3.28	3.34	3.44	3.53	3.22	3.52	3.75	3.01	3.33	3.67
Delivered energy	23.37	23.35	23.96	24.53	23.49	25.53	26.83	24.17	26.94	29.11
Electricity related losses	6.89	6.73	6.94	7.15	6.50	7.09	7.50	5.89	6.46	7.10
Total	30.26	30.08	30.90	31.68	29.99	32.61	34.33	30.06	33.39	36.21

Table B2. Energy consumption by sector and source (continued)
(quadrillion Btu per year, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth
Transportation										
Liquefied petroleum gases	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.04	0.05	0.06
E85 ⁸	0.00	0.01	0.01	0.01	0.40	0.30	0.21	1.14	1.22	1.22
Motor gasoline ²	16.91	16.00	16.13	16.29	14.26	14.90	15.49	13.43	14.53	15.38
Jet fuel ⁹	3.07	3.01	3.03	3.04	3.15	3.19	3.24	3.25	3.33	3.42
Distillate fuel oil ¹⁰	5.77	6.35	6.55	6.77	6.50	7.03	7.51	7.06	7.44	8.27
Residual fuel oil	0.90	0.91	0.91	0.91	0.92	0.93	0.93	0.93	0.94	0.95
Other petroleum ¹¹	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.18
Liquid fuels and other petroleum subtotal	26.88	26.48	26.83	27.22	25.43	26.57	27.60	26.03	27.67	29.47
Pipeline fuel natural gas	0.65	0.68	0.68	0.69	0.65	0.67	0.69	0.66	0.69	0.74
Compressed / liquefied natural gas	0.04	0.06	0.06	0.06	0.11	0.11	0.12	0.16	0.16	0.17
Liquid hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.07	0.07	0.08
Delivered energy	27.59	27.24	27.60	28.00	26.24	27.40	28.45	26.92	28.60	30.46
Electricity related losses	0.05	0.05	0.05	0.05	0.08	0.08	0.09	0.13	0.14	0.15
Total	27.63	27.30	27.65	28.05	26.32	27.49	28.54	27.05	28.75	30.62
Delivered energy consumption for all sectors										
Liquefied petroleum gases	2.75	2.49	2.51	2.52	2.75	2.86	2.89	2.69	2.86	2.95
E85 ⁸	0.00	0.01	0.01	0.01	0.40	0.30	0.21	1.14	1.22	1.22
Motor gasoline ²	17.21	16.32	16.46	16.63	14.58	15.25	15.87	13.75	14.88	15.77
Jet fuel ⁹	3.07	3.01	3.03	3.04	3.15	3.19	3.24	3.25	3.33	3.42
Kerosene	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Distillate fuel oil	7.99	8.41	8.69	9.00	8.30	8.99	9.61	8.74	9.29	10.29
Residual fuel oil	1.11	1.07	1.08	1.08	1.08	1.09	1.10	1.09	1.11	1.12
Petrochemical feedstocks	0.94	1.00	1.01	1.01	1.22	1.29	1.29	1.21	1.30	1.33
Other petroleum ¹²	3.76	3.45	3.61	3.76	2.97	3.27	3.62	2.97	3.36	3.77
Liquid fuels and other petroleum subtotal	36.87	35.80	36.43	37.07	34.48	36.28	37.87	34.86	37.38	39.90
Natural gas	15.15	15.49	15.64	15.83	15.25	15.85	16.29	14.85	15.79	16.80
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lease and plant fuel ⁶	1.37	1.42	1.43	1.43	1.54	1.57	1.60	1.57	1.63	1.71
Pipeline natural gas	0.65	0.68	0.68	0.69	0.65	0.67	0.69	0.66	0.69	0.74
Natural gas subtotal	17.17	17.58	17.75	17.94	17.44	18.09	18.58	17.08	18.11	19.26
Metallurgical coal	0.55	0.55	0.57	0.59	0.41	0.49	0.54	0.34	0.43	0.53
Other coal	1.08	1.07	1.09	1.11	1.08	1.14	1.18	1.07	1.15	1.21
Coal-to-liquids heat and power	0.00	0.00	0.00	0.00	0.11	0.36	0.37	0.31	0.60	0.61
Net coal coke imports	-0.01	-0.01	-0.01	-0.00	-0.03	-0.03	-0.03	-0.05	-0.06	-0.07
Coal subtotal	1.62	1.62	1.65	1.70	1.58	1.96	2.06	1.67	2.12	2.28
Biofuels heat and coproducts	0.84	0.80	0.81	0.82	1.26	1.27	1.27	2.39	2.57	2.69
Renewable energy ¹³	2.03	2.12	2.15	2.17	2.20	2.36	2.47	2.25	2.50	2.68
Liquid hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity	12.79	12.61	12.81	12.98	13.34	13.96	14.60	14.13	15.06	16.20
Delivered energy	71.32	70.54	71.59	72.69	70.30	73.92	76.86	72.39	77.75	83.01
Electricity related losses	26.84	25.42	25.84	26.27	26.91	28.07	29.20	27.65	29.18	31.37
Total	98.16	95.96	97.43	98.96	97.20	101.99	106.05	100.04	106.93	114.38
Electric power¹⁴										
Distillate fuel oil	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09
Residual fuel oil	0.30	0.21	0.21	0.22	0.21	0.22	0.23	0.22	0.23	0.24
Liquid fuels and other petroleum subtotal	0.38	0.29	0.29	0.30	0.30	0.31	0.32	0.31	0.32	0.34
Natural gas	7.54	8.15	8.25	8.15	7.77	8.04	8.46	8.84	9.16	9.58
Steam coal	19.13	15.56	16.15	16.67	16.65	18.06	19.24	17.50	19.03	20.15
Nuclear / uranium ¹⁵	8.44	8.68	8.68	8.68	9.60	9.60	9.60	9.14	9.28	10.13
Renewable energy ¹⁶	3.85	5.05	4.96	5.15	5.66	5.75	5.91	5.75	6.22	7.14
Electricity imports	0.09	0.10	0.10	0.10	0.08	0.08	0.08	0.04	0.04	0.04
Total¹⁷	39.63	38.03	38.64	39.25	40.25	42.03	43.80	41.78	44.24	47.57

Table B2. Energy consumption by sector and source (continued)
(quadrillion Btu per year, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth
Total energy consumption										
Liquefied petroleum gases	2.75	2.49	2.51	2.52	2.75	2.86	2.89	2.69	2.86	2.95
E85 ⁸	0.00	0.01	0.01	0.01	0.40	0.30	0.21	1.14	1.22	1.22
Motor gasoline ²	17.21	16.32	16.46	16.63	14.58	15.25	15.87	13.75	14.88	15.77
Jet fuel ⁹	3.07	3.01	3.03	3.04	3.15	3.19	3.24	3.25	3.33	3.42
Kerosene	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Distillate fuel oil	8.07	8.50	8.78	9.08	8.39	9.07	9.70	8.83	9.38	10.38
Residual fuel oil	1.41	1.28	1.29	1.30	1.29	1.31	1.33	1.31	1.34	1.36
Petrochemical feedstocks	0.94	1.00	1.01	1.01	1.22	1.29	1.29	1.21	1.30	1.33
Other petroleum ¹²	3.76	3.45	3.61	3.76	2.97	3.27	3.62	2.97	3.36	3.77
Liquid fuels and other petroleum subtotal	37.25	36.09	36.72	37.38	34.78	36.58	38.19	35.17	37.70	40.23
Natural gas	22.69	23.64	23.89	23.97	23.02	23.89	24.74	23.70	24.94	26.38
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lease and plant fuel ⁶	1.37	1.42	1.43	1.43	1.54	1.57	1.60	1.57	1.63	1.71
Pipeline natural gas	0.65	0.68	0.68	0.69	0.65	0.67	0.69	0.66	0.69	0.74
Natural gas subtotal	24.71	25.73	26.00	26.09	25.21	26.14	27.04	25.93	27.26	28.83
Metallurgical coal	0.55	0.55	0.57	0.59	0.41	0.49	0.54	0.34	0.43	0.53
Other coal	20.21	16.63	17.24	17.78	17.73	19.20	20.42	18.57	20.18	21.36
Coal-to-liquids heat and power	0.00	0.00	0.00	0.00	0.11	0.36	0.37	0.31	0.60	0.61
Net coal coke imports	-0.01	-0.01	-0.01	-0.00	-0.03	-0.03	-0.03	-0.05	-0.06	-0.07
Coal subtotal	20.76	17.17	17.80	18.36	18.23	20.02	21.30	19.16	21.15	22.43
Nuclear / uranium ¹⁵	8.44	8.68	8.68	8.68	9.60	9.60	9.60	9.14	9.28	10.13
Biofuels heat and coproducts	0.84	0.80	0.81	0.82	1.26	1.27	1.27	2.39	2.57	2.69
Renewable energy ¹⁸	5.88	7.18	7.11	7.33	7.85	8.11	8.38	8.00	8.71	9.82
Liquid hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity imports	0.09	0.10	0.10	0.10	0.08	0.08	0.08	0.04	0.04	0.04
Total	98.16	95.96	97.43	98.96	97.20	101.99	106.05	100.04	106.93	114.38
Energy use and related statistics										
Delivered energy use	71.32	70.54	71.59	72.69	70.30	73.92	76.86	72.39	77.75	83.01
Total energy use	98.16	95.96	97.43	98.96	97.20	101.99	106.05	100.04	106.93	114.38
Ethanol consumed in motor gasoline and E85	1.11	1.21	1.22	1.23	1.55	1.55	1.54	1.99	2.15	2.23
Population (millions)	310.83	325.23	326.16	327.19	354.23	358.06	362.48	382.76	390.09	398.74
Gross domestic product (billion 2005 dollars)	13088	14401	14803	15235	17676	19185	20538	21630	24539	27084
Carbon dioxide emissions (million metric tons)	5633.6	5298.2	5407.2	5503.9	5226.8	5552.5	5823.7	5355.8	5757.9	6117.5

¹Includes wood used for residential heating. See Table A4 and/or Table A17 for estimates of nonmarketed renewable energy consumption for geothermal heat pumps, solar thermal water heating, and electricity generation from wind and solar photovoltaic sources.

²Includes ethanol (blends of 15 percent or less) and ethers blended into gasoline.

³Excludes ethanol. Includes commercial sector consumption of wood and wood waste, landfill gas, municipal waste, and other biomass for combined heat and power. See Table A5 and/or Table A17 for estimates of nonmarketed renewable energy consumption for solar thermal water heating and electricity generation from wind and solar photovoltaic sources.

⁴Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public.

⁵Includes petroleum coke, asphalt, road oil, lubricants, still gas, and miscellaneous petroleum products.

⁶Represents natural gas used in well, field, and lease operations, and in natural gas processing plant machinery.

⁷Includes consumption of energy produced from hydroelectric, wood and wood waste, municipal waste, and other biomass sources. Excludes ethanol blends (15 percent or less) in motor gasoline.

⁸E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.

⁹Includes only kerosene type.

¹⁰Diesel fuel for on- and off- road use.

¹¹Includes aviation gasoline and lubricants.

¹²Includes unfinished oils, natural gasoline, motor gasoline blending components, aviation gasoline, lubricants, still gas, asphalt, road oil, petroleum coke, and miscellaneous petroleum products.

¹³Includes electricity generated for sale to the grid and for own use from renewable sources, and non-electric energy from renewable sources. Excludes ethanol and nonmarketed renewable energy consumption for geothermal heat pumps, buildings photovoltaic systems, and solar thermal water heaters.

¹⁴Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes small power producers and exempt wholesale generators.

¹⁵These values represent the energy obtained from uranium when it is used in light water reactors. The total energy content of uranium is much larger, but alternative processes are required to take advantage of it.

¹⁶Includes conventional hydroelectric, geothermal, wood and wood waste, biogenic municipal waste, other biomass, wind, photovoltaic, and solar thermal sources. Excludes net electricity imports.

¹⁷Includes non-biogenic municipal waste not included above.

¹⁸Includes conventional hydroelectric, geothermal, wood and wood waste, biogenic municipal waste, other biomass, wind, photovoltaic, and solar thermal sources. Excludes ethanol, net electricity imports, and nonmarketed renewable energy consumption for geothermal heat pumps, buildings photovoltaic systems, and solar thermal water heaters.

Blu = British thermal unit.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2010 consumption based on: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011) 2010 population and gross domestic product: IHS Global Insight Industry and Employment models, August 2011. 2010 carbon dioxide emissions: EIA, *Monthly Energy Review, October 2011* DOE/EIA-0035(2011/10) (Washington, DC, October 2011). Projections: EIA, AEO2012 National Energy Modeling System runs LM2012 D022412A, REF2012 D020112C, and HM2012 D022412A.

Domestic growth rate assumption

Table B3. Energy prices by sector and source
(2010 dollars per million Btu, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth
Residential										
Liquefied petroleum gases	27 02	30 48	30 70	30 86	31 69	32 27	32 91	33 94	34 64	35 27
Distillate fuel oil	21 21	27 00	27 26	27 52	29 17	30 15	30 64	32 01	32 73	33 99
Natural gas	11 08	10 10	10 31	10 39	11 46	12 03	12 61	13 16	13 98	14 38
Electricity	33 69	35 59	34 59	34 31	34 30	34 08	34 20	34 14	34 58	35 27
Commercial										
Liquefied petroleum gases	23 52	27 21	27 42	27 57	28 39	28 97	29 59	30 62	31 30	31 89
Distillate fuel oil	20 77	23 72	23 98	24 23	25 89	26 86	27 30	28 58	29 18	30 43
Residual fuel oil	11 07	16 02	16 18	16 35	17 82	18 24	18 62	18 61	18 90	19 61
Natural gas	9 10	8 40	8 60	8 67	9 51	10 02	10 52	10 92	11 64	11 91
Electricity	29 73	29 65	29 03	28 97	28 81	29 00	29 51	28 42	29 48	30 79
Industrial¹										
Liquefied petroleum gases	21 80	27 12	27 43	27 66	28 44	29 24	30 12	31 26	32 18	32 98
Distillate fuel oil	21 32	23 95	24 20	24 45	26 23	27 22	27 61	28 93	29 53	30 79
Residual fuel oil	10 92	18 95	19 21	19 45	20 54	21 23	21 59	21 12	21 65	22 44
Natural gas ²	5 51	4 68	4 88	4 94	5 58	6 04	6 51	6 89	7 54	7 74
Metallurgical coal	5 84	7 30	7 22	7 20	8 24	8 11	8 08	9 24	9 11	9 11
Other industrial coal	2 71	3 27	3 27	3 27	3 38	3 38	3 39	3 61	3 64	3 69
Coal to liquids	--	1 27	1 26	1 26	2 27	2 08	2 14	2 34	2 38	2 42
Electricity	19 63	19 06	18 91	18 94	19 21	19 60	20 15	19 63	20 78	22 00
Transportation										
Liquefied petroleum gases ³	26 88	31 71	31 93	32 09	32 80	33 38	34 04	35 02	35 74	36 31
E85 ⁴	25 21	28 85	29 03	29 26	27 92	28 81	31 30	31 02	31 96	33 04
Motor gasoline ⁵	22 70	29 09	29 26	29 49	30 92	32 10	32 42	32 33	33 61	34 78
Jet fuel ⁶	16 22	23 48	23 74	24 02	25 61	26 45	26 99	28 41	29 13	30 25
Diesel fuel (distillate fuel oil) ⁷	21 87	27 28	27 56	27 83	29 18	30 42	30 85	31 53	32 40	33 80
Residual fuel oil	10 42	17 96	18 32	18 61	19 74	20 62	20 82	20 50	20 95	21 94
Natural gas ⁸	13 20	12 17	12 40	12 51	12 51	13 29	13 86	13 42	14 51	14 87
Electricity	32 99	30 67	30 50	30 54	31 37	31 53	32 45	32 36	33 82	35 11
Electric power⁹										
Distillate fuel oil	18 73	22 50	22 77	23 04	24 44	25 35	25 88	27 17	27 80	29 02
Residual fuel oil	11 89	22 67	23 00	23 03	24 55	25 40	25 41	25 25	25 72	26 49
Natural gas	5 14	4 36	4 55	4 61	5 15	5 60	6 10	6 55	7 21	7 40
Steam coal	2 26	2 33	2 35	2 37	2 50	2 54	2 56	2 75	2 80	2 87
Average price to all users¹⁰										
Liquefied petroleum gases	17 28	22 78	22 99	23 18	23 62	24 19	24 91	25 96	26 63	27 37
E85 ⁴	25 21	28 85	29 03	29 26	27 92	28 81	31 30	31 02	31 96	33 04
Motor gasoline ⁵	22 59	29 09	29 26	29 49	30 91	32 10	32 42	32 33	33 61	34 78
Jet fuel	16 22	23 48	23 74	24 02	25 61	26 45	26 99	28 41	29 13	30 25
Distillate fuel oil	21 65	26 61	26 87	27 14	28 65	29 81	30 23	31 09	31 91	33 27
Residual fuel oil	10 82	18 67	19 01	19 27	20 46	21 31	21 53	21 22	21 68	22 64
Natural gas	7 16	6 27	6 45	6 52	7 29	7 74	8 22	8 63	9 30	9 53
Metallurgical coal	5 84	7 30	7 22	7 20	8 24	8 11	8 08	9 24	9 11	9 11
Other coal	2 29	2 40	2 41	2 43	2 56	2 59	2 62	2 80	2 85	2 92
Coal to liquids	--	1 27	1 26	1 26	2 27	2 08	2 14	2 34	2 38	2 42
Electricity	28 68	29 05	28 38	28 23	28 55	28 54	28 90	28 73	29 56	30 64
Non-renewable energy expenditures by sector (billion 2010 dollars)										
Residential	251 69	247 63	246 72	248 83	253 92	266 75	285 47	270 07	298 72	336 43
Commercial	179 08	179 38	177 92	178 42	197 28	201 89	208 21	220 10	231 98	244 34
Industrial	198 98	214 83	223 88	231 79	232 07	261 92	285 16	242 72	282 31	317 58
Transportation	573 78	731 18	746 84	764 56	736 46	803 52	848 96	777 83	856 65	950 17
Total non-renewable expenditures	1203 54	1373 02	1395 36	1423 60	1419 73	1534 08	1627 80	1510 72	1669 66	1848 51
Transportation renewable expenditures	0 08	0 24	0 25	0 26	11 22	8 74	6 44	35 33	38 86	40 34
Total expenditures	1203.62	1373.26	1395.61	1423.86	1430.95	1542.81	1634.24	1546.05	1708.52	1888.85

Table B3. Energy prices by sector and source (continued)
(nominal dollars per million Btu, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth
Residential										
Liquefied petroleum gases	27.02	33.41	33.08	32.76	47.89	41.41	39.98	74.69	54.86	50.81
Distillate fuel oil	21.21	29.60	29.38	29.22	44.08	38.68	37.22	70.42	51.82	48.97
Natural gas	11.08	11.07	11.11	11.03	17.31	15.43	15.32	28.95	22.14	20.72
Electricity	33.69	39.01	37.27	36.43	51.84	43.72	41.53	75.12	54.76	50.81
Commercial										
Liquefied petroleum gases	23.52	29.82	29.54	29.27	42.91	37.17	35.94	67.37	49.56	45.95
Distillate fuel oil	20.77	26.00	25.83	25.73	39.13	34.47	33.15	62.88	46.20	43.85
Residual fuel oil	11.07	17.55	17.43	17.36	26.93	23.41	22.61	40.96	29.93	28.25
Natural gas	9.10	9.21	9.27	9.21	14.37	12.86	12.78	24.03	18.43	17.16
Electricity	29.73	32.49	31.28	30.75	43.53	37.21	35.84	62.54	46.67	44.37
Industrial¹										
Liquefied petroleum gases	21.80	29.72	29.56	29.37	42.98	37.51	36.59	68.79	50.95	47.52
Distillate fuel oil	21.32	26.25	26.08	25.96	39.64	34.93	33.54	63.67	46.76	44.36
Residual fuel oil	10.92	20.77	20.70	20.64	31.03	27.24	26.22	46.48	34.28	32.33
Natural gas ²	5.51	5.13	5.26	5.25	8.43	7.75	7.91	15.15	11.93	11.15
Metallurgical coal	5.84	8.00	7.78	7.64	12.45	10.40	9.81	20.34	14.42	13.13
Other industrial coal	2.71	3.59	3.52	3.47	5.11	4.34	4.12	7.95	5.77	5.32
Coal to liquids	--	1.39	1.36	1.34	3.42	2.67	2.60	5.15	3.78	3.49
Electricity	19.63	20.89	20.38	20.11	29.03	25.15	24.47	43.20	32.90	31.70
Transportation										
Liquefied petroleum gases ³	26.88	34.76	34.41	34.07	49.57	42.83	41.35	77.05	56.59	52.31
E85 ⁴	25.21	31.62	31.28	31.06	42.19	36.97	38.02	68.26	50.61	47.60
Motor gasoline ⁵	22.70	31.88	31.53	31.31	46.72	41.19	39.38	71.14	53.22	50.11
Jet fuel ⁶	16.22	25.74	25.58	25.50	38.70	33.94	32.78	62.51	46.12	43.58
Diesel fuel (distillate fuel oil) ⁷	21.87	29.90	29.69	29.55	44.10	39.03	37.47	69.37	51.29	48.70
Residual fuel oil	10.42	19.69	19.74	19.76	29.83	26.45	25.28	45.11	33.18	31.60
Natural gas ⁸	13.20	13.34	13.36	13.29	18.91	17.05	16.84	29.54	22.97	21.42
Electricity	32.99	33.62	32.86	32.42	47.41	40.46	39.41	71.19	53.55	50.59
Electric power⁹										
Distillate fuel oil	18.73	24.66	24.53	24.46	36.93	32.52	31.43	59.79	44.02	41.80
Residual fuel oil	11.89	24.85	24.78	24.45	37.10	32.59	30.87	55.56	40.73	38.16
Natural gas	5.14	4.78	4.90	4.90	7.78	7.19	7.41	14.41	11.42	10.66
Steam coal	2.26	2.56	2.53	2.51	3.78	3.25	3.12	6.05	4.43	4.13

Table B3. Energy prices by sector and source (continued)
(nominal dollars per million Btu, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth
Average price to all users¹⁰										
Liquefied petroleum gases	17 28	24 97	24 78	24 61	35 69	31 04	30 26	57 13	42 17	39 44
E85 ⁴	25 21	31 62	31 28	31 06	42 19	36 97	38 02	68 26	50 61	47 60
Motor gasoline ⁵	22 59	31 88	31 53	31 31	46 72	41 19	39 38	71 14	53 22	50 11
Jet fuel	16 22	25 74	25 58	25 50	38 70	33 94	32 78	62 51	46 12	43 58
Distillate fuel oil	21 65	29 16	28 96	28 81	43 29	38 24	36 72	68 42	50 52	47 93
Residual fuel oil	10 82	20 46	20 48	20 46	30 92	27 34	26 15	46 69	34 33	32 61
Natural gas	7 16	6 87	6 95	6 92	11 02	9 93	9 98	18 98	14 73	13 73
Metallurgical coal	5 84	8 00	7 78	7 64	12 45	10 40	9 81	20 34	14 42	13 13
Other coal	2 29	2 63	2 60	2 58	3 87	3 32	3 18	6 17	4 51	4 20
Coal to liquids	--	1 39	1 36	1 34	3 42	2 67	2 60	5 15	3 78	3 49
Electricity	28 68	31 84	30 58	29 97	43 14	36 62	35 11	63 22	46 80	44 14
Non-renewable energy expenditures by sector (billion nominal dollars)										
Residential	251 69	271 41	265 85	264 18	383 71	342 26	346 74	594 24	472 99	484 70
Commercial	179 08	196 61	191 71	189 42	298 11	259 04	252 89	484 30	367 31	352 03
Industrial	198 98	235 47	241 24	246 08	350 69	336 06	346 35	534 08	447 01	457 54
Transportation	573 78	801 41	804 75	811 72	1112 90	1030 98	1031 15	1711 49	1356 41	1368 93
Total non-renewable expenditures	1203 54	1504 89	1503 55	1511 41	2145 42	1968 35	1977 13	3324 10	2643 72	2663 20
Transportation renewable expenditures	0 08	0 27	0 27	0 27	16 95	11 21	7 82	77 73	61 53	58 11
Total expenditures	1203.62	1505.16	1503.82	1511.69	2162.37	1979.56	1984.95	3401.83	2705.26	2721.31

¹Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public

²Excludes use for lease and plant fuel

³Includes Federal and State taxes while excluding county and local taxes

⁴E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.

⁵Sales weighted-average price for all grades. Includes Federal, State and local taxes

⁶Kerosene-type jet fuel. Includes Federal and State taxes while excluding county and local taxes

⁷Diesel fuel for on-road use. Includes Federal and State taxes while excluding county and local taxes

⁸Natural gas used as a vehicle fuel. Includes estimated motor vehicle fuel taxes and estimated dispensing costs or charges

⁹Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public

¹⁰Weighted averages of end-use fuel prices are derived from the prices shown in each sector and the corresponding sectoral consumption.

Btu = British thermal unit

-- = Not applicable

Note: Data for 2010 are model results and may differ slightly from official EIA data reports

Sources: 2010 prices for motor gasoline, distillate fuel oil, and jet fuel are based on prices in the U.S. Energy Information Administration (EIA), *Petroleum Marketing Annual 2009*, DOE/EIA-0487(2009) (Washington, DC, August 2010). 2010 residential and commercial natural gas delivered prices: EIA, *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2010 industrial natural gas delivered prices are estimated based on: EIA, *Manufacturing Energy Consumption Survey* and industrial and wellhead prices from the *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010) and the *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2010 transportation sector natural gas delivered prices are model results. 2010 electric power sector distillate and residual fuel oil prices: EIA, *Monthly Energy Review*, DOE/EIA-0035(2011/09) (Washington, DC, September 2010). 2010 electric power sector natural gas prices: EIA, *Electric Power Monthly*, DOE/EIA-0226, April 2010 and April 2011, Table 4.2, and EIA, *State Energy Data Report 2009*, DOE/EIA-0214(2009) (Washington, DC, June 2011). 2010 coal prices based on: EIA, *Quarterly Coal Report, October-December 2010*, DOE/EIA-0121(2010/4Q) (Washington, DC, May 2011) and EIA, AEO2012 National Energy Modeling System run REF2012 D020112C. 2010 electricity prices: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2010 E85 prices derived from monthly prices in the Clean Cities Alternative Fuel Price Report. Projections: EIA, AEO2012 National Energy Modeling System runs LM2012 D022412A, REF2012 D020112C, and HM2012 D022412A.

Table B4. Macroeconomic indicators
(billion 2005 chain-weighted dollars, unless otherwise noted)

Indicators	2010	Projections								
		2015			2025			2035		
		Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth	Low economic growth	Reference	High economic growth
Real gross domestic product	13088	14401	14803	15235	17676	19185	20538	21630	24539	27084
Components of real gross domestic product										
Real consumption	9221	10007	10218	10510	11874	12697	13606	14594	16220	17889
Real investment	1715	2234	2457	2675	2956	3472	3982	3929	4836	5651
Real government spending	2557	2322	2355	2389	2420	2525	2601	2619	2818	2944
Real exports	1663	2243	2289	2322	3828	4235	4558	5846	6953	7979
Real imports	2085	2370	2463	2596	3258	3516	3909	5020	5690	6596
Energy intensity (thousand Btu per 2005 dollar of GDP)										
Delivered energy	5.45	4.90	4.84	4.77	3.98	3.85	3.74	3.35	3.17	3.06
Total energy	7.50	6.66	6.58	6.50	5.50	5.32	5.16	4.63	4.36	4.22
Price indices										
GDP chain-type price index (2005=1.000)	1.110	1.217	1.196	1.178	1.677	1.424	1.348	2.442	1.758	1.599
Consumer price index (1982-4=1)										
All-urban	2.18	2.47	2.42	2.36	3.53	2.95	2.78	5.38	3.72	3.36
Energy commodities and services	2.12	2.67	2.62	2.59	3.82	3.36	3.20	5.83	4.37	4.07
Wholesale price index (1982=1.00)										
All commodities	1.85	2.15	2.10	2.02	2.96	2.39	2.25	4.46	2.81	2.47
Fuel and power	1.86	2.31	2.29	2.27	3.41	3.01	2.92	5.44	4.12	3.85
Metals and metal products	2.08	2.45	2.43	2.45	2.85	2.57	2.53	3.39	2.64	2.56
Industrial commodities excluding energy	1.83	2.08	2.04	2.02	2.63	2.22	2.12	3.47	2.43	2.24
Interest rates (percent, nominal)										
Federal funds rate	0.17	3.31	3.26	2.50	5.75	4.29	3.58	7.56	4.30	3.59
10-year treasury note	3.21	6.62	4.67	4.09	8.03	5.06	4.49	8.22	5.18	4.47
AA utility bond rate	5.24	9.31	6.74	5.73	11.61	7.17	6.18	12.74	7.56	6.12
Value of shipments (billion 2005 dollars)										
Service sectors	20602	22047	22469	22970	26671	28029	29342	31392	33430	35331
Total industrial	5838	6407	6730	7072	7109	7973	8737	7606	8692	9954
Non-manufacturing	1578	1702	1873	2065	1885	2228	2554	2024	2407	2823
Manufacturing	4260	4705	4857	5008	5224	5745	6183	5583	6285	7131
Energy-intensive	1595	1633	1664	1692	1781	1901	1971	1854	2034	2155
Non-energy-intensive	2664	3072	3194	3316	3443	3844	4212	3729	4251	4976
Total shipments	26440	28454	29199	30042	33780	36002	38079	38998	42122	45285
Population and employment (millions)										
Population with armed forces overseas	310.8	325.2	326.2	327.2	354.2	358.1	362.5	382.8	390.1	398.7
Population, aged 16 and over	244.3	256.0	256.5	257.2	279.9	282.6	285.8	304.2	309.6	316.0
Population, over age 65	40.4	46.7	47.1	47.1	63.4	64.2	64.4	76.9	77.7	78.3
Employment, nonfarm	129.8	138.3	139.4	142.7	150.4	154.2	160.5	158.9	166.8	173.4
Employment, manufacturing	11.5	11.8	12.1	12.3	11.0	11.4	11.9	9.1	9.2	9.9
Key labor indicators										
Labor force (millions)	153.9	157.6	158.0	158.7	167.1	168.6	170.9	178.0	181.7	186.3
Non-farm labor productivity (1992=1.00)	1.10	1.14	1.16	1.18	1.33	1.42	1.47	1.55	1.75	1.85
Unemployment rate (percent)	9.63	8.11	7.51	7.10	6.04	5.54	5.05	6.15	5.54	5.09
Key indicators for energy demand										
Real disposable personal income	10062	10890	11035	11224	13862	14286	14978	17350	18217	19407
Housing starts (millions)	0.63	1.40	1.75	2.22	1.40	1.96	2.78	1.19	1.89	2.95
Commercial floorspace (billion square feet)	81.1	84.0	84.1	84.3	92.7	93.9	95.2	100.5	103.0	105.5
Unit sales of light-duty vehicles (millions)	11.55	15.34	16.16	16.69	16.20	17.79	18.85	15.31	18.64	20.55

GDP = Gross domestic product

Btu = British thermal unit.

Sources: 2010: IHS Global Insight, Global Insight Industry and Employment models, August 2011. Projections: U.S. Energy Information Administration, AEO2012 National Energy Modeling System runs LM2012.D022412A, REF2012.D020112C, and HM2012.D022412A.

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Appendix C

Price case comparisons

Table C1. Total energy supply, disposition, and price summary
(quadrillion Btu per year, unless otherwise noted)

Supply, disposition, and prices	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Production										
Crude oil and lease condensate	11 59	12.66	13 23	13 79	11 57	13 77	15 60	10 29	12 89	14 37
Natural gas plant liquids	2 78	3 15	3 33	3 34	3 84	3 93	4 01	3 80	3 94	4 00
Dry natural gas	22 10	24 02	24 22	24 44	26 20	26 91	27 65	27 80	28 60	29 38
Coal ¹	22 06	20 76	20 24	19 80	22 39	22 25	23 45	23 59	24 14	27 73
Nuclear / uranium ²	8 44	8 68	8 68	8 68	9 60	9 60	9 60	9 42	9 28	9 26
Hydropower	2 51	2 90	2 90	2 90	2 99	2 99	2 98	3 05	3 04	3 04
Biomass ³	4 05	4 52	4 45	4 67	6 14	6 26	7 14	7 92	9 07	11 33
Other renewable energy ⁴	1 34	1 94	1 99	2 02	2 18	2 22	2 19	2 87	2 81	2 66
Other ⁵	0 64	0 54	0 60	0 82	0 55	0 69	0 77	0 68	0 91	0 90
Total	75.50	79.18	79.64	80.46	85.46	88.61	93.38	89.43	94.67	102.65
Imports										
Crude oil	20 14	21 26	18 87	17 01	21 30	16 23	12 08	23 88	16 90	11 22
Liquid fuels and other petroleum ⁶	5 02	4 97	4 32	3 89	5 08	4 08	3 43	5 40	4 14	3 26
Natural gas ⁷	3 81	3 87	3 73	3 69	3 16	2 75	2 55	3 28	2 84	2 57
Other imports ⁸	0 52	0 47	0 44	0 40	0 83	1 07	0 81	0 87	0 81	0 76
Total	29.49	30.58	27.37	24.98	30.37	24.14	18.88	33.42	24.69	17.82
Exports										
Liquid fuels and other petroleum ⁹	4 81	5 16	5 00	4 95	4 51	4 46	4 58	4 89	4 95	5 02
Natural gas ¹⁰	1 15	1 93	1 93	1 93	3 51	3 51	3 52	4 17	4 17	4 18
Coal	2 10	2 73	2 73	2 73	2 82	2 82	2 67	3 22	3 13	3 13
Total	8.06	9.82	9.66	9.62	10.84	10.79	10.76	12.28	12.25	12.33
Discrepancy¹¹	-1.23	0.04	-0.08	0.01	0.09	-0.03	-0.01	0.23	0.18	0.27
Consumption										
Liquid fuels and other petroleum ¹²	37 25	38 73	36 72	35 31	39 70	36 58	35 03	41 86	37 70	35 86
Natural gas	24 71	25 93	26 00	26 18	25 80	26 14	26 57	26 86	27 26	27 67
Coal ¹³	20 76	18 35	17 80	17 30	20 17	20 02	20 39	21 05	21 15	22 69
Nuclear / uranium ²	8 44	8 68	8 68	8 68	9 60	9 60	9 60	9 42	9 28	9 26
Hydropower	2 51	2 90	2 90	2 90	2 99	2 99	2 98	3 05	3 04	3 04
Biomass ¹⁴	2 88	3 06	3 04	3 13	4 19	4 17	4 48	4 98	5 44	6 45
Other renewable energy ⁴	1 34	1 94	1 99	2 02	2 18	2 22	2 19	2 87	2 81	2 66
Other ¹⁵	0 29	0 30	0 30	0 30	0 28	0 28	0 28	0 24	0 24	0 24
Total	98.16	99.89	97.43	95.82	104.90	101.99	101.52	110.34	106.93	107.87
Prices (2010 dollars per unit)										
Petroleum (dollars per barrel)										
Low sulfur light crude oil ¹⁶	79 39	58 36	116 91	182 10	59 41	132 56	193 48	62 38	144 98	200 36
Imported crude oil ¹⁶	75 87	55 41	113 97	179 16	48 84	121 21	180 29	53 10	132 95	187 04
Natural gas (dollars per million Btu)										
at Henry hub	4 39	4 21	4 29	4 26	5 61	5 63	5 60	7 36	7 37	7 17
at the wellhead ¹⁷	4 06	3 78	3 84	3 81	4 98	5 00	4 97	6 47	6 48	6 31
Natural gas (dollars per thousand cubic feet)										
at the wellhead ¹⁷	4 16	3 87	3 94	3 91	5 10	5 12	5 09	6 63	6 64	6 46
Coal (dollars per ton)										
at the minemouth ¹⁸	35 61	39 93	42 08	44 26	41 50	44 05	45 62	47 24	50 52	51 12
Coal (dollars per million Btu)										
at the minemouth ¹⁸	1 76	1 98	2 08	2 18	2 10	2 23	2 31	2 40	2 56	2 62
Average end-use ¹⁹	2 38	2 42	2 56	2 68	2 51	2 70	2 81	2 73	2 94	3 07
Average electricity (cents per kilowatthour)	9 8	9 5	9 7	9 9	9 5	9 7	9 9	10 0	10 1	10 2

Table C1. Total energy supply, disposition, and price summary (continued)
(quadrillion Btu per year, unless otherwise noted)

Supply, disposition, and prices	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Prices (nominal dollars per unit)										
Petroleum (dollars per barrel)										
Low sulfur light crude oil ¹⁶⁵	79.39	62.81	125.97	195.67	77.32	170.09	245.37	98.91	229.55	314.93
Imported crude oil ¹⁶	75.87	59.64	122.81	192.52	63.56	155.52	228.64	84.19	210.51	294.00
Natural gas (dollars per million Btu)										
at Henry hub	4.39	4.54	4.62	4.57	7.30	7.23	7.10	11.67	11.67	11.26
at the wellhead ¹⁷	4.06	4.07	4.14	4.10	6.48	6.42	6.30	10.26	10.26	9.91
Natural gas (dollars per thousand cubic feet)										
at the wellhead ¹⁷	4.16	4.16	4.24	4.20	6.64	6.57	6.46	10.51	10.51	10.15
Coal (dollars per ton)										
at the minemouth ¹⁸	35.61	42.97	45.34	47.56	54.01	56.52	57.86	74.91	80.00	80.35
Coal (dollars per million Btu)										
at the minemouth ¹⁸	1.76	2.13	2.24	2.34	2.74	2.86	2.93	3.81	4.05	4.12
Average end-use ¹⁹	2.38	2.61	2.76	2.88	3.27	3.47	3.56	4.33	4.66	4.83
Average electricity (cents per kilowatthour)	9.8	10.2	10.4	10.6	12.4	12.5	12.6	15.9	16.0	16.0

¹Includes waste coal

²These values represent the energy obtained from uranium when it is used in light water reactors. The total energy content of uranium is much larger, but alternative processes are required to take advantage of it

³Includes grid-connected electricity from wood and wood waste; biomass, such as corn, used for liquid fuels production; and non-electric energy demand from wood. Refer to Table A17 for details

⁴Includes grid-connected electricity from landfill gas; biogenic municipal waste; wind; photovoltaic and solar thermal sources; and non-electric energy from renewable sources, such as active and passive solar systems. Excludes electricity imports using renewable sources and nonmarketed renewable energy. See Table A17 for selected nonmarketed residential and commercial renewable energy data

⁵Includes non-biogenic municipal waste, liquid hydrogen, methanol, and some domestic inputs to refineries

⁶Includes imports of finished petroleum products, unfinished oils, alcohols, ethers, blending components, and renewable fuels such as ethanol

⁷Includes imports of liquefied natural gas that is later re-exported

⁸Includes coal, coal coke (net), and electricity (net). Excludes imports of fuel used in nuclear power plants

⁹Includes crude oil, petroleum products, ethanol, and biodiesel

¹⁰Includes re-exported liquefied natural gas and natural gas used for liquefaction at export terminals

¹¹Balancing item. Includes unaccounted for supply, losses, gains, and net storage withdrawals

¹²Includes petroleum-derived fuels and non-petroleum derived fuels, such as ethanol and biodiesel, and coal-based synthetic liquids. Petroleum coke, which is a solid, is included. Also included are natural gas plant liquids and crude oil consumed as a fuel. Refer to Table A17 for detailed renewable liquid fuels consumption

¹³Excludes coal converted to coal-based synthetic liquids and natural gas

¹⁴Includes grid-connected electricity from wood and wood waste, non-electric energy from wood, and biofuels heat and coproducts used in the production of liquid fuels, but excludes the energy content of the liquid fuels

¹⁵Includes non-biogenic municipal waste, liquid hydrogen, and net electricity imports

¹⁶Weighted average price delivered to U.S. refiners

¹⁷Represents lower 48 onshore and offshore supplies

¹⁸Includes reported prices for both open market and captive mines

¹⁹Prices weighted by consumption; weighted average excludes residential and commercial prices, and export free-alongside-ship (f a s) prices

Btu = British thermal unit

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports

Sources: 2010 natural gas supply values and natural gas wellhead price: U.S. Energy Information Administration (EIA), *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2010 coal minemouth and delivered coal prices: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2010 petroleum supply values: EIA, *Petroleum Supply Annual 2010*, DOE/EIA-0340(2010)/1 (Washington, DC, July 2011). 2010 low sulfur light crude oil price: EIA, Form EIA-856, "Monthly Foreign Crude Oil Acquisition Report." Other 2010 coal values: *Quarterly Coal Report, October-December 2010*, DOE/EIA-0121(2010/4Q) (Washington, DC, May 2011). Other 2010 values: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). Projections: EIA, AEO2012 National Energy Modeling System runs LP2012.D022112A, REF2012.D020112C, and HP2012.D022112A

Table C2. Energy consumption by sector and source
(quadrillion Btu per year, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Energy consumption										
Residential										
Liquefied petroleum gases	0.56	0.54	0.51	0.49	0.55	0.50	0.48	0.55	0.51	0.48
Kerosene	0.03	0.03	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02
Distillate fuel oil	0.63	0.61	0.55	0.51	0.49	0.43	0.40	0.41	0.35	0.33
Liquid fuels and other petroleum subtotal	1.22	1.17	1.08	1.02	1.07	0.95	0.90	0.99	0.87	0.82
Natural gas	5.06	4.98	4.97	4.98	4.88	4.88	4.90	4.74	4.76	4.78
Coal	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Renewable energy ¹	0.42	0.37	0.43	0.48	0.36	0.43	0.48	0.35	0.43	0.47
Electricity	4.95	4.78	4.75	4.71	5.27	5.23	5.20	5.90	5.86	5.83
Delivered energy	11.66	11.31	11.24	11.19	11.58	11.51	11.48	11.98	11.93	11.91
Electricity related losses	10.39	9.68	9.58	9.47	10.66	10.52	10.34	11.58	11.35	11.02
Total	22.05	20.99	20.81	20.66	22.24	22.02	21.82	23.56	23.28	22.93
Commercial										
Liquefied petroleum gases	0.14	0.16	0.14	0.12	0.18	0.15	0.13	0.19	0.16	0.14
Motor gasoline ²	0.05	0.06	0.05	0.04	0.06	0.05	0.05	0.07	0.06	0.06
Kerosene	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01
Distillate fuel oil	0.43	0.41	0.35	0.32	0.41	0.33	0.30	0.41	0.32	0.30
Residual fuel oil	0.08	0.13	0.08	0.06	0.14	0.08	0.06	0.14	0.08	0.07
Liquid fuels and other petroleum subtotal	0.72	0.76	0.62	0.55	0.79	0.62	0.56	0.81	0.62	0.57
Natural gas	3.28	3.42	3.41	3.42	3.51	3.53	3.55	3.64	3.69	3.72
Coal	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Renewable energy ³	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Electricity	4.54	4.61	4.59	4.57	5.19	5.16	5.14	5.81	5.80	5.77
Delivered energy	8.70	8.96	8.80	8.70	9.66	9.48	9.41	10.43	10.28	10.23
Electricity related losses	9.52	9.34	9.27	9.18	10.50	10.38	10.21	11.41	11.23	10.90
Total	18.22	18.30	18.06	17.89	20.16	19.86	19.62	21.84	21.50	21.13
Industrial⁴										
Liquefied petroleum gases	2.00	1.86	1.83	1.80	2.22	2.17	2.13	2.23	2.15	2.11
Motor gasoline ²	0.25	0.28	0.28	0.28	0.31	0.30	0.30	0.32	0.30	0.29
Distillate fuel oil	1.16	1.28	1.25	1.24	1.25	1.19	1.17	1.29	1.18	1.16
Residual fuel oil	0.12	0.12	0.09	0.09	0.13	0.08	0.07	0.14	0.08	0.07
Petrochemical feedstocks	0.94	1.01	1.01	1.01	1.30	1.29	1.28	1.32	1.30	1.29
Other petroleum ⁵	3.59	3.82	3.44	3.23	3.82	3.11	2.89	4.10	3.19	2.83
Liquid fuels and other petroleum subtotal	8.05	8.39	7.89	7.65	9.03	8.13	7.83	9.40	8.21	7.76
Natural gas	6.76	7.17	7.19	7.21	7.19	7.32	7.38	7.18	7.18	7.29
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lease and plant fuel ⁶	1.37	1.42	1.43	1.44	1.53	1.57	1.63	1.54	1.63	1.71
Natural gas subtotal	8.14	8.59	8.62	8.65	8.72	8.89	9.09	8.71	8.81	9.07
Metallurgical coal	0.55	0.58	0.57	0.56	0.48	0.49	0.49	0.44	0.43	0.43
Other industrial coal	1.01	1.03	1.03	1.02	1.04	1.08	1.08	1.05	1.08	1.09
Coal-to-liquids heat and power	0.00	0.00	0.00	0.00	0.10	0.36	1.12	0.10	0.60	2.74
Net coal coke imports	-0.01	-0.00	-0.01	-0.01	-0.03	-0.03	-0.03	-0.06	-0.06	-0.06
Coal subtotal	1.56	1.60	1.59	1.58	1.60	1.90	2.67	1.54	2.06	4.21
Biofuels heat and coproducts	0.84	0.85	0.81	0.86	1.19	1.27	1.73	1.99	2.57	3.63
Renewable energy ⁷	1.50	1.63	1.61	1.63	1.90	1.82	1.75	2.10	1.95	1.87
Electricity	3.28	3.52	3.44	3.40	3.57	3.52	3.51	3.40	3.33	3.32
Delivered energy	23.37	24.57	23.96	23.76	26.02	25.53	26.58	27.14	26.94	29.85
Electricity related losses	6.89	7.11	6.94	6.84	7.21	7.09	6.98	6.68	6.46	6.27
Total	30.26	31.69	30.90	30.60	33.24	32.61	33.56	33.82	33.39	36.12

Table C2. Energy consumption by sector and source (continued)
(quadrillion Btu per year, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Transportation										
Liquefied petroleum gases	0.04	0.04	0.04	0.05	0.04	0.04	0.05	0.05	0.05	0.05
E85 ⁸	0.00	0.01	0.01	0.37	0.02	0.30	1.49	0.20	1.22	2.63
Motor gasoline ²	16.91	17.23	16.13	14.85	17.02	14.90	12.48	17.96	14.53	11.70
Jet fuel ⁹	3.07	3.04	3.03	3.01	3.20	3.19	3.18	3.34	3.33	3.32
Distillate fuel oil ¹⁰	5.77	6.71	6.55	6.45	7.08	7.03	7.14	7.58	7.44	7.57
Residual fuel oil	0.90	0.91	0.91	0.91	0.92	0.93	0.93	0.94	0.94	0.94
Other petroleum ¹¹	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Liquid fuels and other petroleum subtotal	26.88	28.11	26.83	25.81	28.45	26.57	25.44	30.24	27.67	26.40
Pipeline fuel natural gas	0.65	0.68	0.68	0.69	0.66	0.67	0.69	0.67	0.69	0.69
Compressed / liquefied natural gas	0.04	0.05	0.06	0.08	0.06	0.11	0.21	0.07	0.16	0.30
Liquid hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity	0.02	0.03	0.03	0.03	0.03	0.04	0.06	0.05	0.07	0.11
Delivered energy	27.59	28.86	27.60	26.61	29.20	27.40	26.40	31.03	28.60	27.49
Electricity related losses	0.05	0.05	0.05	0.06	0.07	0.08	0.12	0.10	0.14	0.20
Total	27.63	28.92	27.65	26.67	29.27	27.49	26.52	31.12	28.75	27.69
Delivered energy consumption for all sectors										
Liquefied petroleum gases	2.75	2.60	2.51	2.46	2.98	2.86	2.79	3.02	2.86	2.79
E85 ⁸	0.00	0.01	0.01	0.37	0.02	0.30	1.49	0.20	1.22	2.63
Motor gasoline ²	17.21	17.57	16.46	15.17	17.39	15.25	12.82	18.35	14.88	12.05
Jet fuel ⁹	3.07	3.04	3.03	3.01	3.20	3.19	3.18	3.34	3.33	3.32
Kerosene	0.04	0.04	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03
Distillate fuel oil	7.99	9.01	8.69	8.52	9.24	8.99	9.02	9.69	9.29	9.36
Residual fuel oil	1.11	1.16	1.08	1.06	1.19	1.09	1.06	1.21	1.11	1.08
Petrochemical feedstocks	0.94	1.01	1.01	1.01	1.30	1.29	1.28	1.32	1.30	1.29
Other petroleum ¹²	3.76	3.98	3.61	3.39	3.98	3.27	3.05	4.27	3.36	3.00
Liquid fuels and other petroleum subtotal	36.87	38.42	36.43	35.02	39.35	36.28	34.73	41.44	37.38	35.55
Natural gas	15.15	15.62	15.64	15.68	15.63	15.85	16.04	15.62	15.79	16.08
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.07
Lease and plant fuel ⁶	1.37	1.42	1.43	1.44	1.53	1.57	1.63	1.54	1.63	1.71
Pipeline natural gas	0.65	0.68	0.68	0.69	0.66	0.67	0.69	0.67	0.69	0.69
Natural gas subtotal	17.17	17.72	17.75	17.81	17.82	18.09	18.43	17.83	18.11	18.55
Metallurgical coal	0.55	0.58	0.57	0.56	0.48	0.49	0.49	0.44	0.43	0.43
Other coal	1.08	1.09	1.09	1.08	1.11	1.14	1.15	1.11	1.15	1.16
Coal-to-liquids heat and power	0.00	0.00	0.00	0.00	0.10	0.36	1.12	0.10	0.60	2.74
Net coal coke imports	-0.01	-0.00	-0.01	-0.01	-0.03	-0.03	-0.03	-0.06	-0.06	-0.06
Coal subtotal	1.62	1.67	1.65	1.64	1.67	1.96	2.74	1.60	2.12	4.28
Biofuels heat and coproducts	0.84	0.85	0.81	0.86	1.19	1.27	1.73	1.99	2.57	3.63
Renewable energy ¹³	2.03	2.10	2.15	2.22	2.37	2.36	2.34	2.56	2.50	2.45
Liquid hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity	12.79	12.94	12.81	12.71	14.07	13.96	13.91	15.16	15.06	15.02
Delivered energy	71.32	73.71	71.59	70.26	76.47	73.92	73.87	80.58	77.75	79.48
Electricity related losses	26.84	26.19	25.84	25.55	28.44	28.07	27.65	29.76	29.18	28.39
Total	98.16	99.89	97.43	95.82	104.90	101.99	101.52	110.34	106.93	107.87
Electric power¹⁴										
Distillate fuel oil	0.08	0.09	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09
Residual fuel oil	0.30	0.22	0.21	0.21	0.27	0.22	0.22	0.33	0.23	0.23
Liquid fuels and other petroleum subtotal	0.38	0.30	0.29	0.29	0.36	0.31	0.31	0.42	0.32	0.32
Natural gas	7.54	8.22	8.25	8.37	7.97	8.04	8.14	9.03	9.16	9.12
Steam coal	19.13	16.68	16.15	15.66	18.50	18.06	17.65	19.45	19.03	18.41
Nuclear / uranium ¹⁵	8.44	8.68	8.68	8.68	9.60	9.60	9.60	9.42	9.28	9.26
Renewable energy ¹⁶	3.85	4.94	4.96	4.96	5.80	5.75	5.59	6.34	6.22	6.07
Electricity imports	0.09	0.10	0.10	0.10	0.08	0.08	0.08	0.04	0.04	0.04
Total¹⁷	39.63	39.13	38.64	38.26	42.50	42.03	41.56	44.91	44.24	43.41

Table C2. Energy consumption by sector and source (continued)
(quadrillion Btu per year, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Total energy consumption										
Liquefied petroleum gases	2.75	2.60	2.51	2.46	2.98	2.86	2.79	3.02	2.86	2.79
E85 ¹	0.00	0.01	0.01	0.37	0.02	0.30	1.49	0.20	1.22	2.63
Motor gasoline ²	17.21	17.57	16.46	15.17	17.39	15.25	12.82	18.35	14.88	12.05
Jet fuel ³	3.07	3.04	3.03	3.01	3.20	3.19	3.18	3.34	3.33	3.32
Kerosene	0.04	0.04	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03
Distillate fuel oil	8.07	9.10	8.78	8.60	9.33	9.07	9.10	9.78	9.38	9.45
Residual fuel oil	1.41	1.38	1.29	1.27	1.46	1.31	1.28	1.55	1.34	1.31
Petrochemical feedstocks	0.94	1.01	1.01	1.01	1.30	1.29	1.28	1.32	1.30	1.29
Other petroleum ¹²	3.76	3.98	3.61	3.39	3.98	3.27	3.05	4.27	3.36	3.00
Liquid fuels and other petroleum subtotal	37.25	38.73	36.72	35.31	39.70	36.58	35.03	41.86	37.70	35.86
Natural gas	22.69	23.84	23.89	24.05	23.60	23.89	24.17	24.65	24.94	25.20
Natural-gas-to-liquids heat and power	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.07
Lease and plant fuel ⁶	1.37	1.42	1.43	1.44	1.53	1.57	1.63	1.54	1.63	1.71
Pipeline natural gas	0.65	0.68	0.68	0.69	0.66	0.67	0.69	0.67	0.69	0.69
Natural gas subtotal	24.71	25.93	26.00	26.18	25.80	26.14	26.57	26.86	27.26	27.67
Metallurgical coal	0.55	0.58	0.57	0.56	0.48	0.49	0.49	0.44	0.43	0.43
Other coal	20.21	17.77	17.24	16.74	19.61	19.20	18.80	20.56	20.18	19.57
Coal-to-liquids heat and power	0.00	0.00	0.00	0.00	0.10	0.36	1.12	0.10	0.60	2.74
Net coal coke imports	-0.01	-0.00	-0.01	-0.01	-0.03	-0.03	-0.03	-0.06	-0.06	-0.06
Coal subtotal	20.76	18.35	17.80	17.30	20.17	20.02	20.39	21.05	21.15	22.69
Nuclear / uranium ¹⁵	8.44	8.68	8.68	8.68	9.60	9.60	9.60	9.42	9.28	9.26
Biofuels heat and coproducts	0.84	0.85	0.81	0.86	1.19	1.27	1.73	1.99	2.57	3.63
Renewable energy ¹⁸	5.88	7.05	7.11	7.18	8.16	8.11	7.93	8.91	8.71	8.52
Liquid hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity imports	0.09	0.10	0.10	0.10	0.08	0.08	0.08	0.04	0.04	0.04
Total	98.16	99.89	97.43	95.82	104.90	101.99	101.52	110.34	106.93	107.87
Energy use and related statistics										
Delivered energy use	71.32	73.71	71.59	70.26	76.47	73.92	73.87	80.58	77.75	79.48
Total energy use	98.16	99.89	97.43	95.82	104.90	101.99	101.52	110.34	106.93	107.87
Ethanol consumed in motor gasoline and E85	1.11	1.30	1.22	1.36	1.56	1.55	2.14	1.77	2.15	2.80
Population (millions)	310.83	326.16	326.16	326.16	358.06	358.06	358.06	390.09	390.09	390.09
Gross domestic product (billion 2005 dollars)	13088	14990	14803	14666	19146	19185	19380	24596	24539	24703
Carbon dioxide emissions (million metric tons)	5633.6	5592.8	5407.2	5251.2	5770.9	5552.5	5450.8	6049.1	5757.9	5737.1

¹Includes wood used for residential heating. See Table A4 and/or Table A17 for estimates of nonmarketed renewable energy consumption for geothermal heat pumps, solar thermal water heating, and electricity generation from wind and solar photovoltaic sources

²Includes ethanol (blends of 15 percent or less) and ethers blended into gasoline

³Excludes ethanol. Includes commercial sector consumption of wood and wood waste, landfill gas, municipal waste, and other biomass for combined heat and power. See Table A5 and/or Table A17 for estimates of nonmarketed renewable energy consumption for solar thermal water heating and electricity generation from wind and solar photovoltaic sources

⁴Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public

⁵Includes petroleum coke, asphalt, road oil, lubricants, still gas, and miscellaneous petroleum products

⁶Represents natural gas used in well, field, and lease operations, and in natural gas processing plant machinery

⁷Includes consumption of energy produced from hydroelectric, wood and wood waste, municipal waste, and other biomass sources. Excludes ethanol blends (15 percent or less) in motor gasoline

⁸E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast

⁹Includes only kerosene type

¹⁰Diesel fuel for on- and off- road use

¹¹Includes aviation gasoline and lubricants

¹²Includes unfinished oils, natural gasoline, motor gasoline blending components, aviation gasoline, lubricants, still gas, asphalt, road oil, petroleum coke, and miscellaneous petroleum products

¹³Includes electricity generated for sale to the grid and for own use from renewable sources, and non-electric energy from renewable sources. Excludes ethanol and nonmarketed renewable energy consumption for geothermal heat pumps, buildings photovoltaic systems, and solar thermal water heaters

¹⁴Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes small power producers and exempt wholesale generators

¹⁵These values represent the energy obtained from uranium when it is used in light water reactors. The total energy content of uranium is much larger, but alternative processes are required to take advantage of it

¹⁶Includes conventional hydroelectric, geothermal, wood and wood waste, biogenic municipal waste, other biomass, wind, photovoltaic, and solar thermal sources. Excludes net electricity imports

¹⁷Includes non-biogenic municipal waste not included above

¹⁸Includes conventional hydroelectric, geothermal, wood and wood waste, biogenic municipal waste, other biomass, wind, photovoltaic, and solar thermal sources. Excludes ethanol, net electricity imports, and nonmarketed renewable energy consumption for geothermal heat pumps, buildings photovoltaic systems, and solar thermal water heaters

Btu = British thermal unit

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports

Sources: 2010 consumption based on: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011) 2010 population and gross domestic product: IHS Global Insight Industry and Employment models, August 2011. 2010 carbon dioxide emissions: EIA, *Monthly Energy Review*, October 2011 DOE/EIA-0035(2011/10) (Washington, DC, October 2011). Projections: EIA, AEO2012 National Energy Modeling System runs LP2012 D022112A, REF2012 D020112C, and HP2012 D022112A

Table C3. Energy prices by sector and source
(2010 dollars per million Btu, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Residential										
Liquefied petroleum gases	27.02	22.54	30.70	39.69	22.18	32.27	40.42	23.49	34.64	42.03
Distillate fuel oil	21.21	16.55	27.26	38.29	17.27	30.15	39.23	18.46	32.73	40.00
Natural gas	11.08	10.22	10.31	10.30	11.96	12.03	12.02	13.97	13.98	13.86
Electricity	33.69	34.06	34.59	35.24	33.37	34.08	34.73	34.31	34.58	35.00
Commercial										
Liquefied petroleum gases	23.52	19.33	27.42	36.38	19.00	28.97	37.09	20.30	31.30	38.66
Distillate fuel oil	20.77	13.91	23.98	34.68	14.39	26.86	35.89	15.51	29.18	36.36
Residual fuel oil	11.07	5.99	16.18	27.80	6.25	18.24	28.32	6.90	18.90	28.11
Natural gas	9.10	8.52	8.60	8.59	9.98	10.02	10.01	11.66	11.64	11.49
Electricity	29.73	28.52	29.03	29.65	28.32	29.00	29.71	29.30	29.48	29.84
Industrial¹										
Liquefied petroleum gases	21.80	16.98	27.43	38.87	16.33	29.24	39.62	17.95	32.18	41.60
Distillate fuel oil	21.32	14.50	24.20	34.82	14.95	27.22	36.32	16.19	29.53	36.60
Residual fuel oil	10.92	9.51	19.21	30.20	9.60	21.23	30.43	9.97	21.65	30.61
Natural gas ²	5.51	4.78	4.88	4.88	5.99	6.04	6.01	7.52	7.54	7.38
Metallurgical coal	5.84	7.04	7.22	7.35	7.86	8.11	8.24	8.85	9.11	9.23
Other industrial coal	2.71	3.11	3.27	3.38	3.18	3.38	3.52	3.38	3.64	3.86
Coal to liquids	--	1.17	1.26	1.32	2.02	2.08	2.26	2.26	2.38	2.64
Electricity	19.63	18.58	18.91	19.26	19.11	19.60	19.96	20.61	20.78	20.97
Transportation										
Liquefied petroleum gases ³	26.88	23.86	31.93	40.71	23.47	33.38	41.43	24.77	35.74	43.04
E85 ⁴	25.21	18.16	29.03	38.11	17.18	28.81	41.93	16.59	31.96	39.01
Motor gasoline ⁵	22.70	18.53	29.26	41.14	18.20	32.10	43.26	18.49	33.61	42.09
Jet fuel ⁶	16.22	12.62	23.74	35.26	12.80	26.45	35.89	13.96	29.13	36.89
Diesel fuel (distillate fuel oil) ⁷	21.87	17.99	27.56	38.22	18.14	30.42	39.66	19.15	32.40	39.63
Residual fuel oil	10.42	8.64	18.32	29.02	8.67	20.62	29.37	8.76	20.95	29.86
Natural gas ⁸	13.20	12.28	12.40	12.45	13.05	13.29	13.41	14.26	14.51	14.47
Electricity	32.99	30.37	30.50	30.24	30.91	31.53	33.04	33.26	33.82	34.36
Electric power⁹										
Distillate fuel oil	18.73	12.06	22.77	33.56	12.54	25.35	34.16	13.56	27.80	35.05
Residual fuel oil	11.89	13.08	23.00	33.74	12.12	25.40	34.30	11.20	25.72	34.59
Natural gas	5.14	4.46	4.55	4.54	5.58	5.60	5.59	7.18	7.21	7.04
Steam coal	2.26	2.22	2.35	2.47	2.34	2.54	2.68	2.56	2.80	3.00
Average price to all users¹⁰										
Liquefied petroleum gases	17.28	14.64	22.99	32.23	13.90	24.19	32.57	15.28	26.63	34.20
E85 ⁴	25.21	18.16	29.03	38.11	17.18	28.81	41.93	16.59	31.96	39.01
Motor gasoline ⁵	22.59	18.53	29.26	41.14	18.19	32.10	43.26	18.49	33.61	42.09
Jet fuel	16.22	12.62	23.74	35.26	12.80	26.45	35.89	13.96	29.13	36.89
Distillate fuel oil	21.65	17.16	26.87	37.56	17.45	29.81	39.04	18.54	31.91	39.12
Residual fuel oil	10.82	9.17	19.01	29.82	9.16	21.31	30.21	9.22	21.68	30.63
Natural gas	7.16	6.36	6.45	6.43	7.70	7.74	7.74	9.26	9.30	9.18
Metallurgical coal	5.84	7.04	7.22	7.35	7.86	8.11	8.24	8.85	9.11	9.23
Other coal	2.29	2.28	2.41	2.53	2.39	2.59	2.73	2.61	2.85	3.06
Coal to liquids	--	1.17	1.26	1.32	2.02	2.08	2.26	2.26	2.38	2.64
Electricity	28.68	27.87	28.38	28.94	27.88	28.54	29.14	29.31	29.56	29.92
Non-renewable energy expenditures by sector (billion 2010 dollars)										
Residential	251.69	236.40	246.72	256.77	255.31	266.75	275.38	289.49	298.72	304.24
Commercial	179.08	171.63	177.92	184.03	193.67	201.89	208.38	225.40	231.98	235.90
Industrial	198.98	175.07	223.88	279.09	194.55	261.92	313.03	212.90	282.31	323.54
Transportation	573.78	489.96	746.84	998.67	491.22	803.52	976.23	537.61	856.65	958.30
Total non-renewable expenditures	1203.54	1073.06	1395.36	1718.56	1134.76	1534.08	1773.02	1265.39	1669.66	1821.97
Transportation renewable expenditures	0.08	0.18	0.25	14.01	0.39	8.74	62.29	3.32	38.86	102.69
Total expenditures	1203.62	1073.25	1395.61	1732.58	1135.15	1542.81	1835.31	1268.71	1708.52	1924.66

Table C3. Energy prices by sector and source (continued)
(nominal dollars per million Btu, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Residential										
Liquefied petroleum gases	27.02	24.26	33.08	42.65	28.87	41.41	51.27	37.25	54.86	66.07
Distillate fuel oil	21.21	17.81	29.38	41.14	22.48	38.68	49.75	29.27	51.82	62.87
Natural gas	11.08	11.00	11.11	11.06	15.57	15.43	15.25	22.15	22.14	21.78
Electricity	33.69	36.66	37.27	37.86	43.43	43.72	44.05	54.40	54.76	55.02
Commercial										
Liquefied petroleum gases	23.52	20.80	29.54	39.09	24.73	37.17	47.04	32.18	49.56	60.77
Distillate fuel oil	20.77	14.97	25.83	37.27	18.73	34.47	45.51	24.59	46.20	57.15
Residual fuel oil	11.07	6.44	17.43	29.87	8.13	23.41	35.92	10.94	29.93	44.18
Natural gas	9.10	9.17	9.27	9.23	12.99	12.86	12.69	18.48	18.43	18.06
Electricity	29.73	30.70	31.28	31.86	36.86	37.21	37.68	46.46	46.67	46.91
Industrial¹										
Liquefied petroleum gases	21.80	18.28	29.56	41.77	21.25	37.51	50.25	28.46	50.95	65.39
Distillate fuel oil	21.32	15.61	26.08	37.41	19.46	34.93	46.06	25.67	46.76	57.53
Residual fuel oil	10.92	10.23	20.70	32.45	12.49	27.24	38.59	15.80	34.28	48.11
Natural gas ²	5.51	5.14	5.26	5.24	7.80	7.75	7.63	11.92	11.93	11.60
Metallurgical coal	5.84	7.57	7.78	7.90	10.23	10.40	10.45	14.04	14.42	14.51
Other industrial coal	2.71	3.35	3.52	3.63	4.13	4.34	4.46	5.36	5.77	6.06
Coal to liquids	--	1.26	1.36	1.42	2.63	2.67	2.86	3.58	3.78	4.14
Electricity	19.63	19.99	20.38	20.69	24.87	25.15	25.31	32.68	32.90	32.96
Transportation										
Liquefied petroleum gases ³	26.88	25.68	34.41	43.74	30.54	42.83	52.54	39.27	56.59	67.66
E85 ⁴	25.21	19.55	31.28	40.95	22.36	36.97	53.17	26.31	50.61	61.31
Motor gasoline ⁵	22.70	19.94	31.53	44.21	23.68	41.19	54.86	29.32	53.22	66.16
Jet fuel ⁶	16.22	13.59	25.58	37.89	16.66	33.94	45.51	22.13	46.12	57.99
Diesel fuel (distillate fuel oil) ⁷	21.87	19.36	29.69	41.07	23.61	39.03	50.30	30.37	51.29	62.29
Residual fuel oil	10.42	9.30	19.74	31.18	11.28	26.45	37.25	13.89	33.18	46.93
Natural gas ⁸	13.20	13.22	13.36	13.38	16.98	17.05	17.00	22.61	22.97	22.75
Electricity	32.99	32.69	32.86	32.50	40.22	40.46	41.90	52.74	53.55	54.01
Electric power⁹										
Distillate fuel oil	18.73	12.98	24.53	36.06	16.32	32.52	43.32	21.50	44.02	55.10
Residual fuel oil	11.89	14.07	24.78	36.26	15.77	32.59	43.50	17.77	40.73	54.38
Natural gas	5.14	4.80	4.90	4.88	7.27	7.19	7.09	11.38	11.42	11.06
Steam coal	2.26	2.39	2.53	2.65	3.04	3.25	3.40	4.06	4.43	4.72

Table C3. Energy prices by sector and source (continued)
(nominal dollars per million Btu, unless otherwise noted)

Sector and source	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Average price to all users¹⁰										
Liquefied petroleum gases	17.28	15.75	24.78	34.64	18.08	31.04	41.30	24.23	42.17	53.76
E85 ⁴	25.21	19.55	31.28	40.95	22.36	36.97	53.17	26.31	50.61	61.31
Motor gasoline ⁵	22.59	19.94	31.53	44.21	23.68	41.19	54.86	29.31	53.22	66.16
Jet fuel	16.22	13.59	25.58	37.89	16.66	33.94	45.51	22.13	46.12	57.99
Distillate fuel oil	21.65	18.47	28.96	40.36	22.71	38.24	49.51	29.39	50.52	61.50
Residual fuel oil	10.82	9.87	20.48	32.04	11.92	27.34	38.32	14.63	34.33	48.14
Natural gas	7.16	6.84	6.95	6.91	10.02	9.93	9.82	14.69	14.73	14.42
Metallurgical coal	5.84	7.57	7.78	7.90	10.23	10.40	10.45	14.04	14.42	14.51
Other coal	2.29	2.45	2.60	2.72	3.11	3.32	3.47	4.14	4.51	4.81
Coal to liquids	--	1.26	1.36	1.42	2.63	2.67	2.86	3.58	3.78	4.14
Electricity	28.68	30.00	30.58	31.10	36.28	36.62	36.96	46.48	46.80	47.03
Non-renewable energy expenditures by sector (billion nominal dollars)										
Residential	251.69	254.44	265.85	275.92	332.26	342.26	349.24	459.02	472.99	478.21
Commercial	179.08	184.73	191.71	197.75	252.04	259.04	264.27	357.40	367.31	370.80
Industrial	198.98	188.43	241.24	299.90	253.19	336.06	396.99	337.58	447.01	508.54
Transportation	573.78	527.35	804.75	1073.14	639.27	1030.98	1238.06	852.44	1356.41	1506.27
Total non-renewable expenditures	1203.54	1154.96	1503.55	1846.71	1476.75	1968.35	2248.56	2006.43	2643.72	2863.82
Transportation renewable expenditures	0.08	0.20	0.27	15.06	0.51	11.21	78.99	5.26	61.53	161.41
Total expenditures	1203.62	1155.16	1503.82	1861.77	1477.26	1979.56	2327.55	2011.69	2705.26	3025.22

¹Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public

²Excludes use for lease and plant fuel.

³Includes Federal and State taxes while excluding county and local taxes

⁴E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast

⁵Sales weighted-average price for all grades. Includes Federal, State and local taxes

⁶Kerosene-type jet fuel. Includes Federal and State taxes while excluding county and local taxes

⁷Diesel fuel for on-road use. Includes Federal and State taxes while excluding county and local taxes

⁸Natural gas used as a vehicle fuel. Includes estimated motor vehicle fuel taxes and estimated dispensing costs or charges

⁹Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public

¹⁰Weighted averages of end-use fuel prices are derived from the prices shown in each sector and the corresponding sectoral consumption.

Btu = British thermal unit.

-- = Not applicable.

Note: Data for 2010 are model results and may differ slightly from official EIA data reports

Sources: 2010 prices for motor gasoline, distillate fuel oil, and jet fuel are based on prices in the U.S. Energy Information Administration (EIA), *Petroleum Marketing Annual 2009*, DOE/EIA-0487(2009) (Washington, DC, August 2010). 2010 residential and commercial natural gas delivered prices: EIA, *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2010 industrial natural gas delivered prices are estimated based on: EIA, *Manufacturing Energy Consumption Survey* and industrial and wellhead prices from the *Natural Gas Annual 2009*, DOE/EIA-0131(2009) (Washington, DC, December 2010) and the *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). 2010 transportation sector natural gas delivered prices are model results. 2010 electric power sector distillate and residual fuel oil prices: EIA, *Monthly Energy Review*, DOE/EIA-0035(2011/09) (Washington, DC, September 2010). 2010 electric power sector natural gas prices: EIA, *Electric Power Monthly*, DOE/EIA-0226, April 2010 and April 2011, Table 4.2, and EIA, *State Energy Data Report 2009*, DOE/EIA-0214(2009) (Washington, DC, June 2011). 2010 coal prices based on: EIA, *Quarterly Coal Report, October-December 2010*, DOE/EIA-0121(2010/4Q) (Washington, DC, May 2011) and EIA, AEO2012 National Energy Modeling System run REF2012 D020112C. 2010 electricity prices: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2010 E85 prices derived from monthly prices in the Clean Cities Alternative Fuel Price Report. Projections: EIA, AEO2012 National Energy Modeling System runs LP2012 D022112A, REF2012 D020112C, and HP2012 D022112A.

Table C4. Liquid fuels supply and disposition
(million barrels per day, unless otherwise noted)

Supply and disposition	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Crude oil										
Domestic crude production ¹	5.47	5.88	6.15	6.41	5.38	6.40	7.25	4.79	5.99	6.68
Alaska	0.60	0.46	0.46	0.46	0.34	0.40	0.68	0.00	0.27	0.36
Lower 48 states	4.87	5.42	5.69	5.95	5.04	6.00	6.57	4.79	5.72	6.32
Net imports	9.17	9.63	8.52	7.64	9.58	7.24	5.32	10.74	7.52	4.91
Gross imports	9.21	9.66	8.56	7.67	9.61	7.27	5.36	10.77	7.55	4.95
Exports	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.04
Other crude supply ²	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total crude supply	14.72	15.52	14.67	14.05	14.96	13.64	12.56	15.53	13.51	11.59
Other petroleum supply	3.50	3.33	3.25	2.98	4.21	3.80	3.29	4.13	3.52	2.81
Natural gas plant liquids	2.07	2.40	2.56	2.56	2.94	3.01	3.07	2.91	3.01	3.06
Net product imports	0.39	-0.01	-0.25	-0.50	0.33	-0.12	-0.62	0.31	-0.34	-0.94
Gross refined product imports ³	1.23	0.97	0.78	0.61	1.06	0.79	0.51	1.14	0.82	0.55
Unfinished oil imports	0.61	0.74	0.64	0.56	0.67	0.51	0.38	0.74	0.50	0.26
Blending component imports	0.74	0.69	0.66	0.63	0.71	0.65	0.61	0.73	0.66	0.61
Exports	2.19	2.41	2.32	2.30	2.12	2.07	2.13	2.31	2.31	2.36
Refinery processing gain ⁴	1.07	0.94	0.95	0.92	0.95	0.91	0.84	0.91	0.85	0.69
Product stock withdrawal	-0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other non-petroleum supply	1.00	1.24	1.22	1.46	1.61	1.86	2.84	2.18	2.96	4.87
Supply from renewable sources	0.87	1.11	1.05	1.20	1.42	1.48	2.01	1.92	2.37	3.24
Ethanol	0.85	1.00	0.94	1.05	1.20	1.19	1.64	1.36	1.65	2.15
Domestic production	0.88	0.99	0.94	0.99	1.18	1.17	1.47	1.35	1.59	1.96
Net imports	-0.02	0.01	0.00	0.06	0.02	0.02	0.17	0.01	0.06	0.19
Biodiesel	0.01	0.08	0.09	0.12	0.12	0.12	0.13	0.13	0.13	0.14
Domestic production	0.02	0.08	0.09	0.11	0.12	0.12	0.13	0.13	0.13	0.14
Net imports	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	-0.00
Other biomass-derived liquids ⁵	0.00	0.02	0.03	0.03	0.10	0.16	0.24	0.44	0.59	0.95
Liquids from gas	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.06
Liquids from coal	0.00	0.00	0.00	0.00	0.05	0.17	0.52	0.05	0.28	1.27
Other ⁶	0.13	0.14	0.17	0.26	0.15	0.21	0.24	0.20	0.31	0.30
Total primary supply⁷	19.22	20.09	19.14	18.49	20.79	19.29	18.69	21.84	19.99	19.27
Liquid fuels consumption										
by fuel										
Liquefied petroleum gases	2.27	2.00	1.94	1.90	2.30	2.21	2.15	2.32	2.21	2.15
E85 ⁸	0.00	0.01	0.01	0.25	0.02	0.21	1.02	0.14	0.83	1.80
Motor gasoline ⁹	8.99	9.48	8.88	8.19	9.45	8.29	6.97	9.97	8.09	6.55
Jet fuel ¹⁰	1.43	1.47	1.46	1.45	1.55	1.54	1.54	1.61	1.61	1.60
Distillate fuel oil ¹¹	3.80	4.34	4.19	4.10	4.45	4.33	4.34	4.67	4.48	4.51
Diesel	3.32	3.82	3.71	3.66	3.99	3.92	3.96	4.24	4.11	4.16
Residual fuel oil	0.54	0.60	0.56	0.55	0.63	0.57	0.56	0.67	0.58	0.57
Other ¹²	2.14	2.23	2.06	1.97	2.38	2.06	1.95	2.51	2.10	1.94
by sector										
Residential and commercial	1.12	1.12	1.00	0.92	1.09	0.94	0.87	1.07	0.91	0.84
Industrial ¹³	4.31	4.41	4.17	4.05	4.83	4.41	4.26	5.00	4.44	4.22
Transportation	13.82	14.47	13.80	13.31	14.69	13.71	13.26	15.64	14.41	13.90
Electric power ¹⁴	0.17	0.14	0.13	0.13	0.16	0.14	0.14	0.19	0.14	0.14
Total	19.17	20.14	19.10	18.41	20.77	19.20	18.53	21.90	19.90	19.12
Discrepancy¹⁵	0.05	-0.05	0.05	0.08	0.01	0.10	0.16	-0.06	0.09	0.15

Area: Liquid Fuels Supply

Table C4. Liquid fuels supply and disposition (continued)
(million barrels per day, unless otherwise noted)

Supply and disposition	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Domestic refinery distillation capacity ¹⁶	17.6	17.6	17.5	17.1	16.8	15.5	14.6	17.1	15.2	13.8
Capacity utilization rate (percent) ¹⁷	86.0	90.3	85.9	84.0	91.0	90.1	88.0	93.0	90.8	85.7
Net import share of product supplied (percent)	49.6	47.9	43.2	38.9	47.8	37.0	26.0	50.7	36.2	21.6
Net expenditures for imported crude oil and petroleum products (billion 2010 dollars)	243.07	207.99	373.00	523.15	189.41	344.58	384.81	226.36	389.97	363.97

¹Includes lease condensate.

²Strategic petroleum reserve stock additions plus unaccounted for crude oil and crude stock withdrawals minus crude product supplied.

³Includes other hydrocarbons and alcohols.

⁴The volumetric amount by which total output is greater than input due to the processing of crude oil into products which, in total, have a lower specific gravity than the crude oil processed.

⁵Includes pyrolysis oils, biomass-derived Fischer-Tropsch liquids, and renewable feedstocks used for the on-site production of diesel and gasoline.

⁶Includes domestic sources of other blending components, other hydrocarbons, and ethers.

⁷Total crude supply plus other petroleum supply plus other non-petroleum supply.

⁸E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.

⁹Includes ethanol and ethers blended into gasoline.

¹⁰Includes only kerosene type.

¹¹Includes distillate fuel oil and kerosene from petroleum and biomass feedstocks.

¹²Includes aviation gasoline, petrochemical feedstocks, lubricants, waxes, asphalt, road oil, still gas, special naphthas, petroleum coke, crude oil product supplied, methanol, and miscellaneous petroleum products.

¹³Includes consumption for combined heat and power, which produces electricity and other useful thermal energy.

¹⁴Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes small power producers and exempt wholesale generators.

¹⁵Balancing item. Includes unaccounted for supply, losses, and gains.

¹⁶End-of-year operable capacity.

¹⁷Rate is calculated by dividing the gross annual input to atmospheric crude oil distillation units by their operable refining capacity in barrels per calendar day.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2010 product supplied based on: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). Other 2010 data: EIA, *Petroleum Supply Annual 2010*, DOE/EIA-0340(2010)/1 (Washington, DC, July 2011). Projections: EIA, AEO2012 National Energy Modeling System runs LP2012.D022112A, REF2012.D020112C, and HP2012.D022112A.

Table C5. Petroleum product prices
(2010 dollars per gallon, unless otherwise noted)

Sector and fuel	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Crude oil prices (2010 dollars per barrel)										
Low sulfur light	79.39	58.36	116.91	182.10	59.41	132.56	193.48	62.38	144.98	200.36
Imported crude oil ¹	75.87	55.41	113.97	179.16	48.84	121.21	180.29	53.10	132.95	187.04
Delivered sector product prices										
Residential										
Liquefied petroleum gases	2.288	1.909	2.600	3.361	1.878	2.733	3.423	1.989	2.934	3.560
Distillate fuel oil	2.941	2.295	3.781	5.310	2.395	4.181	5.441	2.560	4.539	5.547
Commercial										
Distillate fuel oil	2.866	1.917	3.303	4.778	1.982	3.699	4.942	2.136	4.019	5.008
Residual fuel oil	1.657	0.896	2.421	4.161	0.935	2.731	4.240	1.033	2.830	4.207
Residual fuel oil (2010 dollars per barrel) ..	69.58	37.63	101.70	174.76	39.28	114.70	178.07	43.37	118.85	176.71
Industrial²										
Liquefied petroleum gases	1.846	1.438	2.323	3.292	1.383	2.476	3.355	1.520	2.725	3.523
Distillate fuel oil	2.932	1.991	3.322	4.780	2.053	3.737	4.986	2.223	4.054	5.025
Residual fuel oil	1.634	1.423	2.876	4.521	1.436	3.178	4.554	1.492	3.241	4.582
Residual fuel oil (2010 dollars per barrel) ..	68.62	59.77	120.80	189.87	60.33	133.47	191.28	62.65	136.12	192.45
Transportation										
Liquefied petroleum gases	2.276	2.021	2.704	3.447	1.987	2.827	3.508	2.097	3.026	3.645
Ethanol (E85) ³	2.402	1.731	2.766	3.631	1.638	2.746	3.996	1.581	3.046	3.717
Ethanol wholesale price	1.712	2.356	2.228	2.622	2.215	2.333	2.741	1.985	2.159	2.571
Motor gasoline ⁴	2.756	2.240	3.538	4.974	2.185	3.855	5.196	2.219	4.034	5.053
Jet fuel ⁵	2.190	1.704	3.205	4.760	1.728	3.571	4.845	1.884	3.932	4.981
Diesel fuel (distillate fuel oil) ⁶	2.998	2.465	3.776	5.237	2.486	4.168	5.435	2.624	4.439	5.430
Residual fuel oil	1.560	1.294	2.742	4.344	1.298	3.086	4.397	1.311	3.136	4.469
Residual fuel oil (2010 dollars per barrel) ..	65.53	54.33	115.15	182.43	54.50	129.62	184.67	55.06	131.73	187.70
Electric power⁷										
Distillate fuel oil	2.598	1.673	3.157	4.655	1.739	3.515	4.737	1.880	3.856	4.861
Residual fuel oil	1.780	1.957	3.443	5.051	1.814	3.802	5.135	1.677	3.850	5.178
Residual fuel oil (2010 dollars per barrel) ..	74.77	82.21	144.60	212.13	76.19	159.70	215.65	70.44	161.71	217.49
Refined petroleum product prices⁸										
Liquefied petroleum gases	1.464	1.239	1.947	2.729	1.177	2.049	2.758	1.294	2.255	2.896
Motor gasoline ⁴	2.743	2.240	3.538	4.974	2.185	3.855	5.196	2.219	4.034	5.053
Jet fuel ⁵	2.190	1.704	3.205	4.760	1.728	3.571	4.845	1.884	3.932	4.981
Distillate fuel oil	2.975	2.355	3.687	5.153	2.394	4.089	5.355	2.543	4.376	5.366
Residual fuel oil	1.619	1.372	2.845	4.464	1.371	3.189	4.523	1.381	3.246	4.585
Residual fuel oil (2010 dollars per barrel) ..	68.00	57.63	119.50	187.48	57.57	133.95	189.96	57.99	136.32	192.56
Average	2.528	2.059	3.316	4.691	2.015	3.600	4.808	2.101	3.830	4.785

Price and consumption

Table C5. Petroleum product prices (continued)
(nominal dollars per gallon, unless otherwise noted)

Sector and fuel	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Crude oil prices (nominal dollars per barrel)										
Low sulfur light	79.39	62.81	125.97	195.67	77.32	170.09	245.37	98.91	229.55	314.93
Imported crude oil ¹	75.87	59.64	122.81	192.52	63.56	155.52	228.64	84.19	210.51	294.00
Delivered sector product prices										
Residential										
Liquefied petroleum gases	2.288	2.054	2.801	3.612	2.445	3.507	4.341	3.154	4.645	5.595
Distillate fuel oil	2.941	2.470	4.074	5.706	3.117	5.365	6.901	4.060	7.188	8.719
Commercial										
Distillate fuel oil	2.866	2.063	3.559	5.135	2.580	4.747	6.268	3.387	6.364	7.872
Residual fuel oil	1.657	0.964	2.609	4.471	1.217	3.504	5.377	1.637	4.481	6.613
Industrial²										
Liquefied petroleum gases	1.846	1.548	2.503	3.537	1.800	3.177	4.255	2.410	4.315	5.537
Distillate fuel oil	2.932	2.143	3.580	5.136	2.671	4.795	6.323	3.524	6.419	7.898
Residual fuel oil	1.634	1.532	3.099	4.858	1.869	4.077	5.776	2.365	5.132	7.202
Transportation										
Liquefied petroleum gases	2.276	2.175	2.914	3.704	2.586	3.627	4.449	3.326	4.792	5.729
Ethanol (E85) ³	2.402	1.863	2.981	3.902	2.131	3.523	5.067	2.507	4.823	5.843
Ethanol wholesale price	1.712	2.535	2.400	2.818	2.883	2.994	3.477	3.147	3.419	4.041
Motor gasoline ⁴	2.756	2.411	3.812	5.345	2.843	4.946	6.589	3.519	6.388	7.943
Jet fuel ⁵	2.190	1.834	3.454	5.115	2.249	4.582	6.144	2.988	6.226	7.829
Diesel fuel (distillate fuel oil) ⁶	2.998	2.653	4.069	5.628	3.235	5.348	6.893	4.161	7.029	8.535
Residual fuel oil	1.560	1.392	2.954	4.668	1.689	3.960	5.576	2.079	4.966	7.025
Electric power⁷										
Distillate fuel oil	2.598	1.801	3.402	5.002	2.263	4.510	6.008	2.982	6.105	7.641
Residual fuel oil	1.780	2.107	3.710	5.427	2.361	4.879	6.512	2.659	6.096	8.140
Refined petroleum product prices⁸										
Liquefied petroleum gases	1.464	1.334	2.098	2.933	1.531	2.629	3.498	2.052	3.571	4.552
Motor gasoline ⁴	2.743	2.411	3.812	5.345	2.843	4.946	6.589	3.519	6.387	7.942
Jet fuel ⁵	2.190	1.834	3.454	5.115	2.249	4.582	6.144	2.988	6.226	7.829
Distillate fuel oil	2.975	2.534	3.973	5.537	3.115	5.246	6.791	4.032	6.930	8.434
Residual fuel oil (nominal dollars per barrel)	68.00	62.03	128.77	201.46	74.93	171.87	240.90	91.95	215.84	302.67
Average	2.528	2.216	3.573	5.041	2.623	4.620	6.097	3.331	6.064	7.520

¹Weighted average price delivered to U.S. refiners.

²Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public.

³E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.

⁴Sales weighted-average price for all grades. Includes Federal, State and local taxes.

⁵Includes only kerosene type.

⁶Diesel fuel for on-road use. Includes Federal and State taxes while excluding county and local taxes.

⁷Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes small power producers and exempt wholesale generators.

⁸Weighted averages of end-use fuel prices are derived from the prices in each sector and the corresponding sectoral consumption.

Note: Data for 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2010 low sulfur light crude oil price: U.S. Energy Information Administration (EIA), Form EIA-856, "Monthly Foreign Crude Oil Acquisition Report." 2010 imported crude oil price: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2010 prices for motor gasoline, distillate fuel oil, and jet fuel are based on: EIA, *Petroleum Marketing Annual 2009*, DOE/EIA-0487(2009) (Washington, DC, August 2010). 2010 residential, commercial, industrial, and transportation sector petroleum product prices are derived from: EIA, Form EIA-782A, "Refiners/Gas Plant Operators' Monthly Petroleum Product Sales Report." 2010 electric power prices based on: *Monthly Energy Review*, DOE/EIA-0035(2011/09) (Washington, DC, September 2011). 2010 E85 prices derived from monthly prices in the Clean Cities Alternative Fuel Price Report. 2010 wholesale ethanol prices derived from Bloomberg U.S. average rack price. Projections: EIA, AEO2012 National Energy Modeling System runs LP2012.D022112A, REF2012.D020112C, and HP2012.D022112A.

Price units in appropriate

Table C6. International liquids supply and disposition summary
(million barrels per day, unless otherwise noted)

Supply and disposition	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Crude oil prices (2010 dollars per barrel)										
Low sulfur light	79.39	58.36	116.91	182.10	59.41	132.56	193.48	62.38	144.98	200.36
Imported crude oil ¹	75.87	55.41	113.97	179.16	48.84	121.21	180.29	53.10	132.95	187.04
Crude oil prices (nominal dollars per barrel)¹										
Low sulfur light	79.39	62.81	125.97	195.67	77.32	170.09	245.37	98.91	229.55	314.93
Imported crude oil ¹	75.87	59.64	122.81	192.52	63.56	155.52	228.64	84.19	210.51	294.00
Petroleum liquids production²										
OPEC ³										
Middle East	23.43	29.09	25.46	23.39	33.98	29.77	28.26	35.70	33.94	32.96
North Africa	3.89	4.01	3.62	3.48	3.66	3.37	3.41	3.12	3.27	3.28
West Africa	4.45	5.57	5.09	4.86	5.92	5.40	5.47	5.74	5.26	5.27
South America	2.29	2.37	2.13	2.05	2.06	1.92	1.94	1.63	1.72	1.72
Total OPEC petroleum production	34.05	41.03	36.30	33.78	45.62	40.46	39.09	46.18	44.19	43.24
Non-OPEC										
OECD										
United States (50 states)	8.79	9.36	9.82	10.15	9.42	10.53	11.40	8.81	10.15	10.72
Canada	1.91	1.79	1.79	1.82	1.77	1.82	1.85	1.75	1.78	1.87
Mexico	2.98	2.65	2.65	2.59	1.46	1.58	1.50	1.27	1.68	1.67
OECD Europe ⁴	4.36	3.72	3.70	3.63	3.03	3.15	3.01	2.79	2.83	2.82
Japan	0.13	0.15	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16
Australia and New Zealand	0.62	0.55	0.55	0.54	0.52	0.54	0.52	0.52	0.53	0.53
Total OECD petroleum production	18.80	18.22	18.65	18.88	16.34	17.78	18.42	15.29	17.14	17.76
Non-OECD										
Russia	10.14	9.74	10.04	9.79	9.73	11.06	10.38	8.96	12.16	12.02
Other Europe and Eurasia ⁵	3.22	3.68	3.67	3.58	4.02	4.37	4.11	3.27	4.54	4.49
China	4.27	4.32	4.29	4.21	4.55	4.79	4.52	4.66	4.70	4.67
Other Asia ⁶	3.77	3.80	3.79	3.73	3.23	3.38	3.22	2.97	3.00	2.99
Middle East	1.58	1.43	1.43	1.40	1.12	1.18	1.11	0.97	0.97	0.97
Africa	2.41	2.41	2.40	2.36	2.55	2.68	2.54	2.67	2.68	2.67
Brazil	2.19	2.73	2.72	2.66	3.47	3.87	3.64	3.32	4.45	4.40
Other Central and South America	2.01	2.30	2.29	2.26	2.36	2.47	2.35	2.64	2.65	2.63
Total non-OECD petroleum	29.59	30.40	30.63	29.99	31.02	33.80	31.86	29.47	35.15	34.83
Total petroleum liquids production	82.44	89.66	85.58	82.65	92.98	92.04	89.37	90.93	96.47	95.83
Other liquids production⁷										
United States (50 states)	0.90	1.10	1.05	1.14	1.45	1.62	2.42	1.96	2.59	4.38
Other North America	1.93	2.55	2.51	2.90	4.09	3.75	4.78	5.53	5.16	6.53
OECD Europe ³	0.22	0.28	0.23	0.27	0.37	0.26	0.30	0.45	0.28	0.32
Middle East	0.01	0.13	0.17	0.14	0.23	0.24	0.21	0.22	0.24	0.22
Africa	0.21	0.27	0.28	0.28	0.42	0.38	0.39	0.53	0.40	0.41
Central and South America	1.20	2.15	1.78	2.06	4.07	2.61	2.97	5.75	3.17	3.51
Other	0.13	0.21	0.16	0.24	0.81	0.61	1.15	1.75	1.18	1.69
Total other liquids production	4.61	6.70	6.18	7.01	11.43	9.47	12.22	16.19	13.02	17.07
Total production	87.05	96.36	91.76	89.67	104.42	101.51	101.59	107.13	109.50	112.90

Table C6. International liquids supply and disposition summary (continued)

Table C6. International liquids supply and disposition summary (continued)

(million barrels per day, unless otherwise noted)

Supply and disposition	2010	Projections								
		2015			2025			2035		
		Low oil price	Reference	High oil price	Low oil price	Reference	High oil price	Low oil price	Reference	High oil price
Liquids consumption^a										
OECD										
United States (50 states)	19.17	20.14	19.10	18.41	20.77	19.20	18.53	21.90	19.90	19.12
United States territories	0.28	0.32	0.31	0.30	0.32	0.34	0.34	0.31	0.36	0.38
Canada	2.21	2.27	2.15	2.09	2.46	2.25	2.22	2.56	2.35	2.40
Mexico	2.34	2.50	2.38	2.30	2.78	2.50	2.32	3.20	2.68	2.43
OECD Europe ³	14.58	14.86	14.14	13.69	15.97	14.65	13.85	16.10	14.74	13.93
Japan	4.45	4.80	4.51	4.35	5.14	4.62	4.33	4.92	4.42	4.14
South Korea	2.24	2.39	2.25	2.18	2.73	2.46	2.31	2.93	2.56	2.39
Australia and New Zealand	1.13	1.16	1.11	1.07	1.25	1.17	1.09	1.30	1.23	1.13
Total OECD consumption	46.40	48.43	45.95	44.38	51.42	47.19	44.97	53.23	48.24	45.90
Non-OECD										
Russia	2.93	3.14	3.02	2.96	2.88	2.91	2.93	2.71	2.97	3.12
Other Europe and Eurasia ⁵	2.08	2.37	2.30	2.26	2.35	2.45	2.44	2.32	2.63	2.69
China	9.19	12.64	12.10	12.06	15.65	16.03	17.21	16.35	18.50	20.87
India	3.18	3.88	3.70	3.64	5.22	5.40	5.78	4.93	5.80	6.54
Other Asia	6.73	7.56	7.28	7.19	8.44	8.85	9.15	8.48	9.89	10.78
Middle East	7.35	8.26	7.78	7.72	8.35	8.16	8.51	9.03	9.49	10.46
Africa	3.34	3.44	3.30	3.24	3.43	3.57	3.57	3.47	4.09	4.21
Brazil	2.65	3.00	2.84	2.78	3.01	3.15	3.22	3.13	3.80	4.13
Other Central and South America	3.19	3.63	3.49	3.42	3.67	3.81	3.82	3.49	4.09	4.21
Total non-OECD consumption	40.65	47.92	45.82	45.29	52.99	54.32	56.62	53.90	61.26	67.00
Total liquids consumption	87.05	96.36	91.76	89.67	104.42	101.51	101.59	107.13	109.50	112.90
OPEC production ⁹	34.58	42.18	37.30	34.88	47.89	41.91	40.63	49.42	45.89	45.01
Non-OPEC production ⁹	52.47	54.18	54.46	54.79	56.52	59.60	60.97	57.71	63.61	67.89
Net Eurasia exports	10.53	10.64	11.11	10.81	12.00	13.94	12.75	10.52	15.54	15.10
OPEC market share (percent)	39.7	43.8	40.7	38.9	45.9	41.3	40.0	46.1	41.9	39.9

¹Weighted average price delivered to U.S. refiners.

²Includes production of crude oil (including lease condensate and shale oil/tight oil), natural gas plant liquids, other hydrogen and hydrocarbons for refinery feedstocks, and refinery gains.

³OPEC = Organization of Petroleum Exporting Countries - Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.

⁴OECD Europe = Organization for Economic Cooperation and Development - Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom.

⁵Other Europe and Eurasia = Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Macedonia, Malta, Moldova, Montenegro, Romania, Serbia, Slovenia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

⁶Other Asia = Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia (Kampuchea), Fiji, French Polynesia, Guam, Hong Kong, Indonesia, Kiribati, Laos, Malaysia, Macau, Maldives, Mongolia, Myanmar (Burma), Nauru, Nepal, New Caledonia, Niue, North Korea, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Taiwan, Thailand, Tonga, Vanuatu, and Vietnam.

⁷Includes liquids produced from energy crops, natural gas, coal, extra-heavy oil, bitumen (oil sands), and kerogen (oil shale, not to be confused with shale oil/tight oil).

⁸Includes both OPEC and non-OPEC producers in the regional breakdown.

⁹Includes both OPEC and non-OPEC consumers in the regional breakdown.

¹⁰Includes both petroleum and other liquids production.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2010 low sulfur light crude oil price: U.S. Energy Information Administration (EIA), Form EIA-856, "Monthly Foreign Crude Oil Acquisition Report." 2010 imported crude oil price: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2010 quantities and projections: EIA, AEO2012 National Energy Modeling System runs LP2012.D022112A, REF2012.D020112C, and HP2012.D022112A and EIA, Generate World Oil Balance Model.

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Appendix D

Results from side cases

Table D1. Key results for residential and commercial sector technology cases

Energy consumption	2010	2015				2025			
		Integrated 2011 Demand Technology	Reference	Integrated High Demand Technology	Integrated Best Available Demand Technology	Integrated 2011 Demand Technology	Reference	Integrated High Demand Technology	Integrated Best Available Demand Technology
Residential									
Energy consumption (quadrillion Btu)									
Liquefied petroleum gases	0.56	0.52	0.51	0.51	0.50	0.52	0.50	0.48	0.48
Kerosene	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Distillate fuel oil	0.63	0.56	0.55	0.54	0.53	0.46	0.43	0.41	0.39
Liquid fuels and other petroleum subtotal	1.22	1.10	1.08	1.07	1.05	1.00	0.95	0.91	0.88
Natural gas	5.06	5.03	4.97	4.83	4.63	5.12	4.88	4.51	4.00
Coal	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Renewable energy ¹	0.42	0.43	0.43	0.42	0.41	0.47	0.43	0.41	0.37
Electricity	4.95	4.83	4.75	4.53	4.28	5.48	5.23	4.74	4.10
Delivered energy	11.66	11.40	11.24	10.85	10.38	12.08	11.51	10.57	9.36
Electricity related losses	10.39	9.75	9.58	9.09	8.52	10.98	10.52	9.53	8.17
Total	22.05	21.15	20.81	19.95	18.90	23.07	22.02	20.10	17.53
Delivered energy intensity (million Btu per household)	102.1	96.0	94.6	91.4	87.4	91.1	86.8	79.7	70.6
Nonmarketed renewables consumption (quadrillion Btu)	0.02	0.08	0.08	0.08	0.09	0.10	0.10	0.11	0.13
Commercial									
Energy consumption (quadrillion Btu)									
Liquefied petroleum gases	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.15
Motor gasoline ²	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Kerosene	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Distillate fuel oil	0.43	0.35	0.35	0.35	0.35	0.33	0.33	0.32	0.32
Residual fuel oil	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Liquid fuels and other petroleum subtotal	0.72	0.62	0.62	0.62	0.62	0.62	0.62	0.61	0.61
Natural gas	3.28	3.42	3.41	3.39	3.41	3.53	3.53	3.48	3.56
Coal	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Renewable energy ³	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
Electricity	4.54	4.64	4.59	4.42	4.26	5.39	5.16	4.62	4.17
Delivered energy	8.70	8.85	8.80	8.60	8.46	9.71	9.48	8.87	8.50
Electricity related losses	9.52	9.38	9.27	8.88	8.48	10.79	10.38	9.29	8.30
Total	18.22	18.24	18.06	17.48	16.94	20.50	19.86	18.16	16.80
Delivered energy intensity (thousand Btu per square foot)	107.3	105.3	104.6	102.2	100.6	103.4	101.0	94.5	90.5
Commercial sector generation									
Net summer generation capacity (megawatts)									
Natural gas	711	843	865	900	914	1455	1955	2605	3066
Solar photovoltaic	1197	1251	1253	1254	1262	1490	1578	1753	2235
Wind	83	90	91	94	106	106	132	138	225
Electricity generation (billion kilowatthours)									
Natural gas	5.17	6.13	6.29	6.54	6.64	10.58	14.22	18.95	22.30
Solar photovoltaic	1.87	1.96	1.96	1.96	1.97	2.34	2.51	2.80	3.58
Wind	0.10	0.12	0.12	0.12	0.14	0.14	0.18	0.19	0.31
Nonmarketed renewables consumption (quadrillion Btu)	0.03	0.04	0.04	0.05	0.05	0.04	0.04	0.07	0.08

¹Includes wood used for residential heating. See Table A4 and/or Table A17 for estimates of nonmarketed renewable energy consumption for geothermal heat pumps, solar thermal hot water heating, and solar photovoltaic electricity generation

²Includes ethanol (blends of 15 percent or less) and ethers blended into gasoline

³Includes commercial sector consumption of wood and wood waste, landfill gas, municipal solid waste, and other biomass for combined heat and power

Btu = British thermal unit

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports

Source: U.S. Energy Information Administration, AEO2012 National Energy Modeling System, runs FROZTECH D030812A, REF2012 D020112C, HIGHTECH D032812A, and BESTTECH D032812A

Report from the study

2035				Annual Growth 2010-2035 (percent)			
Integrated 2011 Demand Technology	Reference	Integrated High Demand Technology	Integrated Best Available Demand Technology	Integrated 2011 Demand Technology	Reference	Integrated High Demand Technology	Integrated Best Available Demand Technology
0.53	0.51	0.48	0.47	-0.2%	-0.4%	-0.6%	-0.7%
0.02	0.02	0.02	0.02	-1.2%	-1.7%	-2.1%	-2.4%
0.40	0.35	0.32	0.29	-1.8%	-2.3%	-2.7%	-3.1%
0.95	0.87	0.82	0.78	-1.0%	-1.3%	-1.6%	-1.8%
5.23	4.76	4.28	3.67	0.1%	-0.2%	-0.7%	-1.3%
0.01	0.01	0.00	0.00	-0.5%	-1.1%	-1.5%	-1.8%
0.50	0.43	0.39	0.34	0.6%	0.1%	-0.3%	-0.9%
6.23	5.86	5.26	4.45	0.9%	0.7%	0.2%	-0.4%
12.91	11.93	10.75	9.24	0.4%	0.1%	-0.3%	-0.9%
12.14	11.35	10.31	8.65	0.6%	0.4%	-0.0%	-0.7%
25.05	23.28	21.06	17.89	0.5%	0.2%	-0.2%	-0.8%
88.7	81.9	73.8	63.4	-0.6%	-0.9%	-1.3%	-1.9%
0.10	0.11	0.14	0.19	6.4%	6.9%	7.7%	9.2%
0.15	0.16	0.16	0.16	0.3%	0.3%	0.4%	0.4%
0.06	0.06	0.06	0.06	0.4%	0.4%	0.4%	0.4%
0.01	0.01	0.01	0.01	0.7%	0.7%	0.7%	0.7%
0.32	0.32	0.30	0.30	-1.2%	-1.2%	-1.4%	-1.5%
0.08	0.08	0.08	0.08	-0.1%	-0.0%	-0.0%	-0.0%
0.62	0.62	0.61	0.60	-0.6%	-0.5%	-0.7%	-0.7%
3.63	3.69	3.64	3.74	0.4%	0.5%	0.4%	0.5%
0.06	0.06	0.06	0.06	-0.0%	-0.0%	-0.0%	-0.0%
0.11	0.11	0.11	0.11	0.0%	0.0%	0.0%	0.0%
6.07	5.80	4.87	4.33	1.2%	1.0%	0.3%	-0.2%
10.49	10.28	9.28	8.84	0.8%	0.7%	0.3%	0.1%
11.82	11.23	9.54	8.41	0.9%	0.7%	0.0%	-0.5%
22.32	21.50	18.82	17.25	0.8%	0.7%	0.1%	-0.2%
101.9	99.8	90.1	85.8	-0.2%	-0.3%	-0.7%	-0.9%
2514	4795	6609	7235	5.2%	7.9%	9.3%	9.7%
1832	2311	3177	5546	1.7%	2.7%	4.0%	6.3%
178	270	269	375	3.1%	4.8%	4.8%	6.2%
18.29	34.88	48.08	52.63	5.2%	7.9%	9.3%	9.7%
2.88	3.74	5.17	9.02	1.7%	2.8%	4.2%	6.5%
0.24	0.38	0.38	0.53	3.5%	5.3%	5.3%	6.7%
0.04	0.05	0.11	0.12	1.0%	1.7%	4.8%	5.1%

Table D2. Key results for integrated technology cases

Consumption and emissions	2010	2015			2025			2035		
		Integrated 2011 Technology	Reference	Integrated High Technology	Integrated 2011 Technology	Reference	Integrated High Technology	Integrated 2011 Technology	Reference	Integrated High Technology
Energy consumption by sector (quadrillion Btu)										
Residential	11.66	11.39	11.24	10.87	12.08	11.51	10.60	12.90	11.93	10.80
Commercial	8.70	8.85	8.80	8.62	9.70	9.48	8.90	10.48	10.28	9.33
Industrial ¹	23.37	23.99	23.96	24.03	25.24	25.53	25.88	25.68	26.94	27.69
Transportation	27.59	27.61	27.60	27.48	27.45	27.40	26.80	28.57	28.60	27.64
Electric power ²	39.63	39.09	38.64	37.46	43.38	42.03	39.08	46.11	44.24	40.45
Total	98.16	98.00	97.43	96.02	103.43	101.99	98.25	108.09	106.93	102.23
Energy consumption by fuel (quadrillion Btu)										
Liquid fuels and other petroleum ³	37.25	36.77	36.72	36.54	36.67	36.58	35.84	37.67	37.70	36.52
Natural gas	24.71	26.02	26.00	25.69	26.77	26.14	25.13	28.64	27.26	25.23
Coal	20.76	18.14	17.80	16.64	20.73	20.02	17.87	21.89	21.15	18.45
Nuclear / uranium	8.44	8.68	8.68	8.68	9.60	9.60	9.34	9.14	9.28	9.55
Renewable energy ⁴	6.72	8.10	7.92	8.17	9.38	9.38	9.80	10.48	11.29	12.24
Other ⁵	0.29	0.30	0.30	0.30	0.28	0.28	0.27	0.26	0.24	0.24
Total	98.16	98.00	97.43	96.02	103.43	101.99	98.25	108.09	106.93	102.23
Energy intensity (thousand Btu per 2005 dollar of GDP)										
	7.50	6.62	6.58	6.49	5.39	5.32	5.12	4.41	4.36	4.17
Carbon dioxide emissions by sector (million metric tons)										
Residential	353	343	338	331	341	324	302	342	312	284
Commercial	229	231	231	230	237	237	233	242	246	242
Industrial ¹	909	964	963	962	993	992	983	1015	1011	995
Transportation	1872	1865	1864	1856	1829	1820	1772	1883	1859	1787
Electric power ⁶	2271	2040	2011	1884	2268	2179	1942	2446	2330	1992
Total	5634	5443	5407	5263	5668	5552	5232	5928	5758	5300
Carbon dioxide emissions by fuel (million metric tons)										
Petroleum	2349	2332	2329	2315	2275	2261	2201	2327	2300	2208
Natural gas	1283	1368	1367	1350	1407	1374	1320	1508	1435	1327
Coal	1990	1731	1699	1586	1974	1906	1700	2081	2012	1753
Other ⁷	12	12	12	12	12	12	12	12	12	12
Total	5634	5443	5407	5263	5668	5552	5232	5928	5758	5300
Carbon dioxide emissions (tons per person)										
	18.1	16.7	16.6	16.1	15.8	15.5	14.6	15.2	14.8	13.6

¹Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public

²Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public

³Includes petroleum-derived fuels and non-petroleum derived fuels, such as ethanol and biodiesel, and coal-based synthetic liquids. Petroleum coke, which is a solid, is included. Also included are natural gas plant liquids, crude oil consumed as a fuel, and liquid hydrogen

⁴Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; biogenic municipal solid waste; other biomass; wind; photovoltaic and solar thermal sources; and non-electric energy from renewable sources, such as active and passive solar systems, and wood; and both the ethanol and gasoline components of E85, but not the ethanol component of blends less than 85 percent. Excludes electricity imports using renewable sources and nonmarketed renewable energy

⁵Includes non-biogenic municipal waste, liquid hydrogen, and net electricity imports

⁶Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public

⁷Includes emissions from geothermal power and nonbiogenic emissions from municipal solid waste

Btu = British thermal unit

GDP = Gross domestic product

Note: Includes end-use, fossil electricity, and renewable technology assumptions. Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports

Source: U.S. Energy Information Administration, AEO2012 National Energy Modeling System runs LTRKITE D031312A, REF2012 D020112C, and HTRKITE D032812A

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Table D3. Key results for transportation sector light-duty vehicle efficiency cases

Consumption and indicators	2010	2015		2025		2035	
		Reference	CAFE Standards	Reference	CAFE Standards	Reference	CAFE Standards
Level of travel							
(billion vehicle miles traveled)							
Light-duty vehicles less than 8,501 pounds	2662	2710	2710	3111	3129	3583	3650
Commercial light trucks ¹	64	70	70	83	83	92	93
Freight trucks greater than 10,000 pounds	234	273	273	317	318	345	346
(billion seat miles available)							
Air	999	1028	1028	1120	1120	1208	1208
(billion ton miles traveled)							
Rail	1559	1503	1505	1782	1789	1871	1878
Domestic shipping	522	549	549	604	604	627	625
Energy efficiency indicators							
(miles per gallon)							
Tested new light-duty vehicle ²	28.3	31.5	31.5	36.8	48.1	37.9	49.0
New car ²	33.3	36.4	36.4	41.2	55.6	42.8	56.9
New light truck ²	24.3	26.7	26.7	31.0	39.6	31.5	39.8
Light-duty stock ³	20.4	21.5	21.5	25.6	27.5	28.2	34.5
New commercial light truck ¹	15.7	16.7	16.7	18.9	22.5	19.1	23.3
Stock commercial light truck ¹	14.4	15.2	15.2	18.0	19.0	19.0	22.5
Freight truck	6.7	6.8	6.8	7.7	7.7	8.1	8.1
(seat miles per gallon)							
Aircraft	62.3	62.8	62.8	65.2	65.2	69.3	69.3
(ton miles per thousand Btu)							
Rail	3.4	3.5	3.5	3.5	3.5	3.5	3.5
Domestic shipping	2.4	2.4	2.4	2.5	2.5	2.5	2.5
Energy use (quadrillion Btu)							
by mode							
Light-duty vehicles	16.06	15.39	15.39	14.73	13.78	15.46	12.84
Commercial light trucks ¹	0.55	0.58	0.58	0.58	0.55	0.61	0.52
Bus transportation	0.25	0.26	0.26	0.29	0.29	0.31	0.31
Freight trucks	4.82	5.51	5.51	5.66	5.67	5.84	5.87
Rail, passenger	0.05	0.05	0.05	0.06	0.06	0.06	0.06
Rail, freight	0.45	0.43	0.44	0.51	0.51	0.53	0.53
Shipping, domestic	0.22	0.23	0.23	0.25	0.25	0.25	0.25
Shipping, international	0.86	0.87	0.87	0.88	0.88	0.89	0.89
Recreational boats	0.25	0.26	0.26	0.27	0.27	0.29	0.29
Air	2.52	2.55	2.55	2.71	2.71	2.79	2.79
Military use	0.77	0.66	0.66	0.66	0.66	0.74	0.74
Lubricants	0.14	0.13	0.13	0.14	0.14	0.14	0.14
Pipeline fuel	0.65	0.68	0.68	0.67	0.67	0.69	0.68
Total	27.59	27.60	27.60	27.40	26.44	28.60	25.92
by fuel							
Liquefied petroleum gases	0.04	0.04	0.04	0.04	0.04	0.05	0.04
E85 ⁴	0.00	0.01	0.01	0.30	0.44	1.22	1.37
Motor gasoline ⁵	16.91	16.13	16.13	14.90	13.81	14.53	11.82
Jet fuel ⁶	3.07	3.03	3.03	3.19	3.19	3.33	3.33
Distillate fuel oil ⁷	5.77	6.55	6.55	7.03	7.02	7.44	7.31
Residual fuel oil	0.90	0.91	0.91	0.93	0.93	0.94	0.94
Other petroleum ⁸	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Liquid fuels and other petroleum	26.88	26.83	26.83	26.57	25.60	27.67	24.99
Pipeline fuel natural gas	0.65	0.68	0.68	0.67	0.67	0.69	0.68
Compressed/liquefied natural gas	0.04	0.06	0.06	0.11	0.11	0.16	0.15
Liquid hydrogen	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electricity	0.02	0.03	0.03	0.04	0.05	0.07	0.09
Delivered energy	27.59	27.60	27.60	27.40	26.44	28.60	25.92
Electricity related losses	0.05	0.05	0.05	0.08	0.10	0.14	0.18
Total	27.63	27.65	27.65	27.49	26.54	28.75	26.11

¹Commercial trucks 8,500 to 10,000 pounds.²Environmental Protection Agency rated miles per gallon.³Combined car and light truck "on-the-road" estimate.⁴E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.⁵Includes ethanol (blends of 15 percent or less) and ethers blended into gasoline.⁶Includes only kerosene type.⁷Diesel fuel for on- and off- road use.⁸Includes aviation gasoline and lubricants.

CAFE = Corporate average fuel economy.

Btu = British thermal unit.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Source: U.S. Energy Information Administration, AEO2012 National Energy Modeling System runs REF2012.D020112C and CAFEY.D032112A.

2015 from AEO 2012

Table D4. Key results for HD NGV Potential case

Sales, consumption, and efficiency	2010	2015		2025		2035	
		Heavy Duty Vehicle Reference	Heavy Duty Natural Gas Vehicle Potential	Heavy Duty Vehicle Reference	Heavy Duty Natural Gas Vehicle Potential	Heavy Duty Vehicle Reference	Heavy Duty Natural Gas Vehicle Potential
Truck sales by size class (millions)	0.36	0.56	0.56	0.65	0.65	0.80	0.81
Medium	0.21	0.29	0.29	0.33	0.33	0.40	0.40
Diesel	0.13	0.20	0.20	0.24	0.20	0.28	0.21
Motor gasoline	0.07	0.08	0.08	0.08	0.07	0.10	0.08
Liquefied petroleum gases	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Natural gas	0.00	0.00	0.01	0.01	0.06	0.02	0.11
Heavy	0.15	0.27	0.27	0.32	0.32	0.40	0.40
Diesel	0.15	0.26	0.25	0.30	0.22	0.37	0.23
Motor gasoline	0.00	0.01	0.01	0.01	0.01	0.02	0.01
Liquefied petroleum gases	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Natural gas	0.00	0.00	0.01	0.00	0.08	0.01	0.16
Consumption by size class (quadrillion Btu)	4.82	5.50	5.51	5.66	5.68	5.85	5.93
Medium	0.83	1.03	1.03	1.12	1.12	1.15	1.16
Diesel	0.56	0.72	0.71	0.79	0.72	0.83	0.65
Motor gasoline	0.26	0.30	0.30	0.28	0.27	0.26	0.21
Liquefied petroleum gases	0.01	0.01	0.01	0.01	0.01	0.02	0.02
Natural gas	0.01	0.01	0.02	0.03	0.12	0.05	0.28
Heavy	3.99	4.47	4.48	4.55	4.56	4.71	4.77
Diesel	3.87	4.36	4.32	4.44	3.82	4.57	3.11
Motor gasoline	0.11	0.09	0.09	0.08	0.07	0.08	0.06
Liquefied petroleum gases	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Natural gas	0.00	0.01	0.06	0.02	0.66	0.05	1.59
New truck fuel efficiency by size class (gasoline equivalent miles per gallon)	6.63	7.41	7.38	8.11	7.88	8.22	7.82
Medium	11.92	13.42	13.34	15.06	14.32	15.43	14.12
Diesel	13.50	14.49	14.49	16.29	16.29	16.37	16.35
Motor gasoline	10.13	10.49	10.49	11.87	11.87	13.07	13.07
Liquefied petroleum gases	9.95	10.56	10.56	12.11	12.11	13.39	13.39
Natural gas	9.17	9.99	9.99	11.07	11.07	11.07	11.07
Heavy	5.79	6.82	6.80	7.46	7.29	7.58	7.29
Diesel	5.79	6.85	6.85	7.50	7.49	7.63	7.59
Motor gasoline	5.50	5.35	5.35	5.45	5.45	5.46	5.46
Liquefied petroleum gases	5.15	5.58	5.58	5.75	5.75	5.75	5.75
Natural gas	5.56	6.04	6.35	6.40	6.87	6.42	6.95
Stock fuel efficiency by size class (gasoline equivalent miles per gallon)	6.66	6.83	6.82	7.72	7.61	8.12	7.81
Medium	11.48	12.06	12.05	13.90	13.60	14.99	14.04
Diesel	13.87	13.89	13.89	15.54	15.49	16.27	16.23
Motor gasoline	9.23	9.66	9.66	10.82	10.79	12.35	12.30
Liquefied petroleum gases	8.67	9.59	9.59	11.31	11.31	12.87	12.86
Natural gas	8.69	9.32	9.49	10.85	10.95	11.05	11.06
Heavy	6.05	6.16	6.16	7.05	6.97	7.44	7.22
Diesel	6.07	6.19	6.18	7.09	7.04	7.50	7.44
Motor gasoline	5.36	5.34	5.34	5.38	5.38	5.44	5.44
Liquefied petroleum gases	5.43	5.43	5.43	5.62	5.62	5.71	5.71
Natural gas	5.51	5.75	6.06	6.31	6.79	6.41	6.92

¹Includes lease condensate

²Includes natural gas plant liquids, refinery processing gain, other crude oil supply, and stock withdrawals

³Includes liquids, such as ethanol and biodiesel, derived from biomass, natural gas, and coal. Includes net imports of ethanol and biodiesel

-- = Not applicable

Btu = British thermal unit.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports

Sources: 2010 data based on: Oak Ridge National Laboratory, *Transportation Energy Data Book: Edition 28 and Annual* (Oak Ridge, TN, 2009); U.S. Department of Commerce, Bureau of the Census, "Vehicle Inventory and Use Survey," EC02TV (Washington, DC, December 2004); Federal Highway Administration, *Highway Statistics 2007* (Washington, DC, October 2008); U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011); and EIA, AEO2012 National Energy Modeling System run RFNGV12 D050412A. Projections: EIA, AEO2012 National Energy Modeling System runs RFNGV12 D050412A and NOSUBNGV12 D050412A.

Table D5. Energy consumption and carbon dioxide emissions for extended policy cases

Consumption and emissions	2010	2015			2025			2035		
		Reference	No Sunset	Extended Policies	Reference	No Sunset	Extended Policies	Reference	No Sunset	Extended Policies
Energy consumption by sector (quadrillion Btu)										
Residential	11.66	11.24	11.21	11.22	11.51	11.34	11.03	11.93	11.58	10.92
Commercial	8.70	8.80	8.79	8.78	9.48	9.49	9.20	10.28	10.31	9.79
Industrial ¹	23.37	23.96	23.95	23.96	25.53	25.73	25.42	26.94	26.99	26.60
Transportation	27.59	27.60	27.59	27.59	27.40	27.43	26.41	28.60	28.57	25.42
Electric power ²	39.63	38.64	38.60	38.53	42.03	41.63	40.45	44.24	43.95	42.24
Total	98.16	97.43	97.35	97.30	101.99	101.78	99.11	106.93	106.64	100.79
Energy consumption by fuel (quadrillion Btu)										
Liquid fuels and other petroleum ³	37.25	36.72	36.72	36.71	36.58	36.57	35.44	37.70	37.62	34.20
Natural gas	24.71	26.00	25.98	26.00	26.14	25.93	25.52	27.26	26.37	25.42
Coal	20.76	17.80	17.84	17.82	20.02	19.96	19.27	21.15	20.59	19.82
Nuclear / uranium	8.44	8.68	8.68	8.68	9.60	9.60	9.50	9.28	9.16	9.05
Renewable energy ⁴	6.72	7.92	7.82	7.79	9.38	9.45	9.10	11.29	12.66	12.05
Other ⁵	0.29	0.30	0.30	0.30	0.28	0.27	0.27	0.24	0.24	0.24
Total	98.16	97.43	97.35	97.30	101.99	101.78	99.11	106.93	106.64	100.79
Energy intensity (thousand Btu per 2005 dollar of GDP)	7.50	6.58	6.58	6.58	5.32	5.30	5.16	4.36	4.35	4.11
Carbon dioxide emissions by sector (million metric tons)										
Residential	353	338	337	338	324	322	319	312	307	293
Commercial	229	231	231	231	237	238	232	246	248	236
Industrial ¹	909	963	962	963	992	993	983	1011	1016	991
Transportation	1872	1864	1864	1863	1820	1813	1749	1859	1853	1642
Electric power ⁶	2271	2011	2015	2012	2179	2161	2084	2330	2221	2133
Total	5634	5407	5409	5407	5552	5526	5367	5758	5645	5295
Carbon dioxide emissions by fuel (million metric tons)										
Petroleum	2349	2329	2329	2328	2261	2251	2180	2300	2289	2061
Natural gas	1283	1367	1366	1367	1374	1363	1341	1435	1387	1337
Coal	1990	1699	1702	1700	1906	1901	1835	2012	1957	1885
Other ⁷	12	12	12	12	12	12	12	12	12	12
Total	5634	5407	5409	5407	5552	5526	5367	5758	5645	5295
Carbon dioxide emissions (tons per person)	18.1	16.6	16.6	16.6	15.5	15.4	15.0	14.8	14.5	13.6

¹Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public.

²Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

³Includes petroleum-derived fuels and non-petroleum derived fuels, such as ethanol and biodiesel, and coal-based synthetic liquids. Petroleum coke, which is a solid, is included. Also included are natural gas plant liquids, crude oil consumed as a fuel, and liquid hydrogen.

⁴Includes grid-connected electricity from conventional hydroelectric; wood and wood waste; landfill gas; biogenic municipal solid waste; other biomass; wind; photovoltaic and solar thermal sources; and non-electric energy from renewable sources, such as active and passive solar systems, and wood; and both the ethanol and gasoline components of E85, but not the ethanol component of blends less than 85 percent. Excludes electricity imports using renewable sources and nonmarketed renewable energy.

⁵Includes non-biogenic municipal waste and net electricity imports.

⁶Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

⁷Includes emissions from geothermal power and nonbiogenic emissions from municipal solid waste.

Btu = British thermal unit.

GDP = Gross domestic product.

Note: Includes end-use, fossil electricity, and renewable technology assumptions. Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Source: U.S. Energy Information Administration, AEO2012 National Energy Modeling System runs REF2012 D020112C, NOSUNSET D032112A, and EXTENDED D050612B.

Results from the cases

Table D6. Electricity generation and generating capacity in extended policy cases
(gigawatts, unless otherwise noted)

Net summer capacity, generation, consumption, and emissions	2010	2015			2025			2035		
		Reference	No Sunset	Extended Policies	Reference	No Sunset	Extended Policies	Reference	No Sunset	Extended Policies
Capacity	1036.1	1042.0	1020.7	1011.3	1091.1	1088.5	1059.4	1190.0	1232.9	1167.6
Electric power sector ¹	1006.5	998.7	977.3	967.6	1033.3	1004.8	976.6	1112.5	1098.0	1032.8
Pulverized coal	312.8	280.7	271.7	264.2	272.8	265.8	257.0	273.6	265.7	256.9
Coal gasification combined-cycle	0.5	0.9	0.9	0.9	1.8	1.8	1.7	1.7	1.7	1.5
Conventional natural gas combined-cycle	198.0	212.4	212.4	212.5	213.5	213.0	212.4	218.8	215.7	213.6
Advanced natural gas combined-cycle	0.0	1.2	1.0	1.3	10.3	4.7	2.4	53.4	20.5	8.4
Conventional combustion turbine	137.6	136.3	133.5	133.0	132.3	129.7	127.8	130.3	129.2	126.8
Advanced combustion turbine	0.0	5.2	3.7	4.0	23.2	11.7	6.8	41.5	24.9	10.2
Fuel cells	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Nuclear / uranium	101.2	103.6	103.6	103.6	114.7	114.7	113.6	110.9	109.3	108.1
Oil and natural gas steam	108.1	90.7	85.2	84.2	89.6	83.3	81.4	87.9	83.1	80.6
Renewable sources	126.1	145.3	143.0	141.6	152.1	157.5	151.2	170.2	224.4	203.8
Pumped storage	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
Distributed generation	0.0	0.2	0.1	0.1	0.8	0.5	0.3	2.1	1.3	0.5
Combined heat and power ²	29.6	43.3	43.4	43.7	57.8	83.7	82.8	77.5	134.9	134.9
Fossil fuels / other	22.0	25.7	25.7	26.0	34.4	35.7	35.8	47.0	49.9	49.6
Renewable fuels	7.6	17.6	17.7	17.7	23.4	48.0	47.0	30.6	85.0	85.3
Cumulative additions	0.0	69.8	65.8	65.3	126.7	140.0	124.8	235.0	290.9	240.4
Electric power sector ¹	0.0	56.1	52.0	51.2	98.5	85.9	71.6	187.1	185.6	135.2
Pulverized coal	0.0	8.7	8.7	8.7	8.7	8.7	8.7	9.4	8.7	8.7
Coal gasification combined-cycle	0.0	0.6	0.6	0.6	1.5	1.5	1.5	1.5	1.5	1.5
Conventional natural gas combined-cycle	0.0	14.5	14.5	14.5	15.8	15.3	14.7	21.1	18.0	15.9
Advanced natural gas combined-cycle	0.0	1.2	1.0	1.3	10.3	4.7	2.4	53.4	20.5	8.4
Conventional combustion turbine	0.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Advanced combustion turbine	0.0	5.2	3.7	4.0	23.2	11.7	6.8	41.5	24.9	10.2
Nuclear / uranium	0.0	1.1	1.1	1.1	6.8	6.8	6.8	8.5	6.9	6.8
Renewable sources	0.0	19.6	17.3	15.9	26.4	31.8	25.5	44.5	98.7	78.1
Distributed generation	0.0	0.2	0.1	0.1	0.8	0.5	0.3	2.1	1.3	0.5
Combined heat and power ²	0.0	13.7	13.8	14.1	28.2	54.1	53.2	47.9	105.3	105.3
Fossil fuels / other	0.0	3.7	3.8	4.1	12.4	13.7	13.9	25.0	27.9	27.6
Renewable fuels	0.0	10.0	10.0	10.0	15.8	40.3	39.3	22.9	77.4	77.7
Cumulative retirements	0.0	65.2	82.5	91.4	78.9	94.9	108.8	88.4	101.3	116.2
Generation by fuel (billion kilowatthours)	4126	4152	4147	4142	4556	4559	4427	4992	5004	4813
Electric power sector ¹	3971	3956	3950	3944	4279	4229	4106	4586	4498	4310
Coal	1831	1562	1565	1563	1741	1736	1673	1834	1781	1711
Petroleum	34	26	26	26	27	27	26	28	28	27
Natural gas	898	1028	1030	1030	1006	971	938	1196	1030	976
Nuclear / uranium	807	830	830	830	917	917	909	887	875	865
Renewable sources	395	508	498	493	584	574	557	634	780	728
Pumped storage	2	2	2	2	2	2	2	2	2	2
Distributed generation	0	0	0	0	2	1	1	4	2	1
Combined heat and power ²	155	197	197	198	277	330	321	406	506	502
Fossil fuels / other	122	142	142	144	198	206	206	281	298	294
Renewable fuels	34	55	55	55	78	124	115	125	208	208
Average electricity price (cents per kilowatthour)	9.8	9.7	9.8	9.8	9.7	9.6	9.6	10.1	9.9	9.6

¹Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes small power producers and exempt wholesale generators.

²Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors. Includes small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid. Excludes off-grid photovoltaics and other generators not connected to the distribution or transmission systems.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Source: U.S. Energy Information Administration, AEO2012 National Energy Modeling System runs REF2012 D020112C, NOSUNSET D032112A, and EXTENDED D050612B.

Table D7. Key results for advanced nuclear plant life cases
(gigawatts, unless otherwise noted)

Net summer capacity, generation, emissions, and fuel prices	2010	2015			2025			2035		
		Low Nuclear	Reference	High Nuclear	Low Nuclear	Reference	High Nuclear	Low Nuclear	Reference	High Nuclear
Capacity										
Coal steam	313.4	280.7	281.6	281.3	273.4	274.7	275.3	276.2	275.2	275.4
Oil and natural gas steam	108.1	88.2	90.7	91.0	87.0	89.6	89.4	84.5	87.9	86.9
Combined cycle	198.0	212.6	213.6	213.8	224.1	223.8	219.0	279.8	272.2	257.3
Combustion turbine / diesel	137.6	138.1	141.5	141.3	150.8	155.5	155.4	168.1	171.8	172.6
Nuclear / uranium	101.2	103.1	103.6	103.6	108.2	114.7	121.4	77.9	110.9	122.7
Pumped storage	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2	22.2
Fuel cells	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewable sources	126.1	145.4	145.3	145.0	153.2	152.1	151.4	175.7	170.2	167.4
Distributed generation (natural gas)	0.0	0.1	0.2	0.2	0.7	0.8	0.8	1.7	2.1	2.1
Combined heat and power ¹	29.6	43.4	43.3	43.3	57.8	57.8	58.0	78.6	77.5	77.4
Total	1036.1	1033.8	1042.0	1041.6	1077.4	1091.1	1093.0	1164.8	1190.0	1183.9
Cumulative additions										
Coal steam	0.0	9.3	9.3	9.3	10.2	10.2	10.2	13.2	10.9	10.4
Oil and natural gas steam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combined cycle	0.0	14.7	15.7	15.9	26.4	26.1	21.3	82.1	74.5	59.6
Combustion turbine / diesel	0.0	8.6	10.2	10.2	25.7	28.2	28.0	44.7	46.5	46.0
Nuclear / uranium	0.0	1.1	1.1	1.1	6.8	6.8	13.5	6.8	8.5	14.8
Pumped storage	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fuel cells	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Renewable sources	0.0	19.7	19.6	19.3	27.5	26.4	25.7	50.0	44.5	41.7
Distributed generation	0.0	0.1	0.2	0.2	0.7	0.8	0.8	1.7	2.1	2.1
Combined heat and power ¹	0.0	13.8	13.7	13.7	28.2	28.2	28.4	49.0	47.9	47.7
Total	0.0	67.2	69.8	69.7	125.5	126.7	127.9	247.5	235.0	222.4
Cumulative retirements	0.0	70.4	65.2	65.4	85.0	78.9	78.3	119.6	88.4	81.9
Generation by fuel (billion kilowatthours)										
Coal	1831	1570	1562	1565	1760	1741	1727	1853	1834	1822
Petroleum	34	26	26	26	27	27	27	28	28	28
Natural gas	898	1022	1028	1026	1029	1006	972	1361	1196	1136
Nuclear / uranium	807	826	830	830	866	917	970	625	887	979
Pumped storage	2	2	2	2	2	2	2	2	2	2
Renewable sources	395	508	508	507	585	584	585	653	634	632
Distributed generation	0	0	0	0	2	2	2	3	4	4
Combined heat and power ¹	155	197	197	197	277	277	278	412	406	404
Total	4124	4151	4152	4152	4547	4556	4562	4936	4992	5006
Carbon dioxide emissions by the electric power sector (million metric tons)²										
Petroleum	33	23	23	23	24	24	24	24	25	25
Natural gas	399	436	438	437	435	427	415	545	485	467
Coal	1828	1547	1539	1543	1737	1717	1703	1823	1809	1798
Other ³	12	12	12	12	12	12	12	12	12	12
Total	2271	2017	2011	2014	2207	2179	2154	2404	2330	2301
Prices to the electric power sector² (2010 dollars per million Btu)										
Petroleum	13.32	22.93	22.93	22.94	25.38	25.38	25.38	26.53	26.31	26.13
Natural gas	5.14	4.52	4.55	4.54	5.70	5.60	5.46	8.03	7.21	7.00
Coal	2.26	2.36	2.35	2.35	2.54	2.54	2.53	2.81	2.80	2.78

¹Includes combined heat and power plants and electricity-only plants in commercial and industrial sectors. Includes small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid. Excludes off-grid photovoltaics and other generators not connected to the distribution or transmission systems.

²Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

³Includes emissions from geothermal power and nonbiogenic emissions from municipal solid waste.

Btu = British thermal unit.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Source: U.S. Energy Information Administration, AEO2012 National Energy Modeling System runs LOWNUC12.D022312A, REF2012.D020112C, and HINUC12.D022312A.

Results by Region

Table D8. Key results for Low Renewable Technology Cost case

Capacity, generation, and emissions	2010	2015		2025		2035	
		Reference	Low Renewable Technology Cost	Reference	Low Renewable Technology Cost	Reference	Low Renewable Technology Cost
Net summer capacity (gigawatts)							
Electric power sector¹							
Conventional hydropower	78.03	78.55	78.76	80.14	81.34	81.25	84.36
Geothermal ²	2.37	2.86	2.58	4.45	4.37	6.30	6.82
Municipal waste ³	3.30	3.36	3.36	3.36	3.36	3.36	3.36
Wood and other biomass ⁴	2.45	2.72	2.72	2.72	2.82	2.89	4.31
Solar thermal	0.47	1.36	1.36	1.36	1.36	1.36	1.36
Solar photovoltaic	0.38	2.02	2.05	2.30	5.12	8.18	34.27
Wind	39.05	54.46	61.41	57.77	65.59	66.85	105.87
Total	126.06	145.34	152.25	152.10	163.96	170.19	240.35
End-use sector⁵							
Conventional hydropower	0.33	0.33	0.33	0.33	0.33	0.33	0.33
Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Municipal waste ⁶	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Wood and other biomass	4.56	5.73	5.89	8.44	10.52	13.81	17.21
Solar photovoltaic	2.05	8.98	9.19	11.69	14.29	13.33	23.29
Wind	0.36	2.25	3.18	2.60	4.06	2.74	5.26
Total	7.65	17.64	18.95	23.41	29.55	30.57	46.43
Generation (billion kilowatthours)							
Electric power sector¹							
Coal	1831	1562	1547	1741	1731	1834	1780
Petroleum	34	26	26	27	27	28	28
Natural gas	898	1028	1018	1006	974	1196	1037
Total fossil	2764	2616	2591	2774	2732	3058	2846
Conventional hydropower	255.32	295.43	296.17	305.00	310.24	310.08	321.78
Geothermal	15.67	18.68	16.42	31.53	30.91	46.54	50.89
Municipal waste ⁷	16.56	14.66	14.66	14.67	14.67	14.67	14.67
Wood and other biomass ⁴	11.51	21.28	24.10	63.90	68.89	49.28	78.41
Dedicated plants	10.15	10.13	12.58	13.30	12.84	10.37	23.13
Cofiring	1.36	11.15	11.52	50.60	56.05	38.92	55.28
Solar thermal	0.82	2.86	2.86	2.86	2.86	2.86	2.86
Solar photovoltaic	0.46	3.61	3.68	4.37	11.91	20.19	84.04
Wind	94.49	150.97	174.49	161.49	188.46	190.67	310.55
Total renewable	394.82	507.49	532.38	583.81	627.94	634.30	863.20
End-use sector⁵							
Total fossil	106	123	123	180	177	262	260
Conventional hydropower ⁸	1.76	1.75	1.75	1.75	1.75	1.75	1.75
Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Municipal waste ⁶	2.02	2.79	2.79	2.79	2.79	2.79	2.79
Wood and other biomass	26.10	33.30	34.27	52.34	67.01	96.17	118.46
Solar photovoltaic	3.21	13.88	14.20	18.22	22.41	20.91	37.06
Wind	0.47	2.88	3.92	3.36	5.09	3.56	6.78
Total renewable	33.56	54.59	56.92	78.45	99.05	125.17	166.82
Carbon dioxide emissions by the electric power sector (million metric tons)¹							
Coal	1828	1539	1525	1717	1706	1809	1754
Petroleum	33	23	23	24	24	25	25
Natural gas	399	438	434	427	416	485	435
Other ⁹	12	12	12	12	12	12	12
Total	2271	2011	1993	2179	2157	2330	2225

¹Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public

²Includes hydrothermal resources only (hot water and steam)

³Includes all municipal waste, landfill gas, and municipal sewage sludge. Incremental growth is assumed to be for landfill gas facilities. All municipal waste is included, although a portion of the municipal waste stream contains petroleum-derived plastics and other non-renewable sources

⁴Includes projections for energy crops after 2010

⁵Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid. Excludes off-grid photovoltaics and other generators not connected to the distribution or transmission systems

⁶Includes municipal waste, landfill gas, and municipal sewage sludge. All municipal waste is included, although a portion of the municipal waste stream contains petroleum-derived plastics and other non-renewable sources

⁷Includes biogenic municipal waste, landfill gas, and municipal sewage sludge. Incremental growth is assumed to be for landfill gas facilities

⁸Represents own-use industrial hydroelectric power

⁹Includes emissions from geothermal power and nonbiogenic emissions from municipal solid waste

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports

Source: U.S. Energy Information Administration, AEO2012 National Energy Modeling System runs REF2012.D020112C, and LORENCST12.D041312A

Table D9. Key results for environmental cases

Net summer capacity, generation, emissions, and fuel prices	2010	2035					
		Reference	Reference 05	High EUR	Low Gas Price 05	Greenhouse Gas \$15	Greenhouse Gas \$25
Capacity (gigawatts)							
Coal steam	313.4	275.2	261.6	268.3	254.2	124.3	39.1
Oil and natural gas steam	108.1	87.9	86.5	88.1	90.7	81.9	72.3
Combined cycle	198.0	272.2	276.2	273.1	285.6	298.0	312.7
Combustion turbine / diesel	137.6	171.8	173.9	181.5	178.4	154.7	142.9
Nuclear / uranium	101.2	110.9	111.1	109.3	109.3	160.5	225.0
Pumped storage	22.2	22.2	22.2	22.2	22.2	22.2	22.2
Renewable sources	126.1	170.2	174.2	159.4	165.3	227.6	257.6
Distributed generation (natural gas)	0.0	2.1	2.0	5.2	5.6	0.3	0.2
Combined heat and power ¹	29.6	77.5	78.3	80.8	81.2	96.7	105.2
Total	1036.1	1190.0	1186.0	1187.8	1192.5	1166.0	1177.3
Cumulative additions (gigawatts)							
Coal steam	0.0	10.9	11.1	10.2	10.6	10.2	10.3
Combined cycle	0.0	74.5	78.4	75.4	87.9	100.3	115.0
Combustion turbine / diesel	0.0	46.5	43.4	52.1	48.0	38.9	24.7
Nuclear / uranium	0.0	8.5	8.7	6.9	6.9	58.1	122.7
Renewable sources	0.0	44.5	48.5	33.7	39.6	101.9	131.9
Distributed generation	0.0	2.1	2.0	5.2	5.6	0.3	0.2
Combined heat and power ¹	0.0	47.9	48.7	51.2	51.6	67.0	75.6
Total	0.0	235.0	240.8	234.6	250.2	376.8	480.4
Cumulative retirements (gigawatts)	0.0	88.4	98.3	90.2	101.1	254.1	346.6
Generation by fuel (billion kilowatthours)							
Coal	1831	1834	1752	1748	1664	699	102
Petroleum	34	28	27	29	28	24	21
Natural gas	898	1196	1253	1347	1404	1351	1306
Nuclear / uranium	807	887	889	875	875	1268	1782
Pumped storage	5	2	2	2	2	2	2
Renewable sources	395	634	642	601	618	888	876
Distributed generation	0	4	4	16	16	0	0
Combined heat and power ¹	155	406	410	426	428	512	545
Total	4126	4992	4979	5044	5034	4743	4634
Emissions by the electric power sector²							
Carbon dioxide (million metric tons)	2271	2330	2263	2310	2238	1228	555
Sulfur dioxide (million short tons)	5.11	1.71	1.68	1.54	1.57	0.61	0.15
Nitrogen oxides (million short tons)	2.06	1.96	1.93	1.93	1.93	0.85	0.42
Mercury (short tons)	34.70	7.86	7.57	7.49	7.15	3.40	0.91
Retrofits (gigawatts)							
Scrubber	0.00	47.57	19.91	52.97	18.31	30.07	25.69
Nitrogen oxide controls							
Combustion	0.00	7.97	6.08	4.16	1.51	2.38	2.38
Selective catalytic reduction post-combustion	0.00	19.17	10.29	13.44	6.10	7.67	5.91
Selective non-catalytic reduction post-combustion	0.00	0.71	0.71	0.71	0.71	0.70	2.50
Prices to the electric power sector²							
(2010 dollars per million Btu)							
Natural gas	5.14	7.21	7.35	6.03	6.14	9.37	11.10
Coal	2.26	2.80	2.77	2.73	2.70	6.64	9.45

¹Includes combined heat and power plants and electricity-only plants in commercial and industrial sectors. Includes small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid. Excludes off-grid photovoltaics and other generators not connected to the distribution or transmission systems.

²Includes electricity-only and combined heat and power plants whose primary business to sell electricity, or electricity and heat, to the public.

EUR = Estimated ultimate recovery.

Btu = British thermal unit.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Source: U.S. Energy Information Administration, AEO2012 National Energy Modeling System runs REF2012.D020112C, REF12_R05.D030712A, HEUR12.D022212A, HEUR12_R05.D022312A, CO2FEE15.D031312A, and CO2FEE25.D031312A.

Source: EIA, AEO2012

Table D10. Natural gas supply and disposition, oil and gas resource cases
(trillion cubic feet per year, unless otherwise noted)

Supply, disposition, and prices	2010	2015				2025				2035			
		Low EUR	Reference	High EUR	High TRR	Low EUR	Reference	High EUR	High TRR	Low EUR	Reference	High EUR	High TRR
Natural gas prices													
(2010 dollars per million Btu)													
Henry Hub spot price	4.39	4.58	4.29	3.94	3.10	6.93	5.63	4.77	3.45	8.26	7.37	5.99	4.25
Average lower 48 wellhead	4.06	4.10	3.84	3.54	2.80	6.11	5.00	4.26	3.11	7.24	6.48	5.31	3.81
(2010 dollars per thousand cubic feet)													
Average lower 48 wellhead	4.16	4.19	3.94	3.62	2.87	6.25	5.12	4.36	3.19	7.41	6.64	5.43	3.90
Dry gas production²	21.58	22.80	23.65	24.38	26.54	24.25	26.28	27.81	30.85	26.11	27.93	30.07	34.15
Lower 48 onshore	18.66	20.62	21.48	22.20	24.37	21.48	23.64	25.24	28.60	21.19	24.97	27.19	31.66
Associated-dissolved	1.40	1.47	1.52	1.58	1.70	1.31	1.41	1.50	1.60	0.90	1.00	1.13	1.29
Non-associated	17.26	19.15	19.96	20.62	22.68	20.17	22.23	23.74	27.00	20.28	23.97	26.07	30.37
Tight gas	5.68	6.13	6.08	6.01	5.88	6.40	6.17	6.02	5.86	6.30	6.14	5.93	5.76
Shale gas	4.99	7.35	8.24	8.99	11.24	8.88	11.26	12.98	16.44	9.74	13.63	16.01	20.53
Coalbed methane	1.99	1.85	1.83	1.80	1.74	1.84	1.77	1.73	1.69	1.80	1.76	1.70	1.66
Other	4.59	3.81	3.82	3.82	3.82	3.04	3.03	3.02	3.02	2.44	2.44	2.43	2.42
Lower 48 offshore	2.56	1.89	1.88	1.88	1.87	2.51	2.38	2.31	1.99	3.12	2.72	2.64	2.27
Associated-dissolved	0.71	0.55	0.55	0.55	0.55	0.71	0.67	0.67	0.59	0.84	0.73	0.71	0.60
Non-associated	1.85	1.34	1.33	1.33	1.32	1.81	1.71	1.65	1.40	2.28	2.00	1.93	1.67
Alaska	0.36	0.29	0.29	0.29	0.29	0.25	0.25	0.25	0.25	1.80	0.23	0.23	0.22
Supplemental natural gas ³	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Net imports	2.58	1.77	1.73	1.65	1.42	-0.39	-0.79	-1.06	-1.62	-1.16	-1.36	-1.73	-2.35
Pipeline ⁴	2.21	1.61	1.56	1.49	1.27	0.22	-0.13	-0.40	-0.95	-0.50	-0.70	-1.07	-1.69
Liquefied natural gas	0.37	0.17	0.16	0.16	0.15	-0.61	-0.66	-0.66	-0.66	-0.66	-0.66	-0.66	-0.66
Total supply	24.22	24.64	25.45	26.09	28.02	23.92	25.55	26.81	29.30	25.01	26.63	28.40	31.86
Consumption by sector													
Residential	4.94	4.83	4.85	4.88	4.94	4.69	4.76	4.82	4.92	4.59	4.64	4.72	4.84
Commercial	3.20	3.30	3.33	3.37	3.47	3.32	3.44	3.54	3.71	3.50	3.60	3.75	3.97
Industrial ⁵	6.60	6.99	7.01	7.07	7.20	6.96	7.14	7.26	7.51	6.85	7.00	7.24	7.61
Electric power ⁶	7.38	7.40	8.08	8.56	10.07	6.74	7.87	8.78	10.54	7.67	8.96	10.13	12.62
Transportation ⁷	0.04	0.06	0.06	0.06	0.06	0.11	0.11	0.12	0.12	0.15	0.16	0.17	0.18
Pipeline fuel	0.63	0.66	0.67	0.67	0.69	0.64	0.66	0.67	0.69	0.72	0.67	0.69	0.74
Lease and plant fuel ⁸	1.34	1.35	1.39	1.43	1.55	1.44	1.53	1.60	1.78	1.54	1.60	1.70	1.91
Total	24.13	24.59	25.39	26.04	27.97	23.90	25.53	26.79	29.28	25.01	26.63	28.40	31.87
Discrepancy⁹	0.10	0.05	0.05	0.05	0.05	0.02	0.02	0.02	0.02	-0.00	-0.00	-0.01	-0.01
Lower 48 end of year reserves	260.50	265.85	274.79	283.88	298.90	280.90	299.77	318.24	347.21	291.70	311.58	333.43	371.70

¹Represents lower 48 onshore and offshore supplies

²Marketed production (wet) minus extraction losses

³Synthetic natural gas, propane air, coke oven gas, refinery gas, biomass gas, air injected for Btu stabilization, and manufactured gas commingled and distributed with natural gas

⁴Includes any natural gas regasified in the Bahamas and transported via pipeline to Florida

⁵Includes energy for combined heat and power plants, except those whose primary business is to sell electricity, or electricity and heat, to the public

⁶Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes small power producers and exempt wholesale generators

⁷Natural gas used as a vehicle fuel.

⁸Represents natural gas used in field gathering and processing plant machinery

⁹Balancing item. Natural gas lost as a result of converting flow data measured at varying temperatures and pressures to a standard temperature and pressure and the merger of different data reporting systems which vary in scope, format, definition, and respondent type. In addition, 2010 values include net storage injections

EUR = Estimated ultimate recovery

TRR = Technically recoverable resources

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports

Sources: 2010 supply values; lease, plant, and pipeline fuel consumption; and wellhead price: U.S. Energy Information Administration (EIA), *Natural Gas Monthly*, DOE/EIA-0130(2011/07) (Washington, DC, July 2011). Other 2010 consumption based on: EIA, *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011)

Projections: EIA, AEO2012 National Energy Modeling System runs LEUR12 D022212A, REF2012 D020112C, HEUR12 D022212A, and HTRR12 D050412A

Table D11. Liquid fuels supply and disposition, oil and gas resource cases
(million barrels per day, unless otherwise noted)

Supply, disposition, and prices	2010	2015				2025				2035			
		Low EUR	Reference	High EUR	High TRR	Low EUR	Reference	High EUR	High TRR	Low EUR	Reference	High EUR	High TRR
Prices													
(2010 dollars per barrel)													
Low sulfur light crude oil ¹	79.39	117.84	116.91	116.11	113.74	134.54	132.56	130.60	127.97	146.78	144.98	143.27	139.78
Imported crude oil ¹	75.87	114.90	113.97	113.17	110.80	123.99	121.21	118.63	115.77	135.38	132.95	131.20	127.55
Crude oil supply													
Domestic production ²	5.47	5.91	6.15	6.38	7.09	5.82	6.40	6.95	7.69	5.49	5.99	6.62	7.76
Alaska	0.60	0.46	0.46	0.46	0.46	0.40	0.40	0.40	0.34	0.27	0.27	0.27	0.38
Lower 48 onshore	3.21	3.85	4.09	4.32	5.04	3.77	4.43	5.00	5.98	3.22	3.99	4.67	5.97
Lower 48 offshore	1.67	1.60	1.60	1.60	1.59	1.65	1.57	1.54	1.36	2.00	1.74	1.69	1.41
Net imports	9.17	8.80	8.52	8.28	7.57	7.87	7.24	6.68	5.89	8.12	7.52	6.90	5.65
Other crude oil supply	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total crude oil supply	14.72	14.71	14.67	14.65	14.66	13.69	13.64	13.63	13.58	13.61	13.51	13.52	13.40
Other petroleum supply	3.50	3.17	3.25	3.33	3.40	3.66	3.80	3.94	4.13	3.40	3.52	3.73	4.02
Natural gas plant liquids	2.07	2.43	2.56	2.68	2.97	2.67	3.01	3.27	3.91	2.66	3.01	3.33	4.04
Net product imports ³	0.39	-0.20	-0.25	-0.30	-0.54	0.08	-0.12	-0.24	-0.69	-0.12	-0.34	-0.43	-0.89
Refinery processing gain ⁴	1.07	0.94	0.95	0.94	0.97	0.90	0.91	0.91	0.91	0.86	0.85	0.83	0.86
Product stock withdrawal	-0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other non-petroleum supply	1.00	1.22	1.22	1.22	1.22	1.87	1.86	1.86	1.85	2.91	2.96	2.87	2.81
From renewable sources ⁵	0.87	1.05	1.05	1.05	1.05	1.48	1.48	1.48	1.49	2.33	2.37	2.32	2.27
From non-renewable sources ⁶	0.13	0.17	0.17	0.17	0.16	0.38	0.38	0.37	0.36	0.58	0.58	0.55	0.53
Total primary supply⁷	19.22	19.10	19.14	19.20	19.27	19.21	19.29	19.42	19.56	19.91	19.99	20.11	20.23
Refined petroleum products supplied													
Residential and commercial	1.12	1.00	1.00	1.00	1.00	0.93	0.94	0.94	0.95	0.90	0.91	0.91	0.92
Industrial ⁸	4.31	4.17	4.17	4.19	4.19	4.38	4.41	4.44	4.46	4.41	4.44	4.46	4.47
Transportation	13.82	13.78	13.80	13.82	13.88	13.66	13.71	13.79	13.88	14.37	14.41	14.49	14.57
Electric power ⁹	0.17	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.14
Total	19.17	19.07	19.10	19.14	19.21	19.11	19.20	19.31	19.44	19.83	19.90	20.01	20.10
Discrepancy¹⁰	0.05	0.03	0.05	0.06	0.07	0.10	0.10	0.11	0.12	0.09	0.09	0.11	0.12
Lower 48 end of year reserves (billion barrels)²	18.33	19.39	20.55	21.66	23.49	21.36	23.64	25.77	27.83	22.68	24.23	26.27	29.06

¹Weighted average price delivered to U.S. refiners.

²Includes lease condensate.

³Includes net imports of finished petroleum products, unfinished oils, other hydrocarbons, alcohols, ethers, and blending components.

⁴The volumetric amount by which total output is greater than input due to the processing of crude oil into products which, in total, have a lower specific gravity than the crude oil processed.

⁵Includes ethanol (including imports), biodiesel (including imports), pyrolysis oils, biomass-derived Fischer-Tropsch liquids, and renewable feedstocks for the production of green diesel and gasoline.

⁶Includes alcohols, ethers, domestic sources of blending components, other hydrocarbons, natural gas converted to liquid fuel, and coal converted to liquid fuel.

⁷Total crude supply plus natural gas plant liquids, other inputs, refinery processing gain, and net product imports.

⁸Includes consumption for combined heat and power, which produces electricity and other useful thermal energy.

⁹Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public. Includes small power producers and exempt wholesale generators.

¹⁰Balancing item. Includes unaccounted for supply, losses and gains.

EUR = Estimated ultimate recovery.

TRR = Technically recoverable resources.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2010 product supplied data and imported crude oil price based on: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2010 imported low sulfur light crude oil price: EIA, Form EIA-856, "Monthly Foreign Crude Oil Acquisition Report." Other 2010 data: EIA, *Petroleum Supply Annual 2010*, DOE/EIA-0340(2010)/1 (Washington, DC, July 2011). Projections: EIA, AEO2012 National Energy Modeling System runs LEUR12.D022212A, REF2012.D020112C, HEUR12.D022212A, and HTRR.D050412A.

*Data from table 1.10

Table D12. Volumetric and mass representations of liquid fuels production cases
(volume in million barrels per day, mass in billion tons, unless otherwise noted)

Supply and disposition	2000		2011			2035		
	Volume	Mass	PMM Volume	LFMM Volume	LFMM Mass	PMM Volume	LFMM Volume	LFMM Mass
Primary feedstocks¹								
Crude oil ²	15.36	0.83	15.37	14.87	0.83	14.05	13.73	0.78
Natural gas ³	0.00	0.00	0.00	0.00	0.00	0.00	2.95	0.03
Natural gas plant liquids ⁴	1.91	0.07	2.16	1.21	0.09	3.01	0.30	0.11
Coal ⁵	0.00	0.00	0.00	0.00	0.00	0.28	0.27	0.09
Biomass ⁶	0.10	0.01	0.92	13.99	0.14	2.37	14.64	0.31
Total primary feedstocks	17.37	0.91	18.45	--	1.06	19.71	--	1.32
Refined products¹								
Residual fuel oil	0.91	0.04	0.47	0.52	0.03	0.58	0.58	0.03
Middle distillates ⁷	2.55	0.26	3.21	5.90	0.30	3.73	6.69	0.34
Biodiesel ⁸	0.00	0.00	0.05	0.02	0.00	0.13	0.01	0.00
Gasoline blendstocks ⁹	8.37	0.37	7.84	8.57	0.41	6.94	7.73	0.37
Ethanol ¹⁰	0.10	0.00	0.86	0.95	0.05	1.65	1.61	0.08
Chemicals ¹¹	2.62	0.10	2.11	2.17	0.05	2.10	3.20	0.08
Solid products ¹²	--	0.05	--	--	0.07	--	--	0.08
Fuel consumption and other ¹³	--	0.10	--	0.00	0.15	0.00	0.00	0.34
Total refined products	14.55	0.91	14.54	18.13	1.06	15.13	19.82	1.32
End use products								
Residual fuel oil	0.91	0.04	0.47	0.50	0.03	0.58	0.57	0.03
Heating oil ¹⁴	1.17	0.03	0.62	0.53	0.03	0.37	0.37	0.02
Diesel fuel ¹⁵	2.55	0.16	3.27	3.40	0.17	4.11	4.19	0.21
Jet fuel	1.73	0.08	1.44	1.51	0.08	1.61	1.67	0.08
Motor Gasoline ¹⁶	8.47	0.38	8.76	9.29	0.44	8.09	8.32	0.40
E85 ¹⁷	0.00	0.00	0.00	0.00	0.00	0.83	0.84	0.04
Liquefied petroleum gases	2.43	0.02	2.26	0.46	0.01	2.21	0.74	0.01
Chemical feedstocks ¹⁸	0.40	0.07	0.33	1.70	0.06	0.57	2.47	0.06
Agricultural products ¹⁹	--	0.00	--	--	0.05	--	--	0.06
Biomass heat and power ²⁰	--	0.00	--	--	0.00	--	--	0.02
Other ²¹	1.91	0.04	1.89	0.34	0.02	1.79	0.36	0.02
Total end use products	19.57	0.82	19.04	17.73	0.89	20.16	19.53	0.95

¹Includes domestic production and net imports²Includes unfinished oils and lease condensate³Natural gas that remains after the liquefiable hydrocarbon portion has been removed from the gas stream at lease and/or plant separation facilities. Volume in billion cubic feet per day.⁴Liquids in the natural gas production stream that stay in gaseous form at the surface and are separated at a gas processing plant. Once extracted, these liquids are separated into distinct products, or "fractions", such as propane, butane, and ethane.⁵Coal input to the coal-to-liquids process. Volume in million barrels per day fuel oil equivalent⁶Biological material from living, or recently living organisms such as grain crops, sugars, cellulosic biomass, or renewable oils. Volume in million barrels per day fuel oil equivalent⁷Includes all fuels that meet ASTM D396 and D975 (#4 and lighter) and D1655/D6615, including those derived from fossil and renewable feedstock⁸Methyl ester based fuel produced from fatty acids in renewable oils⁹Includes all blendstocks that meet ASTM D4814, including those derived from fossil and renewable feedstock¹⁰Includes denaturant¹¹Includes liquefied petroleum gases and petrochemical feedstocks¹²Includes petroleum coke, distillers grains, sulfur, and asphalt sales¹³Includes fuels burned for internal use, heat and power sales, solid waste, and process emissions¹⁴A distillate fuel oil for use in atomizing type burners for domestic heating or for use in medium capacity commercial-industrial burner units¹⁵For on-road use¹⁶Includes ethanol and ethers blended into motor gasoline.¹⁷E85 refers to a blend of 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable). To address cold starting issues, the percentage of ethanol varies seasonally. The annual average ethanol content of 74 percent is used for this forecast.¹⁸Includes petrochemical feedstocks and chemicals from Fischer-Tropsch processes, such as coal-to-liquids, biomass-to-liquids, and natural gas-to-liquids¹⁹Non-liquid co-products for use in the agricultural sector. Includes dried distiller grains²⁰Heat and power generated from the burning of residual biomass.²¹Includes petroleum coke, asphalt, road oil, and still gas

-- = Not applicable

PMM = Petroleum market module

LFMM = Liquid fuels market module

Note: PMM and LFMM projections do not exactly match due to differences in accounting for additional materials and updated refinery stream representations. Totals may not equal sum of components due to independent rounding. Data for 2000 are model results and may differ slightly from official EIA data reports

Sources: 2000 product supplied data and imported crude oil price based on: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011). 2000 crude oil production: EIA, *Petroleum Supply Annual 2001*, DOE/EIA-0340(2001)/1 (Washington, DC, June 2002). Other 2000 data: EIA, *Petroleum Supply Annual 2000*, DOE/EIA-0340(2000)/1 (Washington, DC, June 2001). Projections: EIA, AEO2012 National Energy Modeling System runs REF2012 D020112C, and REF_LFMM D050312A

Table D13. Key results for No GHG Concern case
(million short tons per year, unless otherwise noted)

Supply, disposition, and prices	2010	2015		2025		2035	
		Reference	No GHG Concern	Reference	No GHG Concern	Reference	No GHG Concern
Production¹	1084	993	1016	1118	1169	1212	1339
Appalachia	336	300	301	271	263	291	301
Interior	156	151	156	163	173	198	216
West	592	542	558	684	733	722	822
Waste coal supplied²	14	15	18	16	16	19	24
Net imports³	-64	-95	-97	-71	-57	-94	-88
Total supply⁴	1034	914	936	1064	1128	1138	1276
Consumption by sector							
Residential and commercial	3	3	3	3	3	3	3
Coke plants	21	22	22	19	19	17	17
Other industrial ⁵	52	50	50	52	52	53	53
Coal-to-liquids heat and power	0	0	0	19	47	34	90
Coal-to-liquids liquids production	0	0	0	18	44	32	85
Electric power ⁶	975	839	861	952	962	998	1028
Total coal use	1051	914	936	1063	1127	1137	1276
Average minemouth price⁷							
(2010 dollars per short ton)	35.61	42.08	41.83	44.05	43.14	50.52	49.88
(2010 dollars per million Btu)	1.76	2.08	2.07	2.23	2.21	2.56	2.54
Delivered prices⁸							
(2010 dollars per short ton)							
Coke plants	153.59	189.11	188.05	212.18	212.06	238.32	237.86
Other industrial ⁵	59.28	70.14	70.04	72.77	73.23	78.53	79.88
Coal to liquids	--	18.65	18.62	39.03	36.06	41.54	43.46
Electric power ⁶							
(2010 dollars per short ton)	44.27	45.17	44.94	48.13	48.40	53.31	55.05
(2010 dollars per million Btu)	2.26	2.35	2.34	2.54	2.55	2.80	2.87
Average	47.17	49.95	49.60	51.90	51.28	56.48	56.89
Exports ⁹	120.41	140.89	140.22	163.43	163.15	177.66	176.61
Cumulative electricity generating capacity additions (gigawatts)¹⁰							
Coal	0.0	9.1	9.1	13.5	18.4	16.6	39.9
Conventional	0.0	8.7	8.7	8.7	9.1	9.4	21.8
Advanced without sequestration	0.0	0.6	0.6	0.6	0.7	0.6	2.0
Advanced with sequestration	0.0	0.0	0.0	0.9	0.9	0.9	0.9
End-use generators ¹¹	0.0	-0.1	-0.1	3.4	7.8	5.6	15.2
Petroleum	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Natural gas	0.0	29.1	28.0	63.3	61.4	141.6	128.9
Nuclear / uranium	0.0	1.1	1.1	6.8	6.8	8.5	7.4
Renewables ¹²	0.0	29.6	29.3	42.2	41.3	67.4	58.2
Other	0.0	0.8	0.8	0.8	0.8	0.8	0.8
Total	0.0	69.8	68.4	126.7	128.8	235.0	235.3
Liquids from coal (million barrels per day)	0.00	0.00	0.00	0.17	0.38	0.28	0.73

¹Includes anthracite, bituminous coal, subbituminous coal, and lignite.

²Includes waste coal consumed by the electric power and industrial sectors. Waste coal supplied is counted as a supply-side item to balance the same amount of waste coal included in the consumption data.

³Excludes imports to Puerto Rico and the U.S. Virgin Islands.

⁴Production plus waste coal supplied plus net imports.

⁵Includes consumption for combined heat and power plants, except those plants whose primary business is to sell electricity, or electricity and heat, to the public. Excludes all coal use in the coal-to-liquids process.

⁶Includes all electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

⁷Includes reported prices for both open market and captive mines.

⁸Prices weighted by consumption tonnage; weighted average excludes residential and commercial prices, and export free-alongside-ship (f.a.s.) prices.

⁹F.a.s. price at U.S. port of exit.

¹⁰Cumulative additions after December 31, 2010. Includes all additions of electricity only and combined heat and power plants projected for the electric power, industrial, and commercial sectors.

¹¹Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.

¹²Includes conventional hydroelectric, geothermal, wood, wood waste, municipal waste, landfill gas, other biomass, solar, and wind power. Facilities co-firing biomass and coal are classified as coal.

-- = Not applicable.

Btu = British thermal unit.

GHG = Greenhouse gas.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2010 data based on: U.S. Energy Information Administration (EIA), *Annual Coal Report 2010*, DOE/EIA-0584(2010) (Washington, DC, November 2011); EIA, *Quarterly Coal Report, October-December 2010*, DOE/EIA-0121(2010/4Q) (Washington, DC, May 2011); and EIA, AEO2012 National Energy Modeling System run REF2012.D020112C. Projections: EIA, AEO2012 National Energy Modeling System runs REF2012.D020112C and NOGHGCONCERN.D031212A.

Results from DOE report

Table D14. Key results for coal cost cases
(million short tons per year, unless otherwise noted)

Supply, disposition, and prices	2010	2020			2035			Annual growth 2010-2035 (percent)		
		Low Coal Cost	Reference	High Coal Cost	Low Coal Cost	Reference	High Coal Cost	Low Coal Cost	Reference	High Coal Cost
Production¹	1084	1096	1034	962	1336	1212	946	0.8%	0.4%	-0.5%
Appalachia	336	281	262	253	309	291	261	-0.3%	-0.6%	-1.0%
Interior	156	168	159	159	194	198	202	0.9%	1.0%	1.0%
West	592	647	613	550	833	722	483	1.4%	0.8%	-0.8%
Waste coal supplied ²	14	13	15	18	14	19	40	0.2%	1.4%	4.4%
Net imports ³	-64	-78	-67	-73	-87	-94	-59	1.2%	1.5%	-0.3%
Total supply⁴	1034	1031	982	907	1263	1138	927	0.8%	0.4%	-0.4%
Consumption by sector										
Residential and commercial	3	3	3	3	3	3	3	-0.2%	-0.3%	-0.4%
Coke plants	21	19	18	18	17	17	16	-0.8%	-1.0%	-1.1%
Other industrial ⁵	52	51	51	50	53	53	52	0.1%	0.0%	-0.0%
Coal-to-liquids heat and power	0	15	13	12	57	34	29	--	--	--
Coal-to-liquids liquids production	0	14	12	11	54	32	27	--	--	--
Electric power ⁶	975	929	885	812	1079	998	800	0.4%	0.1%	-0.8%
Total coal use	1051	1031	982	907	1263	1137	926	0.7%	0.3%	-0.5%
Average minemouth price⁷										
(2010 dollars per short ton)	35.61	32.70	40.96	52.91	25.80	50.52	106.78	-1.3%	1.4%	4.5%
(2010 dollars per million Btu)	1.76	1.64	2.06	2.65	1.31	2.56	5.24	-1.2%	1.5%	4.5%
Delivered prices⁸										
(2010 dollars per short ton)										
Coke plants	153.59	165.27	198.45	239.32	136.73	238.32	413.77	-0.5%	1.8%	4.0%
Other industrial ⁵	59.28	60.23	70.89	84.14	50.11	78.53	127.31	-0.7%	1.1%	3.1%
Coal to liquids	--	34.43	40.67	49.20	25.22	41.54	68.76	--	--	--
Electric power ⁶										
(2010 dollars per short ton)	44.27	39.19	45.98	55.09	34.16	53.31	94.16	-1.0%	0.7%	3.1%
(2010 dollars per million Btu)	2.26	2.04	2.41	2.89	1.77	2.80	4.79	-1.0%	0.9%	3.0%
Average	47.17	42.38	49.99	60.26	35.44	56.48	100.09	-1.1%	0.7%	3.1%
Exports ⁹	120.41	121.34	155.03	187.16	96.75	177.66	338.54	-0.9%	1.6%	4.2%
Cumulative electricity generating capacity additions (gigawatts)¹⁰										
Coal	0.0	12.9	12.5	12.2	30.7	16.6	14.5	--	--	--
Conventional	0.0	8.7	8.7	8.7	19.8	9.4	8.7	--	--	--
Advanced without sequestration	0.0	0.6	0.6	0.6	1.0	0.6	0.6	--	--	--
Advanced with sequestration	0.0	0.9	0.9	0.9	0.9	0.9	0.9	--	--	--
End-use generators ¹¹	0.0	2.7	2.3	2.1	9.0	5.6	4.3	--	--	--
Petroleum	0.0	0.1	0.1	0.1	0.1	0.1	0.1	--	--	--
Natural gas	0.0	36.6	39.7	43.1	128.1	141.6	131.7	--	--	--
Nuclear / uranium	0.0	6.8	6.8	6.8	7.3	8.5	7.7	--	--	--
Renewables ¹²	0.0	34.2	34.5	41.0	67.9	67.4	65.9	--	--	--
Other	0.0	0.8	0.8	0.8	0.8	0.8	0.8	--	--	--
Total	0.0	91.3	94.3	104.0	234.9	235.0	220.6	--	--	--
Liquids from coal (million barrels per day)	0.00	0.14	0.12	0.11	0.45	0.28	0.21	--	--	--

Table D14. Key results for coal cost cases (continued)
(million short tons per year, unless otherwise noted)

Supply, disposition, and prices	2010	2020			2035			Annual growth 2010-2035 (percent)		
		Low Coal Cost	Reference	High Coal Cost	Low Coal Cost	Reference	High Coal Cost	Low Coal Cost	Reference	High Coal Cost
Cost indices										
(constant dollar index, 2010=1.000)										
Transportation rate multipliers										
Eastern railroads	1.000	0.970	1.067	1.170	0.780	1.044	1.300	-1.0%	0.2%	1.1%
Western railroads	1.000	0.870	0.963	1.050	0.750	0.999	1.250	-1.1%	-0.0%	0.9%
Mine equipment costs										
Underground	1.000	0.914	1.000	1.094	0.786	1.000	1.270	-1.0%	0.0%	1.0%
Surface	1.000	0.914	1.000	1.094	0.786	1.000	1.270	-1.0%	0.0%	1.0%
Other mine supply costs										
East of the Mississippi: all mines	1.000	0.914	1.000	1.094	0.786	1.000	1.270	-1.0%	0.0%	1.0%
West of the Mississippi: underground	1.000	0.914	1.000	1.094	0.786	1.000	1.270	-1.0%	0.0%	1.0%
West of the Mississippi: surface	1.000	0.914	1.000	1.094	0.786	1.000	1.270	-1.0%	0.0%	1.0%
Coal mining labor productivity (short tons per miner per hour)	5.55	6.29	4.92	3.67	8.06	3.88	1.68	1.5%	-1.4%	-4.7%
Average coal miner wage (2010 dollars per year)	77,466	84,135	92,285	100,436	78,164	99,537	124,954	0.0%	1.0%	1.9%

¹Includes anthracite, bituminous coal, subbituminous coal, and lignite.

²Includes waste coal consumed by the electric power and industrial sectors. Waste coal supplied is counted as a supply-side item to balance the same amount of waste coal included in the consumption data.

³Excludes imports to Puerto Rico and the U.S. Virgin Islands.

⁴Production plus waste coal supplied plus net imports.

⁵Includes consumption for combined heat and power plants, except those plants whose primary business is to sell electricity, or electricity and heat, to the public. Excludes all coal use in the coal to liquids process.

⁶Includes all electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

⁷Includes reported prices for both open market and captive mines.

⁸Prices weighted by consumption tonnage; weighted average excludes residential and commercial prices, and export free-alongside-ship (f.a.s.) prices.

⁹F. a. s. price at U.S. port of exit.

¹⁰Cumulative additions after December 31, 2010. Includes all additions of electricity only and combined heat and power plants projected for the electric power, industrial, and commercial sectors.

¹¹Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.

¹²Includes conventional hydroelectric, geothermal, wood, wood waste, municipal waste, landfill gas, other biomass, solar, and wind power. Facilities co-firing biomass and coal are classified as coal.

-- = Not applicable.

Btu = British thermal unit.

Note: Totals may not equal sum of components due to independent rounding. Data for 2010 are model results and may differ slightly from official EIA data reports.

Sources: 2010 data based on: U.S. Energy Information Administration (EIA), *Annual Coal Report 2010*, DOE/EIA-0584(2010) (Washington, DC, November 2011); EIA, *Quarterly Coal Report, October-December 2010*, DOE/EIA-0121(2010/4Q) (Washington, DC, May 2011); U.S. Department of Labor, Bureau of Labor Statistics, Average Hourly Earnings of Production Workers: Coal Mining, Series ID: ceu1021210008; and EIA, AEO2012 National Energy Modeling System run REF2012.D020112C. Projections: EIA, AEO2012 National Energy Modeling System runs LCCST12.D031312A, REF2012.D020112C, and HCCST12.D031312A.

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Appendix E

NEMS overview and brief description of cases

The National Energy Modeling System

Projections in the *Annual Energy Outlook 2012 (AEO2012)* are generated using the National Energy Modeling System (NEMS) [142], developed and maintained by the Office of Energy Analysis of the U.S. Energy Information Administration (EIA). In addition to its use in developing the *Annual Energy Outlook (AEO)* projections, NEMS is also used to complete analytical studies for the U.S. Congress, the Executive Office of the President, other offices within the U.S. Department of Energy (DOE), and other Federal agencies. NEMS is also used by other nongovernment groups, such as the Electric Power Research Institute, Duke University, Georgia Institute of Technology, and OnLocation, Inc. In addition, the AEO projections are used by analysts and planners in other government agencies and nongovernment organizations.

The projections in NEMS are developed with the use of a market-based approach, subject to regulations and standards. For each fuel and consuming sector, NEMS balances energy supply and demand, accounting for economic competition among the various energy fuels and sources. The time horizon of NEMS extends to 2035. To represent regional differences in energy markets, the component modules of NEMS function at the regional level: the nine Census divisions for the end-use demand modules; production regions specific to oil, natural gas, and coal supply and distribution; 22 regions and subregions of the North American Electric Reliability Corporation for electricity, and the five Petroleum Administration for Defense Districts (PADDs) for refineries.

NEMS is organized and implemented as a modular system. The modules represent each of the fuel supply markets, conversion sectors, and end-use consumption sectors of the energy system. The modular design also permits the use of the methodology and level of detail most appropriate for each energy sector. NEMS executes each of the component modules to solve for prices of energy delivered to end users and the quantities consumed, by product, region, and sector. The delivered fuel prices encompass all the activities necessary to produce, import, and transport fuels to end users. The information flows also include other data on such areas as economic activity, domestic production, and international petroleum supply. NEMS calls each supply, conversion, and end-use demand module in sequence until the delivered prices of energy and the quantities demanded have converged within tolerance, thus achieving an economic equilibrium of supply and demand in the consuming sectors. A solution is reached annually through the projection horizon. Other variables, such as petroleum product imports, crude oil imports, and several macroeconomic indicators, also are evaluated for convergence.

Each NEMS component represents the impacts and costs of legislation and environmental regulations that affect that sector. NEMS accounts for all combustion-related carbon dioxide (CO₂) emissions, as well as emissions of sulfur dioxide, nitrogen oxides, and mercury from the electricity generation sector.

The version of NEMS used for *AEO2012* generally represents current legislation and environmental regulations, including recent government actions, for which implementing regulations were available as of December 31, 2011, such as: the Mercury and Air Toxics Standards (MATS) [143] issued by the U.S. Environmental Protection Agency (EPA) in December 2011; the Cross-State Air Pollution Rule (CSAPR) [144] as finalized by the EPA in July 2011; the new fuel efficiency standards for medium- and heavy-duty vehicles (HDVs) published by the EPA and the National Highway Traffic Safety Administration (NHTSA) in September 2011 [145]; California's cap-and-trade program authorized by Assembly Bill (AB) 32, the Global Warming Solutions Act of 2006 [146]; the EPA policy memo regarding compliance of surface coal mining operations in Appalachia [147], issued on July 21, 2011; and the American Recovery and Reinvestment Act of 2009 (ARRA2009) [148], which was enacted in mid-February 2009.

The potential impacts of proposed Federal and State legislation, regulations, or standards—or of sections of legislation that have been enacted but require funds or implementing regulations that have not been provided or specified—are not reflected in NEMS. However, many pending provisions are examined in alternative cases included in *AEO2012* or in other analyses completed by EIA.

In general, the historical data presented with the *AEO2012* projections are based on EIA's *Annual Energy Review 2010*, published in October 2011 [149]; however, data were taken from multiple sources. In some cases, only partial or preliminary data were available for 2010. Historical numbers are presented for comparison only and may be estimates. Source documents should be consulted for the official data values. Footnotes to the *AEO2012* appendix tables indicate the definitions and sources of historical data.

Where possible, the *AEO2012* projections for 2011 and 2012 incorporate short-term projections from EIA's December 2011 *Short-Term Energy Outlook (STEO)*. For short-term energy projections, readers are referred to monthly updates of the *STEO* [150].

Component modules

The component modules of NEMS represent the individual supply, demand, and conversion sectors of domestic energy markets and also include international and macroeconomic modules. In general, the modules interact through values representing prices or expenditures for energy delivered to the consuming sectors and the quantities of end-use energy consumption.

Macroeconomic Activity Module

The Macroeconomic Activity Module (MAM) provides a set of macroeconomic drivers to the energy modules and receives energy-related indicators from the NEMS energy components as part of the macroeconomic feedback mechanism within NEMS.

Energy Demand and Supply Projections

Key macroeconomic variables used in the energy modules include gross domestic product (GDP), disposable income, value of industrial shipments, new housing starts, sales of new light-duty vehicles (LDVs), interest rates, and employment. Key energy indicators fed back to the MAM include aggregate energy prices and costs. The MAM uses the following models from IHS Global Insight: Macroeconomic Model of the U.S. Economy, National Industry Model, and National Employment Model. In addition, EIA has constructed a Regional Economic and Industry Model to project regional economic drivers, and a Commercial Floorspace Model to project 13 floorspace types in 9 Census divisions. The accounting framework for industrial value of shipments uses the North American Industry Classification System (NAICS).

International Energy Module

The International Energy Module (IEM) uses assumptions of economic growth and expectations of future U.S. and world petroleum and other liquids production and consumption, by year, to project the interaction of U.S. and international petroleum and other liquids markets. The IEM computes world oil prices, provides a world crude-like liquids supply curve, generates a worldwide oil supply/demand balance for each year of the projection period, and computes initial estimates of crude oil and light and heavy petroleum product imports to the United States by PADD regions. The supply-curve calculations are based on historical market data and a world oil supply/demand balance, which is developed from reduced-form models of international petroleum and other liquids supply and demand, current investment trends in exploration and development, and long-term resource economics by country and territory. The oil production estimates include both conventional and other liquids supply recovery technologies.

In interacting with the rest of NEMS, the IEM changes the oil price—which is defined as the price of light, low-sulfur crude oil delivered to Cushing, Oklahoma (PADD 2)—in response to changes in expected production and consumption of crude oil and other liquids in the United States.

Residential and Commercial Demand Modules

The Residential Demand Module projects energy consumption in the residential sector by Census division, housing type, and end use, based on delivered energy prices, the menu of equipment available, the availability of renewable sources of energy, and changes in the housing stock. The Commercial Demand Module projects energy consumption in the commercial sector by Census division, building type, and category of end use, based on delivered prices of energy, availability of renewable sources of energy, and changes in commercial floorspace.

Both modules estimate the equipment stock for the major end-use services, incorporating assessments of advanced technologies, representations of renewable energy technologies, and the effects of both building shell and appliance standards. The modules also include projections of distributed generation. The Commercial Demand Module also incorporates combined heat and power (CHP) technology. Both modules incorporate changes to “normal” heating and cooling degree-days by Census division, based on a 10-year average and on State-level population projections. The Residential Demand Module projects an increase in the average square footage of both new construction and existing structures, based on trends in new construction and remodeling.

Industrial Demand Module

The Industrial Demand Module (IDM) projects the consumption of energy for heat and power, as well as the consumption of feedstocks and raw materials in each of 21 industry groups, subject to the delivered prices of energy and macroeconomic estimates of employment and the value of shipments for each industry. As noted in the description of the MAM, the representation of industrial activity in NEMS is based on the NAICS. The industries are classified into three groups—energy-intensive manufacturing, non-energy-intensive manufacturing, and nonmanufacturing. Of the eight energy-intensive manufacturing industries, seven are modeled in the IDM, including energy-consuming components for boiler/steam/cogeneration, buildings, and process/assembly use of energy. Energy demand for petroleum refining (the eighth energy-intensive manufacturing industry) is modeled in the Petroleum Market Module (PMM), as described below, but the projected consumption is reported under the industrial totals.

There are several updates and upgrades in the representations of select industries. The base year for the bulk chemical industry has been updated to 2006 in keeping with updates to EIA’s 2006 Manufacturing Energy Consumption Survey [151]. AEO2012 also includes an upgraded representation for the cement and lime industries and agriculture. Instead of assuming that technological development for a particular process occurs on a predetermined (exogenous) path based on engineering judgment, these upgrades allow IDM technological change to be modeled endogenously, while using more detailed process representation. The upgrade allows for technological change, and therefore energy intensity, to respond to economic, regulatory, and other conditions. For subsequent AEOs, other industries represented in the IDM projections will be similarly upgraded.

A generalized representation of CHP is included. A revised methodology for CHP systems, implemented for AEO2012, simulates the utilization of installed CHP systems based on historical utilization rates and is driven by end-use electricity demand. To evaluate the economic benefits of additional CHP capacity, the model also includes an updated appraisal incorporating historical rather than assumed capacity factors and regional acceptance rates for new CHP facilities. The evaluation of CHP systems still uses a discount rate, which is equal to the projected 10-year Treasury bill rate plus a risk premium.

Transportation Demand Module

The Transportation Demand Module projects consumption of energy in the transportation sector—including petroleum products, electricity, methanol, ethanol, compressed natural gas (CNG), and hydrogen—by transportation mode, subject to delivered energy prices and macroeconomic variables such as disposable personal income, GDP, population, interest rates, and industrial shipments. The Transportation Demand Module includes legislation and regulations, such as the Energy Policy Act of 2005 (EPACT2005), the Energy Improvement and Extension Act of 2008 (EIEA2008), and the ARRA2009, which contain tax credits for the purchase of alternatively fueled vehicles. Fleet vehicles are also modeled, allowing for analysis of legislative proposals specific to those markets. Representations of LDV Corporate Average Fuel Economy (CAFE) and greenhouse gas (GHG) emissions standards, HDV fuel consumption and GHG emissions standards, and biofuels consumption in the module reflect standards enacted by NHTSA and the EPA, as well as provisions in the Energy Independence and Security Act of 2007 (EISA2007).

The air transportation component of the Transportation Demand Module explicitly represents air travel in domestic and foreign markets and includes the industry practice of parking aircraft in both domestic and international markets to reduce operating costs, as well as the movement of aging aircraft from passenger to cargo markets. For passenger travel and air freight shipments, the module represents regional fuel use in regional, narrow-body, and wide-body aircraft. An infrastructure constraint, which is also modeled, can potentially limit overall growth in passenger and freight air travel to levels commensurate with industry-projected infrastructure expansion and capacity growth.

Electricity Market Module

There are three primary submodules of the Electricity Market Module—capacity planning, fuel dispatching, and finance and pricing. The capacity expansion submodule uses the stock of existing generation capacity, the cost and performance of future generation capacity, expected fuel prices, expected financial parameters, expected electricity demand, and expected environmental regulations to project the optimal mix of new generation capacity that should be added in future years. The fuel dispatching submodule uses the existing stock of generation equipment types, their operation and maintenance costs and performance, fuel prices to the electricity sector, electricity demand, and all applicable environmental regulations to determine the least-cost way to meet that demand. The submodule also determines transmission and pricing of electricity. The finance and pricing submodule uses capital costs, fuel costs, macroeconomic parameters, environmental regulations, and load shapes to estimate generation costs for each technology.

All specifically identified options promulgated by the EPA for compliance with the Clean Air Act Amendments of 1990 are explicitly represented in the capacity expansion and dispatch decisions. All financial incentives for power generation expansion and dispatch specifically identified in EPACT2005 have been implemented. Several States, primarily in the Northeast, have enacted air emission regulations for CO₂ that affect the electricity generation sector, and those regulations are represented in AEO2012. The AEO2012 Reference case also imposes a limit on power sector CO₂ emissions for plants serving California, to represent the power sector impacts of California's AB 32. The AEO2012 Reference case reflects the CSAPR as finalized by the EPA on July 6, 2011, requiring reductions in emissions from power plants that contribute to ozone and fine particle pollution in 28 States. Reductions in mercury emissions from coal- and oil-fired power plants also are reflected through the inclusion of the mercury and air toxics standards for power plants, finalized by the EPA on December 16, 2011.

Although currently there is no Federal legislation in place that restricts GHG emissions, regulators and the investment community have continued to push energy companies to invest in technologies that are less GHG-intensive. The trend is captured in the AEO2012 Reference case through a 3-percentage-point increase in the cost of capital, when evaluating investments in new coal-fired power plants, new coal-to-liquids (CTL) plants without carbon capture and storage (CCS), and for pollution control retrofits.

Renewable Fuels Module

The Renewable Fuels Module (RFM) includes submodules representing renewable resource supply and technology input information for central-station, grid-connected electricity generation technologies, including conventional hydroelectricity, biomass (dedicated biomass plants and co-firing in existing coal plants), geothermal, landfill gas, solar thermal electricity, solar photovoltaics (PV), and both onshore and offshore wind energy. The RFM contains renewable resource supply estimates representing the regional opportunities for renewable energy development. Investment tax credits (ITCs) for renewable fuels are incorporated, as currently enacted, including a permanent 10-percent ITC for business investment in solar energy (thermal nonpower uses as well as power uses) and geothermal power (available only to those projects not accepting the production tax credit [PTC] for geothermal power). In addition, the module reflects the increase in the ITC to 30 percent for solar energy systems installed before January 1, 2017. The extension of the credit to individual homeowners under EIEA2008 is reflected in the Residential and Commercial Demand Modules.

PTCs for wind, geothermal, landfill gas, and some types of hydroelectric and biomass-fueled plants also are represented. They provide a credit of up to 2.2 cents per kilowatthour for electricity produced in the first 10 years of plant operation. For AEO2012, new wind plants coming on line before January 1, 2013, are eligible to receive the PTC; other eligible plants must be in service before January 1, 2014. As part of the ARRA2009, plants eligible for the PTC may instead elect to receive a 30-percent ITC or an equivalent direct grant. AEO2012 also accounts for new renewable energy capacity resulting from State renewable portfolio standard programs, mandates, and goals, as described in *Assumptions to the Annual Energy Outlook 2012* [152].

Oil and Gas Supply Module

The Oil and Gas Supply Module represents domestic crude oil and natural gas supply within an integrated framework that captures the interrelationships among the various sources of supply—onshore, offshore, and Alaska—by all production techniques, including natural gas recovery from coalbeds and low-permeability formations of sandstone and shale. The framework analyzes cash flow and profitability to compute investment and drilling for each of the supply sources, based on the prices for crude oil and natural gas, the domestic recoverable resource base, and the state of technology. Oil and natural gas production activities are modeled for 12 supply regions, including 6 onshore, 3 offshore, and 3 Alaskan regions.

The Onshore Lower 48 Oil and Gas Supply Submodule evaluates the economics of future exploration and development projects for crude oil and natural gas at the play level. Crude oil resources include conventional resources as well as highly fractured continuous zones, such as the Austin chalk and Bakken shale formations. Production potential from advanced secondary recovery techniques (such as infill drilling, horizontal continuity, and horizontal profile) and enhanced oil recovery (such as CO₂ flooding, steam flooding, polymer flooding, and profile modification) are explicitly represented. Natural gas resources include high-permeability carbonate and sandstone, tight gas, shale gas, and coalbed methane.

Domestic crude oil production quantities are used as inputs to the PMM in NEMS for conversion and blending into refined petroleum products. Supply curves for natural gas are used as inputs to the Natural Gas Transmission and Distribution Module (NGTDM) for determining natural gas wellhead prices and domestic production.

Natural Gas Transmission and Distribution Module

The NGTDM represents the transmission, distribution, and pricing of natural gas, subject to end-use demand for natural gas and the availability of domestic natural gas and natural gas traded on the international market. The module tracks the flows of natural gas and determines the associated capacity expansion requirements in an aggregate pipeline network, connecting the domestic and foreign supply regions with 12 lower 48 U.S. demand regions. The 12 lower 48 regions align with the 9 Census divisions, with three subdivided, and Alaska handled separately. The flow of natural gas is determined for both a peak and off-peak period in the year, assuming a historically based seasonal distribution of natural gas demand. Key components of pipeline and distributor tariffs are included in separate pricing algorithms. An algorithm is included to project the addition of CNG retail fueling capability. The module also accounts for foreign sources of natural gas, including pipeline imports and exports to Canada and Mexico, as well as liquefied natural gas (LNG) imports and exports. For *AEO2012*, LNG exports and re-exports were set exogenously and assumed to reach and maintain a total level of 903 billion cubic feet per year by 2020.

Petroleum Market Module

The PMM projects prices of petroleum products, crude oil and product import activity, and domestic refinery operations, subject to demand for petroleum products, availability and price of imported petroleum, and domestic production of crude oil, natural gas liquids, and biofuels—ethanol, biodiesel, biomass-to-liquids (BTL), CTL, gas-to-liquids (GTL), and coal-and-biomass-to-liquids (CBTL). Costs, performance, and first dates of commercial availability for the advanced other liquids technologies [153] are reviewed and updated annually.

The module represents refining activities in the five PADDs, as well as a less detailed representation of refining activities in the rest of the world. It models the costs of automotive fuels, such as conventional and reformulated gasoline, and includes production of biofuels for blending in gasoline and diesel. Fuel ethanol and biodiesel are included in the PMM, because they are commonly blended into petroleum products. The module allows ethanol blending into gasoline at 10 percent or less by volume (E10), 15 percent by volume (E15) in States that lack explicit language capping ethanol volume or oxygen content, and up to 85 percent by volume (E85) for use in flex-fuel vehicles.

The PMM includes representation of the Renewable Fuels Standard (RFS) included in EISA2007, which mandates the use of 36 billion gallons of ethanol equivalent renewable fuel by 2022. Both domestic and imported ethanol count toward the RFS. Domestic ethanol production is modeled for three feedstock categories: corn, cellulosic plant materials, and advanced feedstock materials. Starch-based ethanol plants are numerous (more than 190 are now in operation, with a total maximum sustainable nameplate capacity of more than 14 billion gallons annually), and they are based on a well-known technology that converts starch and sugar into ethanol. Ethanol from cellulosic sources is a new technology with only a few small pilot plants in operation. Ethanol from advanced feedstocks—defined as plants that ferment and distill grains other than corn and reduce GHG emissions by at least 50 percent—is also a new technology modeled in the PMM.

Fuels produced by Fischer-Tropsch synthesis and through a pyrolysis process are also modeled in the PMM, based on their economics relative to competing feedstocks and products. The five processes modeled are CTL, CBTL, GTL, BTL, and pyrolysis.

Coal Market Module

The Coal Market Module (CMM) simulates mining, transportation, and pricing of coal, subject to end-use demand for coal differentiated by heat and sulfur content. U.S. coal production is represented in the CMM by 41 separate supply curves—differentiated by region, mine type, coal rank, and sulfur content. The coal supply curves respond to capacity utilization of mines, mining capacity, labor productivity, and factor input costs (mining equipment, mining labor, and fuel requirements). Projections of

U.S. coal distribution are determined by minimizing the cost of coal supplied, given coal demands by region and sector, environmental restrictions, and accounting for minemouth prices, transportation costs, and coal supply contracts. Over the projection horizon, coal transportation costs in the CMM vary in response to changes in the cost of rail investments.

The CMM produces projections of U.S. steam and metallurgical coal exports and imports in the context of world coal trade, determining the pattern of world coal trade flows that minimizes production and transportation costs while meeting a specified set of regional world coal import demands, subject to constraints on export capacities and trade flows. The international coal market component of the module computes trade in 3 types of coal for 17 export regions and 20 import regions. U.S. coal production and distribution are computed for 14 supply regions and 16 demand regions.

Annual Energy Outlook 2012 cases

Table E1 provides a summary of the cases produced as part of *AEO2012*. For each case, the table gives the name used in *AEO2012*, a brief description of the major assumptions underlying the projections, and a reference to the pages in the body of the report and in this appendix where the case is discussed. The text sections following Table E1 describe the various cases. The Reference case assumptions for each sector are described in *Assumptions to the Annual Energy Outlook 2012* [154]. Regional results and other details of the projections are available at website www.eia.gov/aeo/supplement.

Macroeconomic growth cases

In addition to the *AEO2012* Reference case, Low Economic Growth and High Economic Growth cases were developed to reflect the uncertainty in projections of economic growth. The alternative cases are intended to show the effects of alternative growth assumptions on energy market projections. The cases are described as follows:

- In the Reference case, population grows by 0.9 percent per year, nonfarm employment by 1.0 percent per year, and labor productivity by 1.9 percent per year from 2010 to 2035. Economic output as measured by real GDP increases by 2.5 percent per year from 2010 through 2035, and growth in real disposable income per capita averages 1.5 percent per year.
- The Low Economic Growth case assumes lower growth rates for population (0.8 percent per year) and labor productivity (1.5 percent per year), resulting in lower nonfarm employment (0.8 percent per year), higher prices and interest rates, and lower growth in industrial output. In the Low Economic Growth case, economic output as measured by real GDP increases by 2.0 percent per year from 2010 through 2035, and growth in real disposable income per capita averages 1.3 percent per year.
- The High Economic Growth case assumes higher growth rates for population (1.0 percent per year) and labor productivity (2.2 percent per year), resulting in higher nonfarm employment (1.2 percent per year). With higher productivity gains and employment growth, inflation and interest rates are lower than in the Reference case, and consequently economic output grows at a higher rate (3.0 percent per year) than in the Reference case (2.5 percent). Disposable income per capita grows by 1.6 percent per year, compared with 1.5 percent in the Reference case.

Oil price cases

The oil price in *AEO2012* is defined as the average price of light, low-sulfur crude oil delivered in Cushing, Oklahoma, and is similar to the price for light, sweet crude oil traded on the New York Mercantile Exchange, referred to as West Texas Intermediate (WTI). *AEO2012* also includes a projection of the U.S. annual average refiners' acquisition cost of imported crude oil, which is more representative of the average cost of all crude oils used by domestic refiners.

The historical record shows substantial variability in oil prices, and there is arguably even more uncertainty about future prices in the long term. *AEO2012* considers three oil price cases (Reference, Low Oil Price, and High Oil Price) to allow an assessment of alternative views on the future course of oil prices.

The Low and High Oil Price cases reflect a wide range of potential price paths, resulting from variation in demand by countries outside the Organization for Economic Cooperation and Development (OECD) for petroleum and other liquid fuels due to different levels of economic growth. The Low and High Oil Price cases also reflect different assumptions about decisions by members of the Organization of the Petroleum Exporting Countries (OPEC) regarding the preferred rate of oil production and about the future finding and development costs and accessibility of conventional oil resources outside the United States.

- In the Reference case, real oil prices rise from a \$93 per barrel (2010 dollars) in 2011 to \$145 per barrel in 2035. The Reference case represents EIA's current judgment regarding exploration and development costs and accessibility of oil resources. It also assumes that OPEC producers will choose to maintain their share of the market and will schedule investments in incremental production capacity so that OPEC's conventional oil production will represent about 40 percent of the world's total petroleum and other liquids production over the projection period.
- In the Low Oil Price case, crude oil prices are only \$62 per barrel (2010 dollars) in 2035, compared with \$145 per barrel in the Reference case. In the Low Oil Price case, the low price results from lower demand for petroleum and other liquid fuels in the non-OECD nations. Lower demand is derived from lower economic growth relative to the Reference case. In this case, GDP growth in the non-OECD countries is reduced by 1.5 percentage points relative to Reference case in each projection year, beginning in 2015. The OECD projections are affected only by the price impact. On the supply side, OPEC countries increase

Table E1. Summary of the AEO2012 cases

Case name	Description	Reference in text	Reference in Appendix E
Reference	Baseline economic growth (2.5 percent per year from 2010 through 2035), oil price, and technology assumptions. Complete projection tables in Appendix A. Light, sweet crude oil prices rise to about \$145 per barrel (2010 dollars) in 2035. Assumes RFS target to be met as soon as possible.	--	--
Low Economic Growth	Real GDP grows at an average annual rate of 2.0 percent from 2010 to 2035. Other energy market assumptions are the same as in the Reference case. Partial projection tables in Appendix B.	p. 72	p. 221
High Economic Growth	Real GDP grows at an average annual rate of 3.0 percent from 2010 to 2035. Other energy market assumptions are the same as in the Reference case. Partial projection tables in Appendix B.	p. 72	p. 221
Low Oil Price	Low prices result from a combination of low demand for petroleum and other liquid fuels in the non-OECD nations and higher global supply. Lower demand is measured by lower economic growth relative to the Reference case. In this case, GDP growth in the non-OECD is reduced by 1.5 percentage points in each projection year relative to Reference case assumptions, beginning in 2015. On the supply side, OPEC increases its market share to 46 percent, and the costs of other liquids production technologies are lower than in the Reference case. Light, sweet crude oil prices fall to \$62 per barrel in 2035. Partial projection tables in Appendix C.	p. 74	p. 221
High Oil Price	High prices result from a combination of higher demand for petroleum and other liquid fuels in the non-OECD nations and lower global supply. Higher demand is measured by higher economic growth relative to the Reference case. In this case, GDP growth rates for China and India are raised by 1.0 percentage point relative to the Reference case in 2012 and decline to 0.3 percentage point above the Reference case in 2035. GDP growth rates for other non-OECD regions average about 0.5 percentage point above the Reference case. OPEC market share remains at about 40 percent throughout the projection, and non-OPEC petroleum production expands more slowly in the short to middle term relative to the Reference case. Light, sweet crude oil prices rise to \$200 per barrel (2010 dollars) in 2035. Partial projection tables in Appendix C.	p. 74	p. 224
No Sunset	Begins with the Reference case and assumes extension of all existing energy policies and legislation that contain sunset provisions, except those requiring additional funding (e.g., loan guarantee programs) and those that involve extensive regulatory analysis, such as CAFE improvements and periodic updates of efficiency standards. Partial projection tables in Appendix D.	p. 18	p. 229
Extended Policies	Begins with the No Sunset case but excludes extension of tax credits for blenders and for other biofuels that were included in the No Sunset case. Assumes an increase in the capacity limitations on the ITC and extension of the program. The case includes additional rounds of efficiency standards for residential and commercial products, as well as new standards for products not yet covered, adds multiple rounds of national building codes by 2026, and increases LDV fuel economy standards in the transportation sector to 62 miles per gallon in 2035. Partial projection tables in Appendix D.	p. 18	p. 230
Transportation: CAFE Standards	Explores energy and market impacts assuming that LDV CAFE and GHG emissions standards proposed for model years 2017-2025 are enacted. Partial projection tables in Appendix D.	p. 29	p. 226
Transportation: High Technology Battery	Explores the impact of significant improvement in vehicle battery and non-battery system cost and performance on new LDV sales, energy consumption, and GHG emissions. Partial projection tables in Appendix D.	p. 31	p. 226
Transportation: HDV Reference	Incorporates revised CNG and LNG pricing assumptions and HDV market acceptance relative to the AEO2012 Reference case. Partial projection tables in Appendix D.	p. 40	p. 226
Transportation: HD NGV Potential	Using the HDV Reference case, explores energy and market issues associated with the assumed expansion of natural gas refueling infrastructure for the HDV market. Partial projection tables in Appendix D.	p. 39	p. 226

Table E1. Summary of the AEO2012 cases (continued)

Case name	Description	Reference in text	Reference in Appendix E
Electricity: Low Nuclear	Assumes that all nuclear plants are limited to a 60-year life (31 gigawatts of retirements), uprates are limited to the 1 gigawatt that has been reported to EIA, and planned additions are the same as in the Reference case. Partial projection tables in Appendix D.	p. 51	p. 226
Electricity: High Nuclear	Assumes that all nuclear plants are life-extended beyond 60 years (except for one announced retirement), and uprates are the same as in the Reference case. New plants include those under construction and plants that have a scheduled U.S. Nuclear Regulatory Commission (NRC) or Atomic Safety and Licensing Board hearing and use a currently certified design (e.g., AP1000). Partial projection tables in Appendix D.	p. 52	p. 227
Electricity: Reference O5	Includes CSAPR and MATS as in the Reference case, with reduced 5-year environmental investment recovery. Partial projection tables in Appendix D.	p. 47	p. 227
Electricity: Low Gas Price O5	Includes CSAPR and MATS as in the Reference case, with reduced 5-year environmental investment recovery combined with the High Estimated Ultimate Recovery (EUR) case. Partial projection tables in Appendix D.	p. 47	p. 227
Renewable Fuels: Low Renewable Technology Cost	Costs for new nonhydropower renewable generating technologies start 20 percent lower in 2012 and decline to 40 percent lower than Reference case levels in 2035. Capital costs of renewable other liquid fuel technologies start 20 percent lower in 2012 and decline to approximately 40 percent lower than Reference case levels in 2035. Partial projection tables in Appendix D.	p. 208	p. 227
Petroleum: LFMM	Changes in the refining industry in the past and prospective future are discussed in the context of the development of the Liquid Fuels Market Module (LFMM) developed for NEMS. Provides overview of large-scale trends and highlights of specific issues that may require further analysis. Partial projection tables in Appendix D.	p. 43	p. 228
Oil and Gas: Low EUR	EUR per tight oil or shale gas well is 50 percent lower than in the Reference case.	p. 60	p. 227
Oil and Gas: High EUR	The EUR per tight oil and shale gas well is 50 percent higher than in the Reference case. Partial projection tables in Appendix D.	p. 60	p. 227
Oil and Gas: High Technically Recoverable Resources (TRR)	The well spacing for all tight oil and shale gas plays is 8 wells per square mile (i.e., each well has an average drainage area of 80 acres), and the EUR for tight oil and shale gas wells is 50 percent higher than in the Reference case. Partial projection tables in Appendix D.	p. 60	p. 227
Coal: Low Coal Cost	Regional productivity growth rates for coal mining are approximately 2.8 percent per year higher than in the Reference case, and coal mining wages, mine equipment, and coal transportation rates in 2035 are between 21 and 25 percent lower than in the Reference case. Partial projection tables in Appendix D.	p. 101	p. 228
Coal: High Coal Cost	Regional productivity growth rates for coal mining are approximately 2.8 percent per year lower than in the Reference case, and coal mining wages, mine equipment, and coal transportation rates in 2035 are between 25 and 27 percent higher than in the Reference case. Partial projection tables in Appendix D.	p. 214	p. 228
Integrated 2011 Demand Technology	Referred to in text as "2011 Demand Technology." Assumes future equipment purchases in the residential and commercial sectors are based only on the range of equipment available in 2011. Energy efficiency of new industrial plant and equipment is held constant at the 2012 level over the projection period. Partial projection tables in Appendix D.	p. 27	p. 224
Integrated Best Available Demand Technology	Referred to in text as "Best Available Demand Technology." Assumes all future equipment purchases in the residential and commercial sectors are made from a menu of technologies that includes only the most efficient models available in a particular year for each fuel, regardless of cost. Partial projection tables in Appendix D.	p. 27	p. 225

Table E1. Summary of the AEO2012 cases (continued)

Case name	Description	Reference in text	Reference in Appendix E
Integrated High Demand Technology	Referred to in text as "High Demand Technology." Assumes earlier availability, lower costs, and higher efficiencies for more advanced residential and commercial equipment. For new residential and commercial construction, building shell efficiencies are assumed to meet ENERGY STAR requirements after 2016. Industrial sector assumes earlier availability, lower costs, and higher efficiency for more advanced equipment and a more rapid rate of improvement in the recovery of biomass byproducts from industrial processes. In the transportation sector, the characteristics of conventional and alternative-fuel LDVs reflect more optimistic assumptions about incremental improvements in fuel economy and costs. Freight trucks are assumed to see more rapid improvement in fuel efficiency for engine and emissions control technologies. More optimistic assumptions for fuel efficiency improvements are also made for the air, rail, and shipping sectors. Partial projection tables in Appendix D.	p. 27	p. 225
Integrated 2011 Technology	Referred to in text as "2011 Technology." Combination of the Integrated 2011 Demand Technology case with the assumption that costs of new power plants do not improve from 2012 levels throughout the projection. Partial projection tables in Appendix D.	p. 202	p. 229
Integrated High Technology	Referred to in text as "High Technology." Combination of the Integrated High Demand Technology case and the Low Renewable Technology Cost case. Also assumes that costs for new nuclear and fossil-fired power plants are lower than Reference case levels, by 20 percent in 2012 and 40 percent in 2035. Partial projection tables in Appendix D.	p. 202	p. 229
No GHG Concern	No GHG emissions reduction policy is enacted, and market investment decisions are not altered in anticipation of such a policy. Partial projection tables in Appendix D.	p. 102	p. 229
GHG15	Applies a price for CO ₂ emissions throughout the economy, starting at \$15 per metric ton in 2013 and rising by 5 percent per year through 2035. The price is set to target the same reduction in CO ₂ emissions as in the <i>Annual Energy Outlook 2011</i> (AEO2011) GHG Price Economywide case. Partial projection tables in Appendix D.	p. 46	p. 229
GHG25	Applies a price for CO ₂ emissions throughout the economy, starting at \$25 per metric ton in 2013 and rising by 5 percent per year through 2035. The price is set at the same dollar amount as in the AEO2011 GHG Price Economywide case. Partial projection tables in Appendix D.	p. 46	p. 229

their conventional oil production to obtain a 46-percent share of total world petroleum and other liquids production, and oil resources outside the United States are more accessible and/or less costly to produce (as a result of technology advances, more attractive fiscal regimes, or both) than in the Reference case.

- In the High Oil Price case, oil prices reach about \$200 per barrel (2010 dollars) in 2035. In the High Oil Price case, the high prices result from higher demand for petroleum and other liquid fuels in the non-OECD nations. Higher demand is measured by higher economic growth relative to the Reference case. In this case, GDP growth in the non-OECD region is raised by 0.1 to 1.0 percentage point relative to the Reference case in each projection year, starting in 2012. GDP growth rates for China and India are raised by 1.0 percentage points relative to the Reference case in 2012, declining to 0.3 percentage point above the Reference case in 2035. GDP growth rates for most other non-OECD regions average about 0.5 percentage point above the Reference case in each projection year. The OECD projections are affected only by the price impact. On the supply side, OPEC countries are assumed to reduce their market share somewhat, and oil resources outside the United States are assumed to be less accessible and/or more costly to produce than in the Reference case.

Buildings sector cases

In addition to the AEO2012 Reference case, three technology-focused cases using the Demand Modules of NEMS were developed to examine the effects of changes in technology. Buildings sector assumptions for the Integrated 2011 Demand Technology case and the Integrated High Demand Technology case are also used in the appropriate Integrated Technology cases.

Residential sector assumptions for the technology-focused cases are as follows:

- For the Integrated 2011 Demand Technology case it is assumed that all future residential equipment purchases are based only on the range of equipment available in 2011. Existing building shell efficiencies are assumed to be fixed at 2011 levels (no further improvements). For new construction, building shell technology options are constrained to those available in 2011.

Commercial sector assumptions for the technology-focused cases

- For the Integrated High Demand Technology case it is assumed that residential advanced equipment is available earlier, at lower costs, and/or at higher efficiencies [155]. For new construction, building shell efficiencies are assumed to meet ENERGY STAR requirements after 2016. Consumers evaluate investments in energy efficiency at a 7-percent real discount rate.
- For the Integrated Best Available Demand Technology case it is assumed that all future residential equipment purchases are made from a menu of technologies that includes only the most efficient models available in a particular year for each fuel, regardless of cost. For new construction, building shell efficiencies are assumed to meet the criteria for the most efficient components after 2011.

Commercial sector assumptions for the technology-focused cases are as follows:

- For the Integrated 2011 Demand Technology case it is assumed that all future commercial equipment purchases are based only on the range of equipment available in 2011. Building shell efficiencies are assumed to be fixed at 2011 levels.
- For the Integrated High Demand Technology case it is assumed that commercial advanced equipment is available earlier, at lower costs, and/or with higher efficiencies than in the Reference case [156]. Energy efficiency investments are evaluated at a 7-percent real discount rate. Building shell efficiencies for new and existing buildings in 2035 assume a 25-percent improvement relative to the Reference case.
- For the Integrated Best Available Demand Technology case it is assumed that all future commercial equipment purchases are made from a menu of technologies that includes only the most efficient models available in a particular year for each fuel, regardless of cost. Building shell efficiencies for new and existing buildings in 2035 assume a 50-percent improvement relative to the Reference case.

The Residential and Commercial Demand Modules of NEMS were also used to complete the Low Renewable Technology Cost case, which is discussed in more detail below, in the renewable fuels cases section. In combination with assumptions for electricity generation from renewable fuels in the electric power sector and industrial sector, this sensitivity case analyzes the impacts of changes in generating technologies that use renewable fuels and in the availability of renewable energy sources. For the Residential and Commercial Demand Modules:

- The Low Renewable Technology Cost case assumes greater improvements in residential and commercial PV and wind systems than in the Reference case. The assumptions for capital cost estimates are 20 percent below Reference case assumptions in 2012 and decline to at least 40 percent lower than Reference case costs in 2035.

The No Sunset and Extended Policies cases described below in the cross-cutting integrated cases discussion also include assumptions in the Residential and Commercial Demand Modules of NEMS. The Extended Policies case builds on the No Sunset case and adds multiple rounds of appliance standards and building codes as described below.

- The No Sunset case assumes that selected policies with sunset provisions will be extended indefinitely rather than allowed to sunset as the law currently prescribes. For the residential sector, these extensions include: personal tax credits for selected end-use equipment, including furnaces, heat pumps, and central air conditioning; personal tax credits for PV installations, solar water heaters, small wind turbines, and geothermal heat pumps; and manufacturer tax credits for refrigerators, dishwashers, and clothes washers, passed on to consumers at 100 percent of the tax credit value. For the commercial sector, business ITCs for PV installations, solar water heaters, small wind turbines, geothermal heat pumps, and CHP are extended to the end of the projection. The business tax credit for solar technologies remains at the current 30-percent level without reverting to 10 percent as scheduled.
- The Extended Policies case includes updates to appliance standards, as prescribed by the timeline in DOE's multiyear plan, and introduces new standards for products currently not covered by DOE. Efficiency levels for the updated residential appliance standards are based on current ENERGY STAR guidelines. Residential end-use technologies subject to updated standards are not eligible for No Sunset incentives in addition to the standards. Efficiency levels for updated commercial equipment standards are based on the technology menu from the AEO2012 Reference case and purchasing specifications for Federal agencies designated by the Federal Energy Management Program (FEMP). The case also adds national building codes to reach 30-percent improvement relative to the 2006 International Energy Conservation Code (IECC 2006) for residential households and to American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1-2004 for commercial buildings by 2020, with additional rounds of improved codes in 2023 and 2026.

Industrial sector cases

In addition to the AEO2012 Reference case, two technology-focused cases using the IDM of NEMS were developed that examine the effects of less rapid and more rapid technology change and adoption. The energy intensity changes discussed in this section exclude the refining industry, which is modeled separately from the IDM in the PMM. Different assumptions for the IDM were also used as part of the Integrated Low Renewable Technology Cost case, No Sunset case, and Extended Policies case, but each is structured on a set of the initial industrial assumptions used for the Integrated 2011 Demand Technology case and Integrated High Demand Technology case. For the industrial sector, assumptions for those two technology-focused cases are as follows:

- For the Integrated 2011 Demand Technology case, the energy efficiency of new industrial plant and equipment is held constant at the 2012 level over the projection period. Changes in aggregate energy intensity may result both from changing equipment and

Energy market interactions

production efficiency and from changing composition of output within an individual industry. Because all AEO2012 side cases are integrated runs, potential feedback effects from energy market interactions are captured. Hence, the level and composition of overall industrial output varies from the Reference case, and any change in energy intensity in the two technology side cases is attributable to process and efficiency changes and increased use of CHP, as well as changes in the level and composition of overall industrial output.

- For the Integrated High Demand Technology case, the IDM assumes earlier availability, lower costs, and higher efficiency for more advanced equipment [157] and a more rapid rate of improvement in the recovery of biomass byproducts from industrial processes—i.e., 0.7 percent per year, as compared with 0.4 percent per year in the Reference case. The same assumption is incorporated in the Low Renewable Technology Cost case, which focuses on electricity generation. Although the choice of the 0.7-percent annual rate of improvement in byproduct recovery is an assumption in the High Demand Technology case, it is based on the expectation of higher recovery rates and substantially increased use of CHP in that case. Due to integration with other NEMS modules, potential feedback effects from energy market interactions are captured.

The industrial No Sunset and Extended Policies cases described below in the cross-cutting integrated cases discussion also include assumptions in the IDM of NEMS. The Extended Policies case builds on the No Sunset case and modifies select industrial assumptions, which are as follows:

- The No Sunset case and Extended Policies case include an assumption for CHP that extends the existing industrial CHP ITC through the end of the projection period. Additionally, the Extended Policies case includes an increase in the capacity limitations on the ITC by increasing the cap on CHP equipment from 15 megawatts to 25 megawatts and eliminating the system-wide cap of 50 megawatts. These assumptions are based on the current proposals in H.R. 2750 and H.R. 2784 of the 112th Congress.

Transportation sector cases

In addition to the AEO2012 Reference case, the NEMS Transportation Demand Module was used to examine the effects of advanced technology costs and efficiency improvement on technology adoption and vehicle fuel economy as part of the Integrated High Demand Technology case [158]. For the Integrated High Demand Technology case, the characteristics of conventional and alternative-fuel LDVs reflect more optimistic assumptions about incremental improvements in fuel economy and costs. In the freight truck sector, the High Demand Technology case assumes more rapid incremental improvement in fuel efficiency and lower costs for engine and emissions control technologies. More optimistic assumptions for fuel efficiency improvements are also made for the air, rail, and shipping sectors.

Three additional integrated cases were developed to examine the potential energy impacts associated with the implementation of proposed model year 2017 to 2025 LDV CAFE standards, the impact of the successful development of advanced batteries, and the impact of the penetration of HDVs using LNG. The specific cases include:

- The CAFE Standards case examines the energy, GHG, and vehicle market impacts of increasing LDV fuel economy standards to reflect those proposed by the EPA and NHTSA for model years 2017-2025. Fuel economy standards are assumed to remain constant after model year 2025.
- The High Technology Battery case examines the energy, GHG emissions, and sales impacts on new LDVs associated with rapid improvement in battery cost and non-battery systems performance.
- The HDV Reference case incorporates revised pricing assumptions for CNG and LNG highway fuels and HDV market acceptance.
- The HD NGV Potential case examines the energy and GHG impacts associated with assumed significant increases in LNG refueling infrastructure to enable market adoption of natural gas use by HDVs in long-haul corridors relative to the HDV Reference case.

Electricity sector cases

In addition to the Reference case, several integrated cases with alternative electric power assumptions were developed to support discussions in the “Issues in focus” section of AEO2012. Two alternative cases were run for nuclear power plants, to address uncertainties about the operating lives of existing reactors, the potential for new nuclear capacity, and capacity uprates at existing plants. These scenarios are discussed in the “Issues in focus” article, “Nuclear power in AEO2012.”

In addition, two alternative cases were run to analyze uncertainties related to the lifetimes of coal-fired power plants due to recent environmental regulations and potential GHG legislation in the future. Over the next few years, electricity generators will begin taking steps to comply with a number of new environmental regulations, primarily by adding environmental controls at existing coal-fired power plants. The additional cases examine the impacts of shorter economic recovery periods for the environmental controls, with the natural gas prices used in the AEO2012 Reference case and lower natural gas prices.

Nuclear cases

- The Low Nuclear case assumes that all existing nuclear plants are retired after 60 years of operation. In the Reference case, existing plants are assumed to run as long as they continue to be economic, implicitly assuming that a second 20-year license renewal will be obtained for most plants that reach 60 years before 2035. The Low Nuclear case was run to analyze the impact

of additional nuclear retirements, which could occur if the oldest plants do not receive a second license extension. In this case, 31 gigawatts of nuclear capacity is assumed to be retired by 2035. The Low Nuclear case assumes that no new nuclear capacity will be added throughout the projection, excluding capacity already planned or under construction. The case also assumes that only those capacity uprates reported to EIA will be completed (1 gigawatt). The Reference case assumes additional uprates based on NRC surveys and industry reports.

- The High Nuclear case assumes that all existing nuclear units will receive a second license renewal and operate beyond 60 years (excluding one announced retirement). In the Reference case, beyond the announced retirement of Oyster Creek, an additional 5.5 gigawatts of nuclear capacity is assumed to be retired through 2035, reflecting uncertainty about the impacts and/or costs of future aging. This case was run to provide a more optimistic outlook, with all licenses renewed and all plants continuing to operate economically beyond 60 years. The High Nuclear case also assumes that additional planned nuclear capacity is completed based on combined license applications issued by the NRC. The Reference case assumes that 6.8 gigawatts of planned capacity is added, compared with 13.5 gigawatts of planned capacity additions in the High Nuclear case.

Environmental Rules cases

- The Reference 05 case assumes that the economic recovery period for investments in new environmental controls in the electric power sector is reduced from 20 years to 5 years.
- The Low Gas Price 05 case uses more optimistic assumptions about future volumes of shale gas production, leading to lower natural gas prices, combined with the 5-year recovery period for new environmental controls in the electric power sector. The domestic shale gas resource assumption comes from the High EUR case.

Renewable fuels cases

In addition to the AEO2012 Reference case, EIA developed a case with alternative assumptions about renewable fuels to examine the effects of more aggressive improvement in the cost of renewable technologies.

- In the Low Renewable Technology Cost case, the levelized costs of new nonhydropower renewable generating technologies are assumed to start at 20 percent below Reference case assumptions in 2012 and decline to 40 percent below the Reference case costs for the same resources in 2035. In general, lower costs are represented by reducing the capital costs of new plant construction. Biomass fuel supplies also are assumed to be 40 percent less expensive than for the same resource quantities used in the Reference case. Assumptions for other generating technologies are unchanged from those in the Reference case. In the Low Renewable Technology Cost case, the rate of improvement in recovery of biomass byproducts from industrial processes also is increased.
- In the No Sunset case and the Extended Policies case, expiring Federal tax credits targeting renewable electricity are assumed to be permanently extended. This applies to the PTC, which is a tax credit of 2.2 cents per kilowatthour available for the first 10 years of production by new generators using wind, geothermal, and certain biomass fuels, or a tax credit of 1.1 cents per kilowatthour available for the first 10 years of production by new generators using geothermal energy, certain hydroelectric technologies, and biomass fuels not eligible for the full credit of 2.2 cents per kilowatthour. This tax credit is scheduled to expire on December 31, 2012, for wind and 1 year later for other eligible technologies. The same schedule applies to the 30-percent ITC, which is available to new solar installations through December 31, 2016, and may also be claimed in lieu of the PTC for eligible technologies, expiring concurrently with the PTC expiration dates indicated above.

Oil and gas supply cases

The sensitivity of the AEO2012 projections to changes in assumptions regarding technically recoverable tight oil and shale gas resources are examined in two cases:

- In the Low EUR case, the EUR per tight oil or shale gas well is assumed to be 50 percent lower than in the Reference case, increasing the per-unit cost of developing the resource. The total unproved TRR of tight oil is decreased to 17 billion barrels, and the shale gas resource is decreased to 241 trillion cubic feet, as compared with unproved resource estimates of 33 billion barrels of tight oil and 482 of shale gas in the Reference case as of January 1, 2010.
- In the High EUR case, the EUR per tight oil and shale gas well is assumed to be 50 percent higher than in the Reference case, decreasing the per-unit cost of developing the resource. The total unproved technically recoverable tight oil resource is increased to 50 billion barrels, and the shale gas resource is increased to 723 trillion cubic feet.
- In the High TRR case, the well spacing for all tight oil and shale gas plays is assumed to be 8 wells per square mile (i.e., each well has an average drainage area of 80 acres), and the EUR for tight oil and shale gas wells is assumed to be 50 percent higher than in the Reference case. The total unproved technically recoverable tight oil resource is increased to 89 billion barrels, and the shale gas resource is increased to 1,091 trillion cubic feet, more than twice the Reference case assumptions for tight oil and shale gas resources.

Petroleum market cases

Production of petroleum and other liquid fuels has evolved and changed significantly in recent years as a result of changes in the mix of feedstocks, production regions, technologies, regulation and policy, and international markets. To better reflect those changes, a new LFMM has been developed for use as part of NEMS. The intent is to use the LFMM in developing the *Annual Energy Outlook 2013 (AEO2013)*. The LFMM was designed as a data-driven tool using a generalized algebraic modeling system. The LFMM uses nine types of crude oil (compared to five types in the current model). The LFMM configuration uses nine refining regions instead of the traditional five PADDs—eight domestic regions and one maritime Canada and Caribbean region that captures imports of refined products into the northeastern United States.

Market conditions and regulations have resulted in the implementation of new technologies using nonpetroleum feedstocks such as grains, biomass, pyrolysis oils, coal, biomass, and natural gas. The EISA2007 RFS mandates the use 36 billion gallons of renewable fuels by 2022, and the LFMM allows analysis of different renewable fuel capacities required to meet the mandate. Because the LFMM is a data-driven model, new technologies can be added easily to help in analysis of the RFS mandate. In addition, the LFMM has extensive representation of the RFS and other policies that affect its implementation. The technologies associated with the RFS have high development costs, and capital recovery is uncertain. That uncertainty can be analyzed by varying the market penetration rates for the technologies under different assumptions. Further, to accommodate evolving international markets, LFMM uses different approaches while interfacing with NEMS PMM. The new interface is able to work with newer crude types, as well as changes in prices for crude oil and petroleum products.

For *AEO2012*, an LFMM case was developed to test the new model and compare results with those produced by the PMM—which is the current model used for *AEO2012*—for the Reference, Low Economic Growth, High Economic Growth, Low Oil Price, and High Oil Price cases produced using the current version of the NEMS. The intent is to highlight areas where the two models produce significantly different results and explore the basis of those differences so that EIA will be able to ensure that the LFMM is ready for use as part of *AEO2013*.

Coal market cases

Two alternative coal cost cases examine the impacts on U.S. coal supply, demand, distribution, and prices that result from alternative assumptions about mining productivity, labor costs, mine equipment costs, and coal transportation rates. The alternative productivity and cost assumptions are applied in every year from 2012 through 2035. For the coal cost cases, adjustments to the Reference case assumptions for coal mining productivity are based on variation in the average annual productivity growth of 2.8 percent observed since 2000. Transportation rates are lowered (in the Low Coal Cost case) or raised (in the High Coal Cost case) from Reference case levels to achieve a 25-percent change in rates relative to the Reference case in 2035. The Low and High Coal Cost cases represent fully integrated NEMS runs, with feedback from the macroeconomic activity, international, supply, conversion, and enduse demand modules.

- In the Low Coal Cost case, the average annual growth rates for coal mining productivity are higher than those in the Reference case and are applied at the supply curve level. As an example, the average annual productivity growth rate for Wyoming's Southern Powder River Basin supply curve is increased from -1.8 percent in the Reference case for the years 2012 through 2035 to 0.8 percent in the Low Coal Cost case. Coal mining wages, mine equipment costs, and other mine supply costs all are assumed to be about 21 percent lower in 2035 in real terms in the Low Coal Cost case than in the Reference case. Coal transportation rates, excluding the impact of fuel surcharges, are assumed to be 25 percent lower in 2035.
- In the High Coal Cost case, the average annual productivity growth rates for coal mining are lower than those in the Reference case and are applied as described in the Low Coal Cost case. Coal mining wages, mine equipment costs, and other mine supply costs in 2035 are assumed to be about 27 percent higher than in the Reference case, and coal transportation rates in 2035 are assumed to be 25 percent higher.

Additional details of the productivity, wage, mine equipment cost, and coal transportation rate assumptions for the Reference and alternative coal cost cases are provided in Appendix D.

Cross-cutting integrated cases

A series of cross-cutting integrated cases are used in *AEO2012* to analyze specific cases with broader sectoral impacts. For example, three integrated technology progress cases analyze the impacts of more rapid and slower technology improvement rates in the demand sector (partially described in the sector-specific sections above), and two other integrated technology cases examine the impacts of more rapid and slower technology improvement rates across both demand and supply/conversion sectors. In addition, two cases also were run with alternative assumptions about expectations of future regulation of GHG emissions.

Integrated technology cases

In the demand sectors (residential, commercial, industrial, and transportation), technology improvement typically means greater efficiency of energy use and/or reduced cost. In the energy supply/conversion sectors (electricity generation, natural gas and petroleum and other liquids supply, petroleum refining, etc.), technology improvement tends to mean greater availability of energy supplies and/or reduced cost of production (and ultimately prices). When alternative cases that examine the impacts of variation

in the rate of technology improvement are completed, combining the demand and supply/conversion sectors, the impacts on energy markets are sometimes masked because of the offsetting nature of technology improvements in the two areas.

Two sets of alternative cases are used in *AEO2012* to examine the potential impacts of variation in the rate of technology improvement. The first set looks at impacts on the demand sector in isolation. The second set looks at the combined impacts of technology changes in both the demand and supply/conversion sectors. The three demand technology cases—Integrated 2011 Demand Technology, Integrated Best Available Demand Technology, and Integrated High Demand Technology—examine the impacts on the end-use demand sectors of variations in the rate of technology improvement, independent of the offsetting impacts of variations in technology improvement in the supply/conversion sectors.

EIA also completed two fully integrated technology cases that examine combined impacts on the demand and supply/conversion sectors. The Integrated 2011 Technology case combines the assumptions from the Integrated 2011 Demand Technology case with an assumption that the costs of new fossil, nuclear, and nonhydroelectric renewable power plants are fixed at 2012 levels and do not improve due to learning during the projection period. The Integrated High Technology case combines the assumptions from the Integrated High Demand Technology and the Low Renewable Technology Cost case with an assumption that the costs of new nuclear and fossil-fired power plants are lower than assumed in the Reference case, with costs 20 percent lower than Reference case levels in 2012 and 40 percent lower than Reference case levels in 2035.

Greenhouse gas cases

On May 13, 2010, the EPA promulgated standards for GHG emissions in the “Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule” [159]. The rule sets up levels of CO₂-equivalent emissions at new and existing facilities that make major modifications that increase GHG emissions which trigger coverage of the facilities in the New Source Review and Title V permitting program. As a result of this and prior actions, regulators and the investment community are beginning to push energy companies to invest in less GHG-intensive technologies. To reflect the market reaction to potential future GHG regulation, a 3-percentage-point increase in the cost of capital is assumed for investments in new coal-fired power plants without CCS and new CTL plants without CCS in the Reference case and all other *AEO2012* cases except the No GHG Concern, GHG15, and GHG25 cases. Those assumptions affect cost evaluations for the construction of new capacity but not the actual operating costs when a new plant begins operation.

The three alternative GHG cases are used to provide a range of potential outcomes, from no concern about future GHG legislation to the imposition of a specific economywide carbon allowance price. *AEO2012* includes two economywide CO₂ price cases, the GHG15 and GHG25 cases, which examine the impacts of economywide carbon allowance prices. In the GHG15 case, the price is set at \$15 per metric ton CO₂ in 2013. In the GHG25 case, the price is set at \$25 per metric ton CO₂ in 2013. In both cases the price begins to rise in 2014 at 5 percent per year. The GHG cases are intended to measure the sensitivity of the *AEO2012* assumptions to different CO₂ prices that are consistent with previously proposed legislation. At the time the *AEO2012* was completed, no legislation including a GHG price was pending, but the EPA is developing technology-based CO₂ standards for new coal-fired power plants. In the two GHG cases for *AEO2012*, no assumptions are made with regard to offsets, bonus allowances for CCS, or specific allocation of allowances.

The No GHG Concern case was run without any adjustment for concern about potential GHG regulations (without the 3-percentage-point increase in the cost of capital). In the No GHG Concern case, the same cost of capital is used to evaluate all new capacity builds, regardless of type.

No Sunset case

In addition to the *AEO2012* Reference case, a No Sunset case was run assuming that selected policies with sunset provisions—such as the PTC, ITC, and tax credits for energy-efficient equipment in the buildings and industrial sectors—will be extended indefinitely rather than allowed to sunset as the law currently prescribes.

For the residential sector, the extensions include: (a) personal tax credits for selected end-use equipment, including furnaces, heat pumps, and central air conditioning; (b) personal tax credits for PV installations, solar water heaters, small wind turbines, and geothermal heat pumps; (c) manufacturer tax credits for refrigerators, dishwashers, and clothes washers, passed on to consumers at 100 percent of the tax credit value.

For the commercial sector, business ITCs for PV installations, solar water heaters, small wind turbines, geothermal heat pumps, and CHP are extended to the end of the projection. The business tax credit for solar technologies remains at the current 30-percent level without reverting to 10 percent as scheduled.

In the industrial sector, the existing ITC for industrial CHP, which currently ends in 2016, is extended to 2035.

For the refinery sector, blending credits are extended; the \$1.00 per gallon biodiesel tax credit is extended; the \$0.54 per gallon tariff on imported ethanol is extended; and the \$1.01 per gallon PTC for cellulosic biofuels is extended.

For renewables, the PTC of 2.2 cents per kilowatthour for wind, geothermal, and certain biomass and the PTC of 1.1 cents per kilowatthour for hydroelectric and landfill gas resources, which currently are set to expire at the end of 2012 for wind and the end of 2013 for other eligible resources, are extended to 2035; and the 30-percent solar power ITC, which currently is scheduled to revert to 10 percent in 2016, is extended indefinitely.

Extended Policies case

In the Extended Policies case, assumptions for tax credit extensions are the same as in the No Sunset case described above with the exception of the PTC extension for cellulosic biofuels and the tax credits for residential equipment subject to updated Federal efficiency standards, which are dropped. Further, updates to Federal appliance efficiency standards are assumed to occur at regular intervals, and new standards for products not currently covered by DOE are assumed to be introduced. Finally, proposed rules by NHTSA and the EPA for national tailpipe CO₂-equivalent emissions and fuel economy standards for LDVs, including both passenger cars and light-duty trucks, are harmonized and incorporated in this case.

Updates to appliance standards are assumed to occur as prescribed by the timeline in DOE's multi-year plan, and new standards for products currently not covered by DOE are introduced by 2019. The efficiency levels chosen for the updated residential appliance standards are based on current ENERGY STAR guidelines. Residential end-use technologies subject to updated standards are not eligible for No Sunset incentives in addition to the standards. The efficiency levels chosen for updated commercial equipment standards are based on the technology menu from the AEO2011 Reference case and either FEMP-designated purchasing specifications for Federal agencies or ENERGY STAR guidelines. National building codes are added to reach 30-percent improvement relative to IECC 2006 for residential households and ASHRAE 90.1-2004 for commercial buildings by 2020, with additional rounds of improvements in 2023 and 2026.

In the industrial sector, the ITC for industrial CHP is further extended to cover all system sizes rather than applying only to systems under 50 megawatts, and the CHP equipment cap is increased from 15 megawatts to 25 megawatts. These extensions are consistent with previously proposed legislation (S. 1639) or pending legislation (H.R. 2750 and 2784).

For transportation, the Extended Policies case assumes that the standards are further increased, so that the minimum fuel economy standard achieved by LDVs continues to increase through 2035.

Endnotes for Appendix E

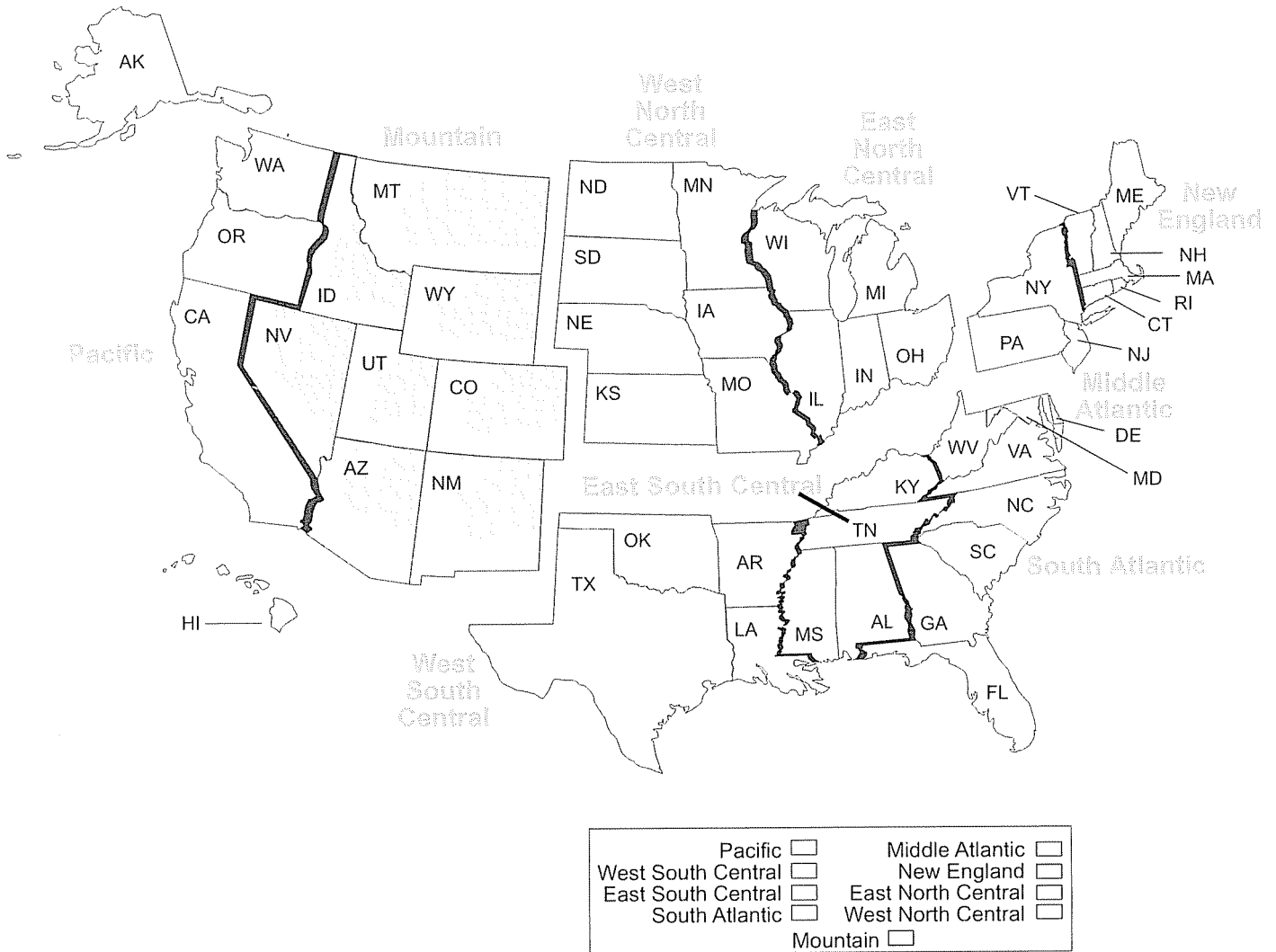
Links current as of April 2012

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143. U.S. Environmental Protection Agency, "Mercury and Air Toxics Standards," website www.epa.gov/mats
144. U.S. Environmental Protection Agency, "Cross-State Air Pollution Rule (CSAPR)," website epa.gov/airtransport. CSAPR was scheduled to begin on January 1, 2012, however, the U.S. Court of Appeals for the D.C. Circuit issued a stay delaying implementation while it addresses legal challenges to the rule that have been raised by several power companies and States. CSAPR is included in AEO2012 despite the stay, because the Court of Appeals had not made a final ruling at the time AEO2012 was published.
145. U.S. Environmental Protection Agency and National Highway Traffic Safety Administration, "Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles, Final Rule," *Federal Register*, Vol. 76, No. 179 (September 15, 2011), pp. 57106-57513, website www.gpo.gov/fdsys/pkg/FR-2011-09-15/html/2011-20740.htm.
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152. U.S. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2012*, DOE/EIA-0554(2012) (Washington, DC: June 2012), website www.eia.gov/forecasts/aeo/assumptions.
153. Alternative other liquids technologies include all biofuels technologies plus CTL and GTL.
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155. High technology assumptions for the residential sector are based on U.S. Energy Information Administration, *EIA—Technology Forecast Updates—Residential and Commercial Building Technologies—Advanced Case* (Navigant Consulting, Inc. with SAIC, September 2011), and *EIA—Technology Forecast Updates—Residential and Commercial Building Technologies—Advanced Case: Residential and Commercial Lighting, Commercial Refrigeration, and Commercial Ventilation Technologies* (Navigant Consulting, Inc., September 2008).
156. High technology assumptions for the commercial sector are based on Energy Information Administration, *EIA—Technology Forecast Updates—Residential and Commercial Building Technologies—Advanced Case* (Navigant Consulting, Inc. with SAIC, September 2011), and *EIA—Technology Forecast Updates—Residential and Commercial Building Technologies—Advanced Case: Residential and Commercial Lighting, Commercial Refrigeration, and Commercial Ventilation Technologies* (Navigant Consulting, Inc., September 2008).
157. These assumptions are based in part on Energy Information Administration, *Industrial Technology and Data Analysis Supporting the NEMS Industrial Model* (FOCIS Associates, October 2005).
158. U.S. Energy Information Administration, *Documentation of Technologies Included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks* (Energy and Environmental Analysis, September 2003).
159. U.S. Environmental Protection Agency, "Final Rule: Prevention of Significant Deterioration and Title V Greenhouse Gas Tailoring Rule," website www.epa.gov/nsr/documents/20100413fs.pdf.

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Appendix F Regional Maps

Figure F1. United States Census Divisions



Source: U.S. Energy Information Administration, Office of Energy Analysis

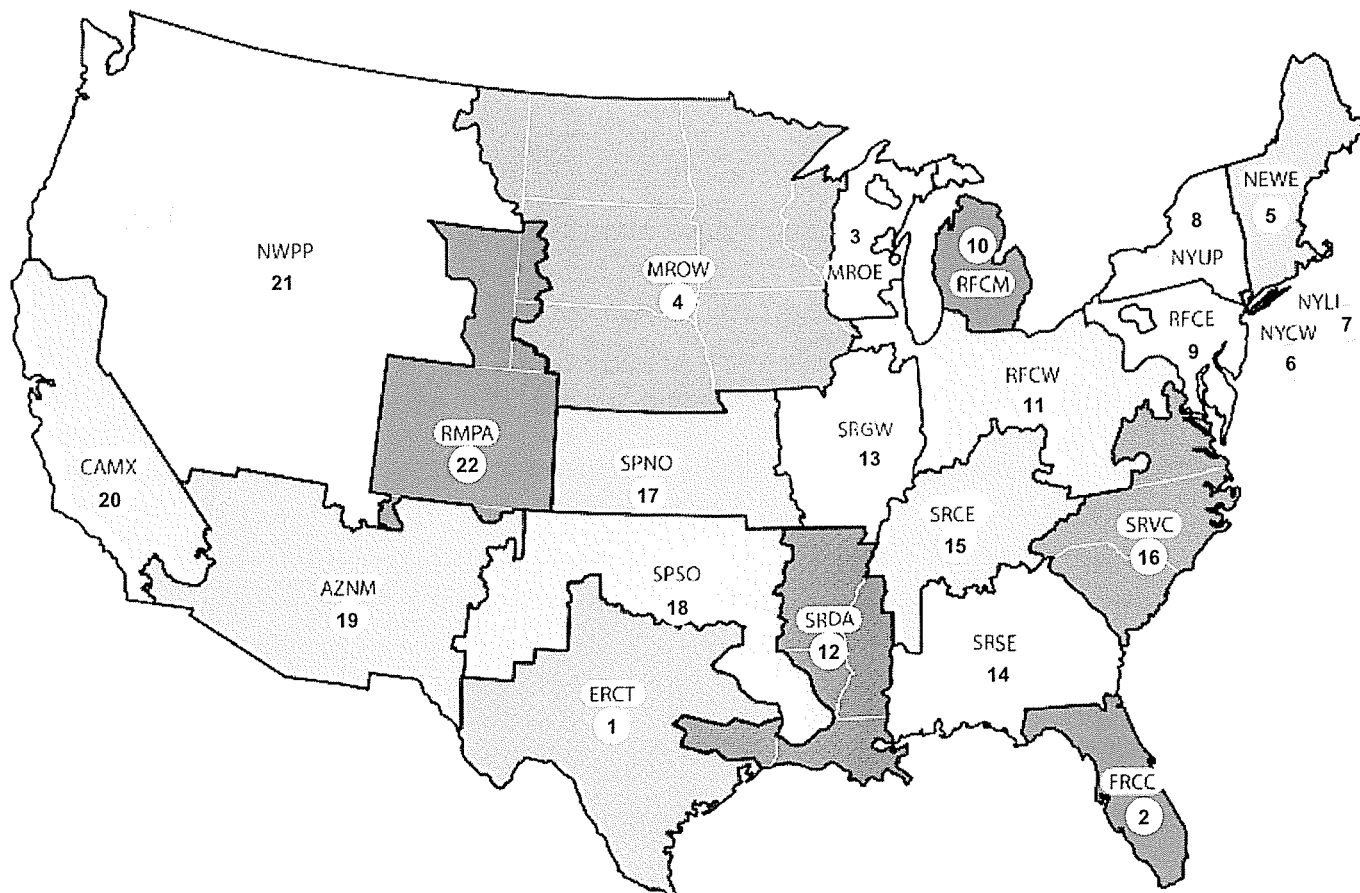
Continued

Figure P1. United States Census Divisions (continued)

<u>Division 1</u> New England	<u>Division 3</u> East North Central	<u>Division 5</u> South Atlantic	<u>Division 7</u> West South Central	<u>Division 9</u> Pacific
Connecticut Maine Massachusetts New Hampshire Rhode Island Vermont	Illinois Indiana Michigan Ohio Wisconsin	Delaware District of Columbia Florida Georgia Maryland North Carolina South Carolina Virginia West Virginia	Arkansas Louisiana Oklahoma Texas	Alaska California Hawaii Oregon Washington
<u>Division 2</u> Middle Atlantic	<u>Division 4</u> West North Central	<u>Division 6</u> East South Central	<u>Division 8</u> Mountain	
New Jersey New York Pennsylvania	Iowa Kansas Minnesota Missouri Nebraska North Dakota South Dakota	Alabama Kentucky Mississippi Tennessee	Arizona Colorado Idaho Montana Nevada New Mexico Utah Wyoming	

Source: U.S. Energy Information Administration, Office of Energy Analysis

Figure F2 Electricity market nodes (cont.)

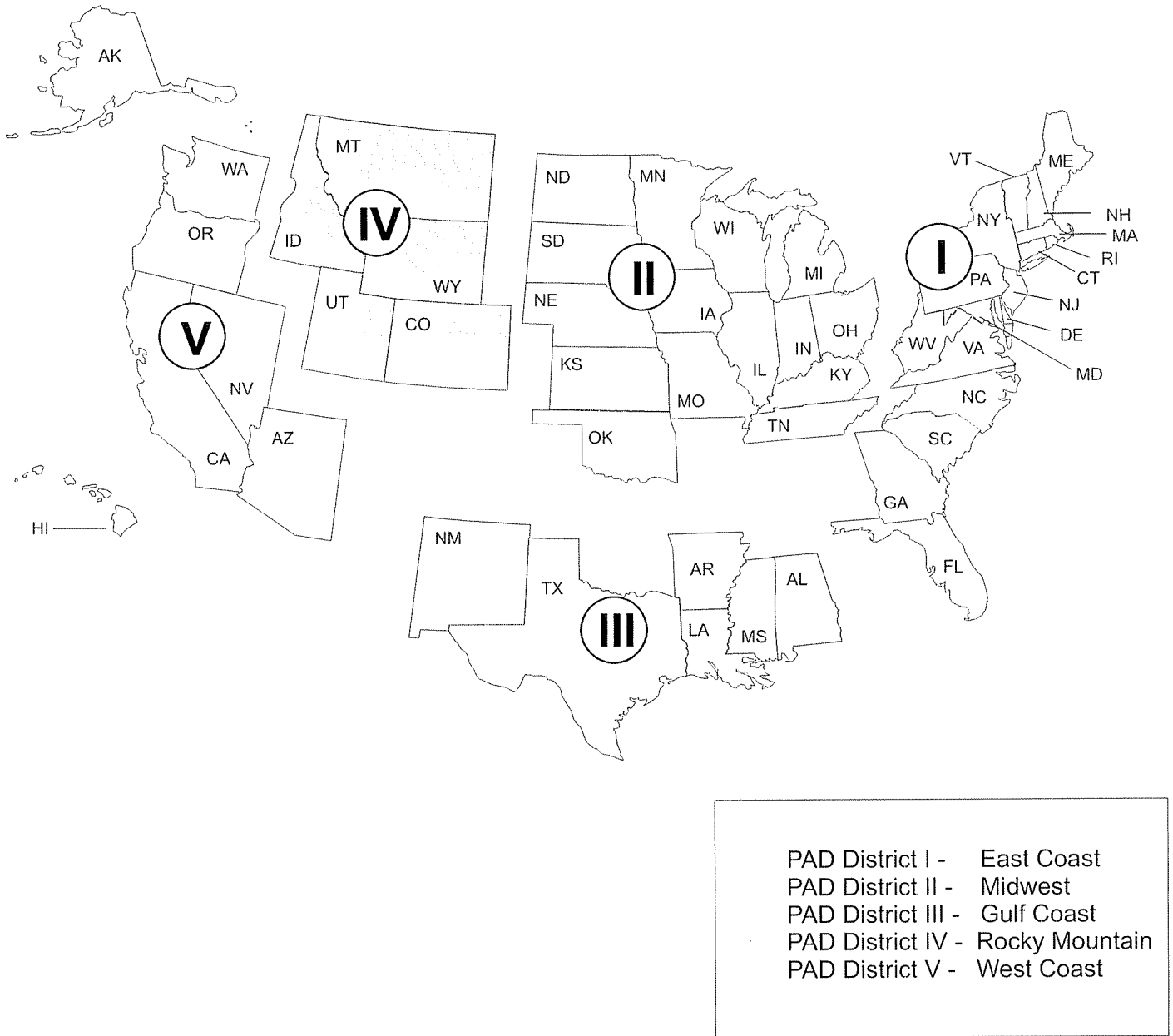


- | | | | |
|----------|----------------------|----------|-------------------|
| 1. ERCT | TRE All | 12. SRDA | SERC Delta |
| 2. FRCC | FRCC All | 13. SRGW | SERC Gateway |
| 3. MROE | MRO East | 14. SRSE | SERC Southeastern |
| 4. MROW | MRO West | 15. SRCE | SERC Central |
| 5. NEWE | NPCC New England | 16. SRVC | SERC VACAR |
| 6. NYCW | NPCC NYC/Westchester | 17. SPNO | SPP North |
| 7. NYLI | NPCC Long Island | 18. SPSO | SPP South |
| 8. NYUP | NPCC Upstate NY | 19. AZNM | WECC Southwest |
| 9. RFCE | RFC East | 20. CAMX | WECC California |
| 10. RFCM | RFC Michigan | 21. NWPP | WECC Northwest |
| 11. RFCW | RFC West | 22. RMPA | WECC Rockies |

Source: U.S. Energy Information Administration, Office of Energy Analysis

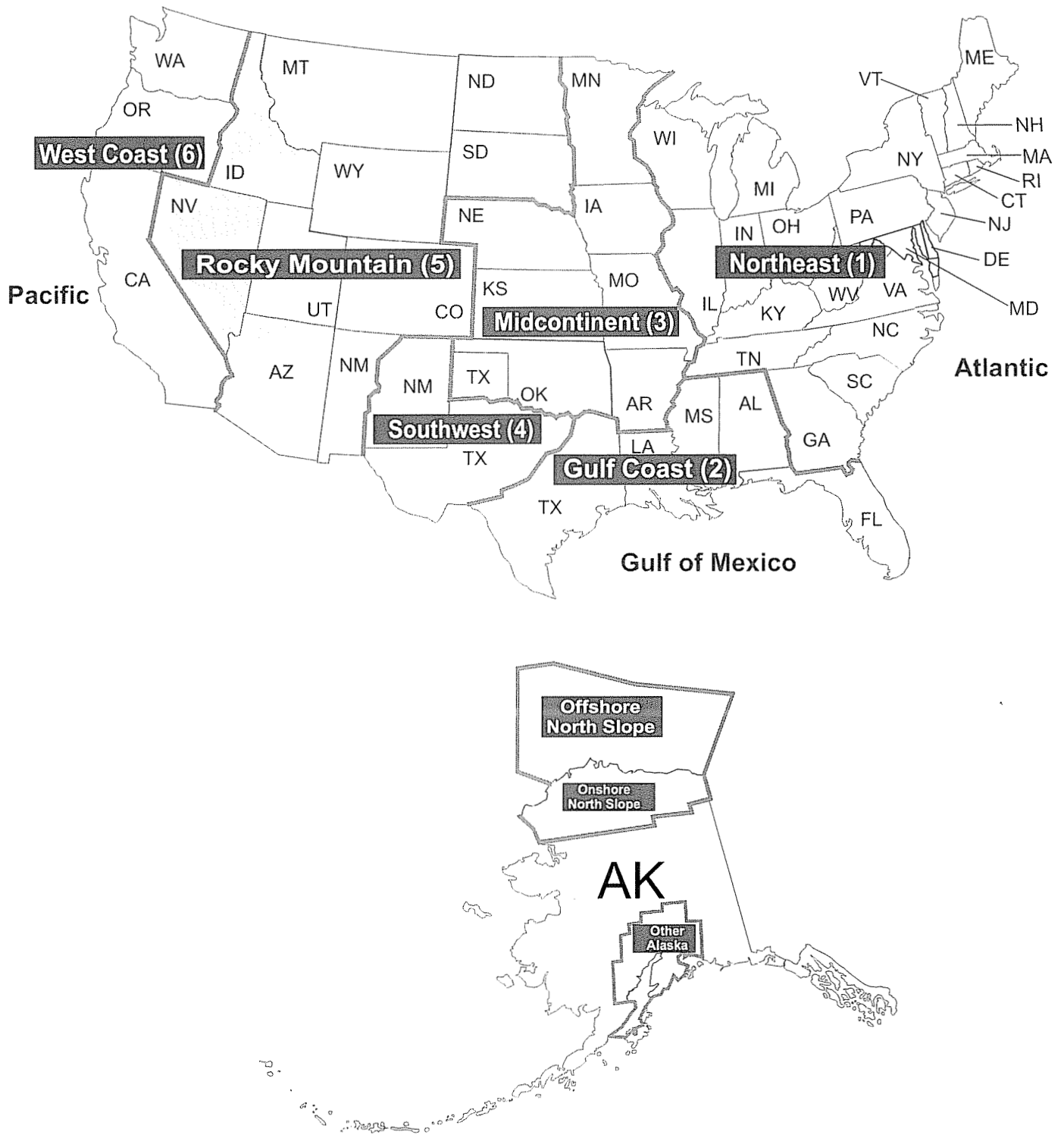
Regional maps

Figure F3. Petroleum Administration for Defense Districts



Source: U.S. Energy Information Administration, Office of Energy Analysis

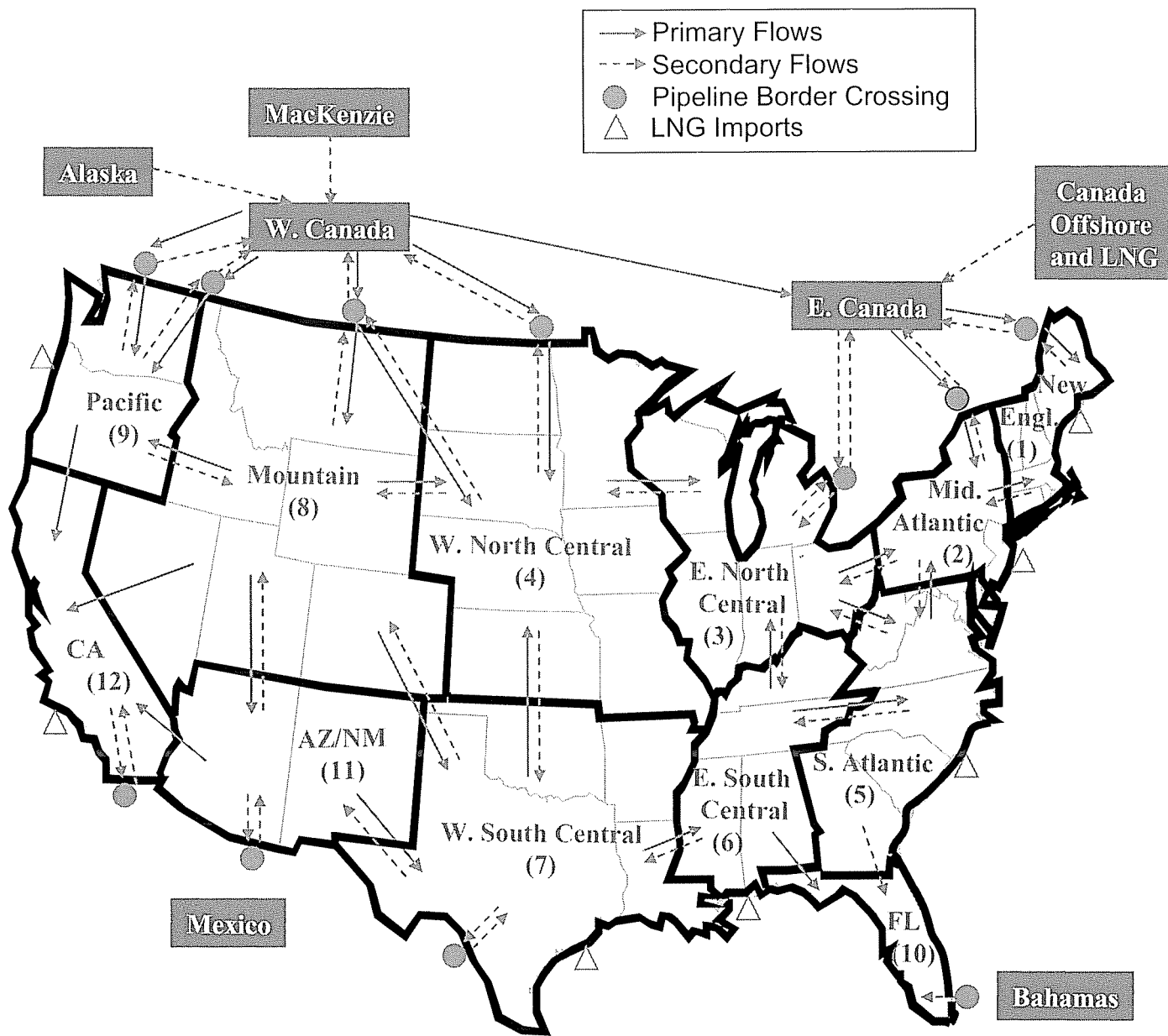
Figure P4. Oil and gas supply model regions



Source: U.S. Energy Information Administration, Office of Energy Analysis

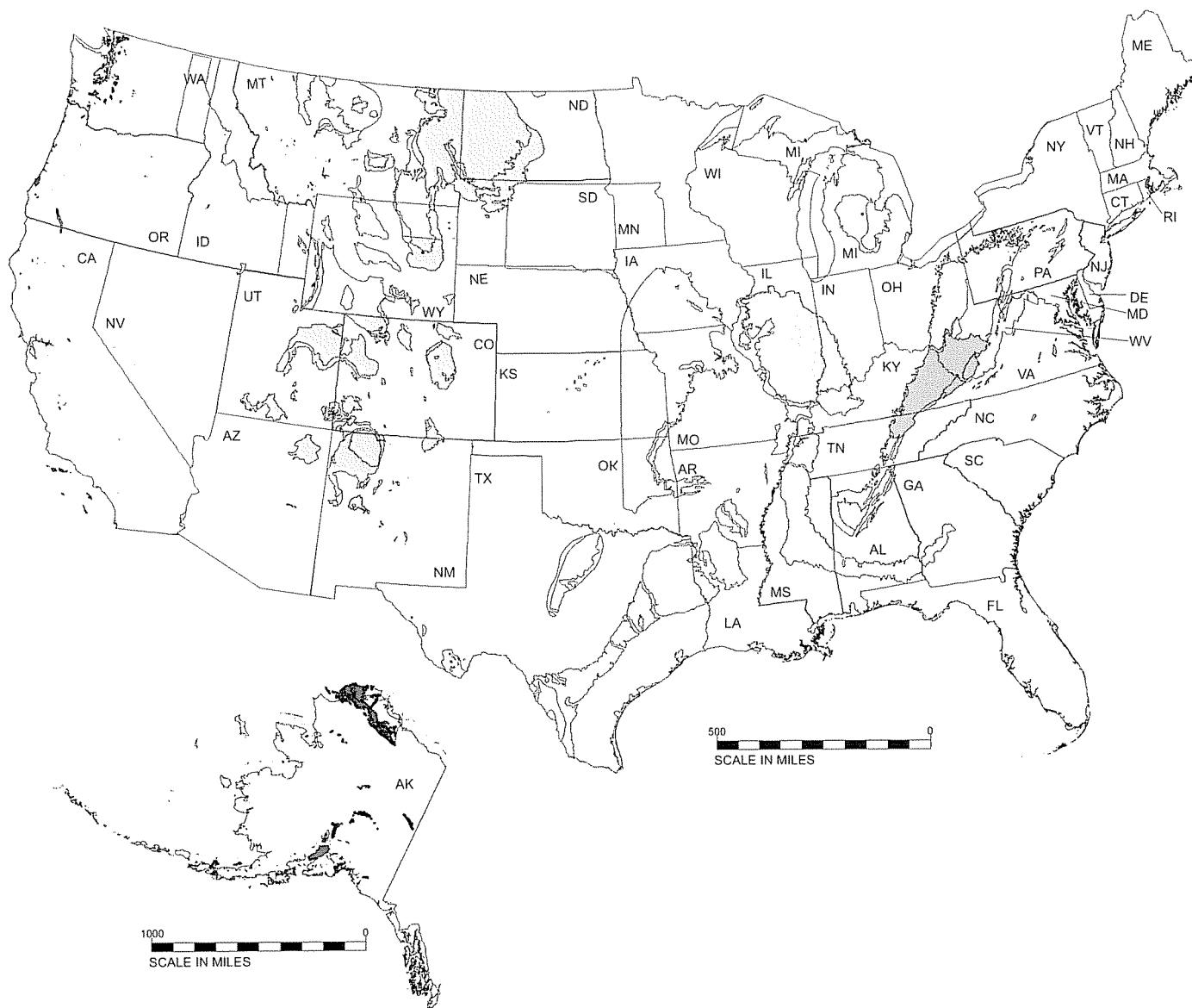
Regional maps

Figure F5. Natural gas transmission and distribution model regions



Source: U.S. Energy Information Administration, Office of Energy Analysis.

Figure F4. Coal supply regions



APPALACHIA

- Northern Appalachia
- Central Appalachia
- Southern Appalachia

INTERIOR

- Eastern Interior
- Western Interior
- Gulf Lignite

NORTHERN GREAT PLAINS

- Dakota Lignite
- Western Montana
- Wyoming, Northern Powder River Basin
- Wyoming, Southern Powder River Basin
- Western Wyoming

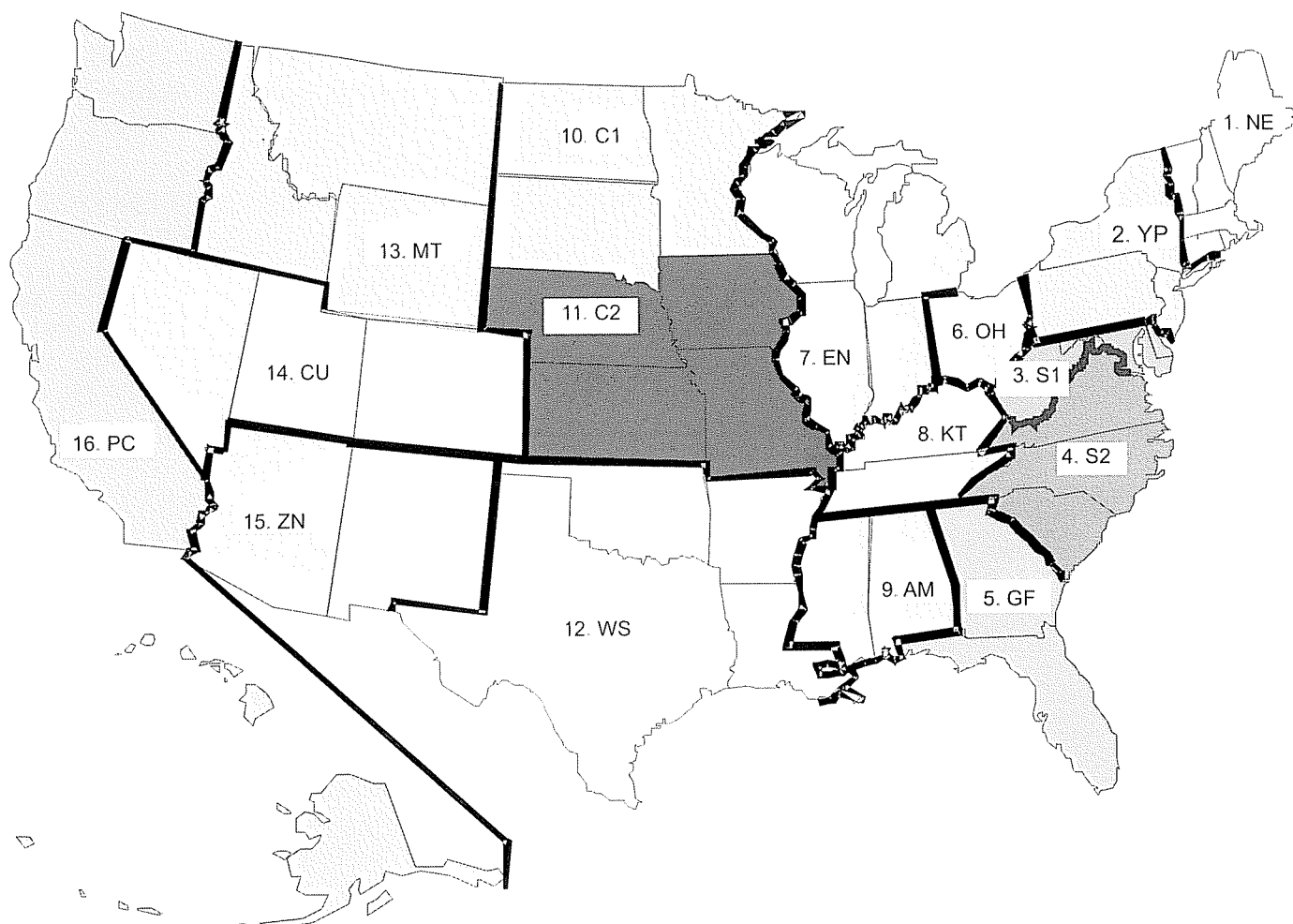
OTHER WEST

- Rocky Mountain
- Southwest
- Northwest

Source: U.S. Energy Information Administration, Office of Energy Analysis

Regional maps

Figure F7 Coal demand regions



Region Code	Region Content
1. NE	CT,MA,ME,NH,RI,VT
2. YP	NY,PA,NJ
3. S1	WV,MD,DC,DE
4. S2	VA,NC,SC
5. GF	GA,FL
6. OH	OH
7. EN	IN,IL,MI,WI
8. KT	KY,TN

Region Code	Region Content
9. AM	AL,MS
10. C1	MN,ND,SD
11. C2	IA,NE,MO,KS
12. WS	TX,LA,OK,AR
13. MT	MT,WY,ID
14. CU	CO,UT,NV
15. ZN	AZ,NM
16. PC	AK,HI,WA,OR,CA

Source: U.S. Energy Information Administration, Office of Energy Analysis

Appendix G

Conversion factors

Table G1. Heat rates

Fuel	Units	Approximate heat content
Coal¹		
Production	million Btu per short ton	20.192
Consumption	million Btu per short ton	19.847
Coke plants	million Btu per short ton	26.297
Industrial	million Btu per short ton	20.433
Residential and commercial	million Btu per short ton	21.188
Electric power sector	million Btu per short ton	19.623
Imports	million Btu per short ton	24.719
Exports	million Btu per short ton	25.698
Coal coke	million Btu per short ton	24.800
Crude oil		
Production	million Btu per barrel	5.800
Imports ¹	million Btu per barrel	5.989
Petroleum products and other liquids		
Consumption ¹	million Btu per barrel	5.254
Motor gasoline ¹	million Btu per barrel	5.100
Jet fuel	million Btu per barrel	5.670
Distillate fuel oil ¹	million Btu per barrel	5.771
Diesel fuel ¹	million Btu per barrel	5.762
Residual fuel oil	million Btu per barrel	6.287
Liquefied petroleum gases ¹	million Btu per barrel	3.557
Kerosene	million Btu per barrel	5.670
Petrochemical feedstocks ¹	million Btu per barrel	5.510
Unfinished oils	million Btu per barrel	6.118
Imports ¹	million Btu per barrel	5.337
Exports ¹	million Btu per barrel	5.851
Ethanol	million Btu per barrel	3.561
Biodiesel	million Btu per barrel	5.359
Natural gas plant liquids		
Production ¹	million Btu per barrel	3.674
Natural gas¹		
Production, dry	Btu per cubic foot	1,024
Consumption	Btu per cubic foot	1,024
End-use sectors	Btu per cubic foot	1,025
Electric power sector	Btu per cubic foot	1,022
Imports	Btu per cubic foot	1,025
Exports	Btu per cubic foot	1,009
Electricity consumption	Btu per kilowatthour	3,412

¹Conversion factor varies from year to year. The value shown is for 2010.

Btu = British thermal unit.

Sources: U.S. Energy Information Administration (EIA), *Annual Energy Review 2010*, DOE/EIA-0384(2010) (Washington, DC, October 2011), and EIA, AEO2012 National Energy Modeling System run REF2012 D020112C.

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Gross International Imports	10.32	9.38	11.61	11.89	12.11	12.35	12.55	13.16	13.77	13.98	13.42	13.48
Gross International Exports	1.18	1.16	1.45	2.37	2.67	2.97	2.96	2.95	2.94	2.93	2.92	2.91
Gross Interregional Electricity Imports	8.74	6.7	9.26	4.39	4.68	5.23	4.96	4.9	4.73	3.43	3.64	1.64
Gross Interregional Electricity Exports	13.71	9.06	4.5	7.43	9.13	17.5	6.71	7.68	8.24	8.01	7.09	10.9
Purchases from Combined Heat and Power 8/	0.91	1.11	1.26	1.39	1.75	1.96	2.01	2.19	2.25	2.32	2.4	2.47
Electric Power Sector Generation for Custo mer	183.1	193.92	190.57	195.9	195.13	203.47	192.37	191.99	192.17	193.83	194.4	201.45
Total Net Energy for Load	188.17	200.9	206.75	203.78	201.86	202.54	202.23	201.61	201.74	202.62	203.85	205.22
Generation by Fuel Type (billion kilowatthours)												
Electric Power Sector												
Coal	125.55	126.25	114.29	122.59	120.53	127.1	114.87	114.56	113.97	116.22	115.51	120.65
Petroleum	0.22	0.27	0.48	0.5	0.5	0.52	0.42	0.42	0.42	0.42	0.42	0.43
Natural Gas	4.31	6.43	9.3	4.94	4.77	5.5	5.89	5.7	6.49	5.63	6.68	6.36
Nuclear	26.51	28.98	26.37	27.34	28.4	29.23	29.8	29.8	29.8	29.8	29.8	31.77
Pumped Storage/Other 12/	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Renewable Sources 13/	26.41	31.82	39.88	40.27	40.67	40.85	41.13	41.25	41.21	41.5	41.72	41.97
Distributed Generation 5/	0	0	0	0	0	0	0	0	0	0	0	0
Total Generation	183.29	194.04	190.6	195.93	195.16	203.5	192.4	192.02	192.2	193.86	194.43	201.48
Sales to Customers	183.1	193.92	190.57	195.9	195.13	203.47	192.37	191.99	192.17	193.83	194.4	201.45
Generation for Own Use	0.19	0.12	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
End-Use Sectors 8/												
Coal	2.41	3.18	3.18	3.18	3.14	3.14	3.15	3.25	3.25	3.25	3.26	3.27
Petroleum	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Natural Gas	0.26	0.22	1.28	2.09	2.83	3.52	4.09	4.64	5	5.4	5.83	6.28
Other Gaseous Fuels 9/	0	0	0	0	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Renewable Sources 13/	0.85	0.92	1.04	1.2	1.71	2.1	2.33	2.67	2.72	2.75	2.85	2.92
Other 10/	0.11	0.1	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Total	3.66	4.44	5.58	6.56	7.77	8.85	9.67	10.65	11.07	11.5	12.03	12.57
Sales to the Grid	0.91	1.11	1.26	1.39	1.75	1.96	2.01	2.19	2.25	2.32	2.4	2.47
Generation for Own Use	2.75	3.32	4.32	5.16	6.03	6.89	7.65	8.46	8.82	9.18	9.63	10.09
Total Electricity Generation	186.94	198.48	196.18	202.49	202.93	212.35	202.07	202.67	203.26	205.36	206.46	214.05

End-Use Prices**(2010 cents per kilowatthour)**

Residential	9.7	10	9.8	9.5	9.8	9.8	10	10.2	10.2	10.1	10	9.9
Commercial	7.6	8	7.8	7.7	7.8	7.8	8	8.2	8.1	8	8	7.9
Industrial	6	5.9	5.9	5.9	5.9	5.9	6	6.1	6.1	6	6	6
Transportation	8.3	7.8	7.4	7.4	7.4	7.3	7.3	7.5	7.9	8.2	8.5	8.7
All Sectors Average	7.7	7.9	7.8	7.6	7.7	7.7	7.9	8.1	8	7.9	7.9	7.8

(nominal cents per kilowatthour)

Residential	9.5	10	10	9.9	10.2	10.4	10.8	11.2	11.3	11.4	11.5	11.6
Commercial	7.5	8	8	8	8.1	8.3	8.6	9	9.1	9.1	9.2	9.3
Industrial	5.9	5.9	6	6.1	6.1	6.2	6.5	6.7	6.8	6.9	7	7
Transportation	8.2	7.8	7.6	7.7	7.7	7.7	7.9	8.2	8.8	9.3	9.8	10.3
All Sectors Average	7.6	7.9	7.9	7.9	8	8.2	8.5	8.8	9	9	9.1	9.2

Prices by Service Category**(2010 cents per kilowatthour)**

Generation	4.8	5	4.8	4.7	4.7	4.6	4.7	4.8	4.8	4.7	4.6	4.5
Transmission	1	1	1	1	1.1	1.1	1.2	1.2	1.2	1.2	1.2	1.2
Distribution	1.9	1.9	1.9	1.9	1.9	2	2	2.1	2.1	2.1	2.1	2.1

(nominal cents per kilowatthour)

Generation	4.7	5	5	4.9	4.9	4.9	5.1	5.3	5.3	5.3	5.3	5.3
Transmission	1	1	1.1	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5
Distribution	1.9	1.9	1.9	1.9	2	2.1	2.2	2.2	2.3	2.3	2.4	2.4

Fuel Consumption (quadrillion Btu) 14/

Coal	1.35	1.35	1.24	1.33	1.29	1.36	1.22	1.22	1.21	1.23	1.23	1.29
Natural Gas	0.04	0.06	0.07	0.04	0.04	0.04	0.05	0.04	0.05	0.04	0.05	0.05
Oil	0	0	0.01	0.01	0.01	0.01	0	0	0	0	0	0
Total	1.39	1.41	1.31	1.37	1.33	1.41	1.27	1.26	1.26	1.28	1.28	1.34

Fuel Prices (2010 dollars per million Btu)

Coal	1.44	1.49	1.53	1.6	1.59	1.63	1.66	1.68	1.71	1.74	1.76	1.79
Natural Gas	4.75	5.18	4.67	4.35	4.27	4.31	4.43	4.44	4.44	4.5	4.59	4.67
Distillate Fuel Oil	15.24	19.06	23.67	23.84	20.07	21.43	22.2	22.54	22.94	23.11	23.29	23.57
Residual Fuel Oil	6.63	6.12	8.69	8.36	6.17	6.17	6.17	6.17	6.17	6.17	6.17	6.17

(nominal dollars per million Btu)

Coal	1.42	1.49	1.56	1.66	1.66	1.72	1.78	1.85	1.91	1.97	2.03	2.1
Natural Gas	4.69	5.18	4.77	4.5	4.45	4.56	4.77	4.86	4.96	5.11	5.3	5.49
Distillate Fuel Oil	15.07	19.06	24.17	24.67	20.92	22.69	23.92	24.72	25.6	26.25	26.91	27.7
Residual Fuel Oil	6.56	6.12	8.87	8.65	6.43	6.53	6.64	6.76	6.88	7	7.12	7.25
Emissions 15/												
Total Carbon (million tons)	40.8	42.71	37.95	40.15	39.06	41.21	37.09	36.97	36.87	37.53	37.41	39.14
Carbon Dioxide (million tons)	149.6	156.61	139.15	147.21	143.22	151.12	135.99	135.55	135.17	137.6	137.17	143.51
Sulfur Dioxide (million tons)	0.38	0.37	0.26	0.27	0.29	0.29	0.06	0.06	0.06	0.06	0.06	0.06
Nitrogen Oxide (million tons)	0.21	0.19	0.19	0.2	0.19	0.19	0.18	0.18	0.17	0.18	0.18	0.18
Mercury (tons)	3.45	3.35	2.85	3.17	3.14	3.37	0.41	0.41	0.41	0.41	0.42	0.43

1/ Net summer capacity is the steady hourly output that generating equipment is expected to supply to system load (exclusive of auxiliary power), as demonstrated by tests during summer peak demand.

2/ Includes electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

3/ Includes oil-, gas-, and dual-fired capacity.

4/ Includes conventional hydroelectric, geothermal, wood, wood waste, municipal waste, other biomass, solar thermal, photovoltaics, and wind power.

5/ Primarily peak-load capacity fueled by natural gas.

6/ Cumulative additions after December 31, 2010.

7/ Cumulative retirements after December 31, 2010.

8/ Includes combined heat and power plants and electricity-only plants in the commercial and industrial sectors; and small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid.

9/ Includes refinery gas and still gas.

10/ Includes batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

11/ Generation to meet system load by source.

12/ Other includes non-biogenic municipal waste.

13/ Includes conventional hydroelectric, geothermal, wood, wood waste, biogenic municipal waste, other biomass, solar thermal, photovoltaics, and wind power.

14/ Includes consumption of energy by electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public.

15/ Estimated emissions from electricity-only and combined heat and power plants whose primary business is to sell electricity, or electricity and heat, to the public (excludes end-use sector plants).

EMM = Electricity market module.

-- = Not applicable.

0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0.02	0.02	0.02	0.16	0.16	0.16	0.19	0.19	0.19	0.23	0.24	0.28	0.28	0.69	
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.05	0.06	0.07	0.09	
0.33	0.35	0.35	0.48	0.87	0.87	1.19	1.43	1.65	1.65	1.7	1.78	2.29	2.58	3.09	
2.54	2.56	2.56	2.7	3.08	3.08	3.4	3.65	3.86	3.87	3.91	3.99	4.5	4.79	5.31	
1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	1.47	
0.04	0.07	0.07	0.07	0.07	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	
0	0	0	0	0	0	0	0	0	0	0	0	0.25	0.25	0.25	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
1.74	1.77	1.77	1.77	1.77	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81	2.06	2.06	2.06
0.82	0.83	0.83	0.83	0.84	0.84	0.84	0.85	0.85	0.86	0.86	0.86	0.86	0.87	0.87	
0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
1.29	1.39	1.49	1.6	1.71	1.83	1.96	2.11	2.26	2.42	2.59	2.74	2.89	3.04	3.2	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0.94	0.97	0.97	0.98	0.99	1	1.01	1.03	1.05	1.07	1.13	1.19	1.24	1.25	1.26	
0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
3.09	3.22	3.33	3.45	3.58	3.72	3.87	4.03	4.21	4.4	4.61	4.84	5.03	5.2	5.38	
59.63	60.19	60.76	61.37	62.04	62.74	63.49	64.23	64.96	65.71	66.45	67.19	68.01	68.78	69.58	
63.42	63.98	64.53	65.09	65.7	66.32	66.96	67.59	68.23	68.85	69.47	70.12	70.8	71.49	72.16	
69.04	69.75	69.5	69.01	68.67	68.27	67.75	67.12	66.4	65.64	65.09	64.99	64.01	63.28	62.48	
0.18	0.2	0.22	0.25	0.27	0.3	0.33	0.36	0.39	0.42	0.46	0.5	0.54	0.58	0.63	
192.26	194.12	195.01	195.72	196.69	197.62	198.52	199.3	199.97	200.62	201.48	202.79	203.36	204.13	204.86	

12.99	12.53	12.31	12.02	11.42	11.39	11.94	11.73	11.49	11.29	11.29	11.29	11.29	11.29	11.29
2.9	2.89	2.88	2.87	2.87	2.86	2.85	2.84	2.83	2.82	2.81	2.8	2.79	2.78	2.77
1.44	1.26	1.08	0.77	0.55	0.36	0.25	0.15	0.16	0.36	0.37	0.82	1.31	1.4	1.38
9.85	10.32	9.67	8.96	7.67	7.25	5.72	6.12	6.47	6.29	6.62	6.8	6.84	7	8.18

2.57	2.67	2.77	2.87	2.99	3.1	3.23	3.37	3.64	3.84	4.28	4.85	5.27	5.4	5.56
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202.65	205.49	206.08	206.62	207.08	207.76	206.61	207.99	209.02	209.34	210.12	210.69	210.42	211.19	212.99
206.9	208.74	209.69	210.45	211.49	212.5	213.46	214.3	215.02	215.72	216.65	218.05	218.67	219.49	220.27

121.66	124.68	125.25	125.63	125.58	126.16	125.44	126.05	126.31	126.85	127.46	128.6	129.43	130.05	130.46
0.43	0.44	0.43	0.43	0.43	0.43	0.42	0.42	0.43	0.43	0.43	0.43	0.43	0.43	0.43
6.56	6.26	6.25	6.61	6.36	6.71	6.28	6.87	7.6	7.48	7.42	6.94	7.56	7.68	7.52
31.77	31.77	31.77	31.77	31.77	31.77	31.77	31.77	31.77	31.77	31.77	31.77	29.8	29.8	29.8
0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
41.96	42.08	42.1	41.91	42.67	42.41	42.42	42.61	42.64	42.54	42.77	42.66	42.9	42.94	44.48
0	0	0	0	0	0	0.01	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.04

202.68	205.52	206.11	206.65	207.11	207.79	206.63	208.02	209.05	209.37	210.15	210.71	210.45	211.22	213.02
202.65	205.49	206.08	206.62	207.08	207.76	206.61	207.99	209.02	209.34	210.12	210.69	210.42	211.19	212.99
0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

3.3	3.34	3.37	3.4	3.42	3.44	3.47	3.5	3.54	3.55	3.57	3.59	3.62	3.64	3.67
0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6.78	7.32	7.91	8.53	9.2	9.92	10.71	11.56	12.49	13.49	14.49	15.46	16.38	17.35	18.36
0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
3.03	3.18	3.22	3.25	3.32	3.38	3.46	3.53	3.72	3.85	4.25	4.77	5.13	5.18	5.25
0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
13.2	13.94	14.6	15.27	16.04	16.85	17.74	18.7	19.84	21	22.41	23.93	25.23	26.27	27.37
2.57	2.67	2.77	2.87	2.99	3.1	3.23	3.37	3.64	3.84	4.28	4.85	5.27	5.4	5.56
10.64	11.27	11.83	12.4	13.05	13.74	14.51	15.33	16.2	17.16	18.13	19.08	19.96	20.88	21.81

215.89	219.46	220.71	221.92	223.14	224.63	224.38	226.72	228.89	230.37	232.56	234.64	235.68	237.5	240.4
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2.17	2.24	2.34	2.43	2.52	2.61	2.7	2.8	2.9	3	3.11	3.22	3.3	3.4	3.54
5.87	6.32	6.64	6.9	7.17	7.53	7.78	8.1	8.44	8.74	9.19	9.59	9.96	10.65	11.33
28.46	29.12	29.86	30.67	31.71	32.68	33.56	34.53	35.71	36.93	38.65	40.04	40.46	41.77	43.39
7.37	7.5	7.63	7.77	7.91	8.07	8.23	8.41	8.59	8.78	8.98	9.19	9.37	9.56	9.76
39.49	40.47	40.66	40.83	40.78	41.03	40.69	40.96	41.15	41.3	41.5	41.82	42.18	42.43	42.57
144.8	148.38	149.09	149.7	149.52	150.46	149.21	150.2	150.88	151.42	152.17	153.35	154.65	155.58	156.08
0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08	0.08
0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.2	0.2
0.44	0.45	0.45	0.45	0.44	0.43	0.43	0.45	0.45	0.46	0.43	0.46	0.44	0.45	0.47

Growth Rate (2010-2035)

-0.20%
-1.20%
1.10%
0.50%
0.30%

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0.70%

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0.30%

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Exhibit__RW-7

	NGCC Replacement 2015 minus Retrofit	% Difference from Retrofit
Wilson	\$152	10.06%
Green 1	\$69	8.12%
Green 2	\$4	0.50%
HMPL 1	\$82	16.22%
HMPL 2	\$65	12.27%
Coleman 1	\$43	7.85%
Coleman 2	\$61	11.73%
Coleman 3	\$50	8.89%
Total	\$527	8.91%

Sierra Club
KY Case No. 2012-00063
Exhibit RSW-9
Witness: Rachel Wilson

	Company Build Case	Company Build + CO2
	Zero CO2 Price, BREC NG price, ECP Retrofits	BREC CO2 Price, BREC NG price, ECP Retrofits
Wilson	\$151.56	\$55.89
Green 1	\$69.35	\$21.46
Green 2	\$4.44	(\$43.48)
HMPL 1	\$82.38	\$53.14
HMPL 2	\$65.29	\$31.36
Coleman 1	\$43.18	\$8.48
Coleman 2	\$60.88	\$26.58
Coleman 3	\$49.72	\$13.57
Total	\$526.81	\$167.00

	Company Build Case	Company Build, AEO NG
	Zero CO2 Price, BREC NG price, ECP Retrofits	Zero CO2 Price, AEO NG price, ECP Retrofits
Wilson	\$151.56	(\$16.88)
Green 1	\$69.35	(\$25.73)
Green 2	\$4.44	(\$86.20)
HMPL 1	\$82.38	\$22.71
HMPL 2	\$65.29	\$3.80
Coleman 1	\$43.18	(\$15.52)
Coleman 2	\$60.88	\$2.70
Coleman 3	\$49.72	(\$12.22)
Total	\$526.81	(\$127.35)

	Company Build Case	Company Build + CO2	Company Build + CO2, AEO NG	All Retrofits but Effluent + CO2, AEO NG	Synapse Recommended
	Zero CO2 Price, BREC NG price, ECP Retrofits	BREC CO2 Price, BREC NG price, ECP Retrofits	BREC CO2 Price, AEO NG price, ECP Retrofits	BREC CO2 Price, AEO NG price, All Retrofits but Effluent	BREC CO2 Price, AEO NG price, All Retrofits
Wilson	\$151.56	\$55.89	(\$112.55)	(\$116.10)	(\$259.04)
Green 1	\$69.35	\$21.46	(\$73.62)	(\$135.37)	(\$203.80)
Green 2	\$4.44	(\$43.48)	(\$134.12)	(\$144.63)	(\$213.05)
HMPL 1	\$82.38	\$53.14	(\$6.54)	(\$15.10)	(\$81.54)
HMPL 2	\$65.29	\$31.36	(\$30.13)	(\$38.69)	(\$106.72)
Coleman 1	\$43.18	\$8.48	(\$50.22)	(\$63.94)	(\$108.28)
Coleman 2	\$60.88	\$26.58	(\$31.60)	(\$45.33)	(\$89.67)
Coleman 3	\$49.72	\$13.57	(\$48.38)	(\$62.10)	(\$103.34)
Total	\$526.81	\$167.00	(\$487.16)	(\$621.25)	(\$1,165.44)

Commonwealth of Kentucky

Before the Public Service Commission

In the Matter of:

APPLICATION OF BIG RIVERS ELECTRIC)
CORPORATION FOR APPROVAL OF ITS)
2012 ENVIRONMENTAL COMPLIANCE)
PLAN, FOR APPROVAL OF ITS)
AMENDED ENVIRONMENTAL COST)
RECOVERY SURCHARGE TARIFF, FOR)
CERTIFICATES OF PUBLIC)
CONVIENENCE AND NECESSITY, AND)
FOR AUTHORITY TO ESTABLISH A)
REGULATORY ACCOUNT.)

Case No. 2012-00063

**Direct Testimony of
William Steinhurst**

**On Behalf of
Sierra Club**

Public Version

July 23, 2012

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1 **1. INTRODUCTION AND QUALIFICATIONS**

2 **Q Please state your name, business address, and position.**

3 **A** My name is William Steinhurst, and I am a Senior Consultant with Synapse
4 Energy Economics (Synapse). My business address is 32 Main Street, #394,
5 Montpelier, Vermont 05602.

6 **Q Please describe Synapse Energy Economics.**

7 **A** Synapse Energy Economics is a research and consulting firm specializing in
8 energy and environmental issues, including electric generation, transmission and
9 distribution system reliability, ratemaking and rate design, electric industry
10 restructuring and market power, electricity market prices, stranded costs,
11 efficiency, renewable energy, environmental quality, and nuclear power.

12 Synapse's clients include state consumer advocates, public utilities commission
13 staff, attorneys general, environmental organizations, federal government and
14 utilities.

15 **Q Please summarize your work experience and educational background.**

16 **A** I have over thirty years of experience in utility regulation and energy policy,
17 including work on renewable portfolio standards and portfolio management
18 practices for default service providers and regulated utilities, green marketing,
19 distributed resource issues, economic impact studies, and rate design. Prior to
20 joining Synapse, I served as Planning Econometrician and Director for Regulated
21 Utility Planning at the Vermont Department of Public Service, the State's Public
22 Advocate and energy policy agency. I have provided consulting services for
23 various clients, including the Connecticut Office of Consumer Counsel, the
24 Illinois Citizens Utility Board, California Division of Ratepayer Advocates, the
25 D.C. and Maryland Offices of the Public Advocate, Delaware Public Utilities
26 Commission, Regulatory Assistance Project, National Association of Regulatory
27 Utility Commissioners (NARUC), National Regulatory Research Institute
28 (NRRI), American Association of Retired Persons (AARP), The Utility Reform

1 Network (TURN), Union of Concerned Scientists, Northern Forest Council, Nova
2 Scotia Utility and Review Board, U.S. Environmental Protection Agency (EPA),
3 Conservation Law Foundation, Sierra Club, Southern Alliance for Clean Energy,
4 Oklahoma Sustainability Network, Natural Resource Defense Council (NRDC),
5 Illinois Energy Office, Massachusetts Executive Office of Energy Resources,
6 James River Corporation, and Newfoundland Department of Natural Resources.

7 I hold a B.A. in Physics from Wesleyan University and an M.S. in Statistics and
8 Ph.D. in Mechanical Engineering from the University of Vermont.

9 I have testified as an expert witness in over 30 cases on topics including utility
10 rates and ratemaking policy, prudence reviews, integrated resource planning,
11 demand side management policy and program design, utility financings,
12 regulatory enforcement, green marketing, power purchases, statistical analysis,
13 and decision analysis. I have been a frequent witness in legislative hearings, and
14 represented the State of Vermont, the Delaware Public Utilities Commission
15 Staff, and several other groups in numerous collaborative settlement processes
16 addressing energy efficiency, resource planning and distributed resources.

17 I was the lead author or co-author of Vermont's long-term energy plans for 1983,
18 1988, and 1991, as well as the 1998 report *Fueling Vermont's Future:*
19 *Comprehensive Energy Plan and Greenhouse Gas Action Plan*, and also
20 Synapse's study *Portfolio Management: How to Procure Electricity Resources to*
21 *Provide Reliable, Low-Cost, and Efficient Electricity Services to All Retail*
22 *Customers*. In 2008, I was commissioned by the National Regulatory Research
23 Institute (NRRI) to write *Electricity at a Glance*, a primer on the industry for new
24 public utility commissioners, which included coverage of energy efficiency
25 programs. In 2011, NRRI commissioned a second edition of that work.

26 A copy of my current resume is attached as Exhibit WS-1.

27 **Q On whose behalf are you testifying in this case?**

28 **A** I am testifying on behalf of Sierra Club.

1 **Q Have you testified previously before the Kentucky Public Service**
2 **Commission?**

3 **A** No, I have not. However, I did prepare prefiled testimony in Kentucky PSC Cases
4 No. 2011-00161 and No. 2011-00162, which were settled.

5 **Q What is the purpose of your testimony?**

6 **A** Big Rivers Electric Corporation (“BREC” or the “Company”) has requested that
7 the Commission issue Certificates of Public Convenience and Necessity
8 (“CPCN”) for certain environmental upgrades at its coal fired power plants. *See*
9 *Berry* prefiled direct at 39 and BREC Exhibit *Berry-2*. I will refer to those
10 projects as the Environmental Retrofits. The purpose of my testimony is to
11 provide an opinion, based on Synapse’s analysis of the Environmental Retrofits
12 and BREC’s studies in support of its Application for the CPCNs, as to whether
13 the proposed Environmental Retrofits are reasonable and cost-effective for
14 complying with the environmental requirements the Company faces and
15 providing least-cost service. Witness Wilson’s accompanying testimony reviews
16 the regulatory requirements and the Company’s economic justifications for the
17 Environmental Retrofits. For that purpose, she reviews the current and expected
18 running costs of the Company’s coal-fired units, and compares these costs to
19 different alternatives. My testimony discusses the resource options BREC
20 evaluated, the range of future scenarios it used to evaluate those resource options,
21 its projection of revenue requirements for each resource option under those future
22 scenarios and its conclusions regarding the merits of its proposed CPCN based
23 upon its projections and analyses.

24 **2. FINDINGS AND OVERVIEW OF TESTIMONY**

25 **Q In your opinion, do the facts and evidence presented in this case support the**
26 **Company’s request for a CPCN for the proposed environmental upgrades?**

27 **A** No. The Company has not demonstrated that its proposed CPCN is reasonable
28 and cost-effective for complying with the environmental requirements the
29 Company is facing. That conclusion is based upon the results of our review

1 which indicates that the Company has not evaluated the full range of resource
2 options available to it, that its projections of revenue requirements for the
3 resource options it did evaluate are not correct, that its evaluation of future
4 scenarios does not include a reasonable projection of carbon prices and that its
5 risk analysis is subjective and flawed As set out in the testimony of witness
6 Wilson, the Company's economic justification for these environmental retrofits
7 did not consider a full range of alternative compliance options and contained
8 several flaws that bias its analysis in favor of installation of emission control
9 retrofit projects. When a number of those errors are corrected, the results show
10 that alternatives to the Environmental Retrofits are less costly and less risky.

11 **Q What is your understanding of the standard for issuance of a CPCN in**
12 **Kentucky?**

13 **A**My understanding is that, before the Commission can grant such a certificate for a
14 facility, it must determine that there is both a need for the facility and that
15 construction of the new system or facility will not result in duplication. This
16 standard requires more than just a showing that there is a need for new generation,
17 as the statutory mandate to avoid "wasteful duplication" logically means that the
18 new system or facility should not represent an excessive investment. Commission
19 decision-making is guided by the overall requirement that utility rates are "fair,
20 just, and reasonable." KRS § 278.030(1); KRS § 278.040. As a policy matter, I
21 view these requirements as equating to the need for a showing that resources are
22 the least-cost means of providing utility service since a resource plan that is not
23 least cost cannot result in just and reasonable rates.

24 **3. EXPECTATION FOR SOUND UTILITY PLANNING**

25 **Q HOW DOES BREC's DECISION MAKING PROCESS COMPARE WITH**
26 **THE PROCESS A COMPANY WOULD FOLLOW TO INFORM A**
27 **REASONABLE DECISION?**

28 **A**BREC is conducting a business affected with the public interest. It should plan for
29 the provision of utility service in a manner designed and implemented to provide
30 adequate and reliable service consistent with public policy and in a manner

1 designed to minimize long-term cost of service to customers while managing risk
2 to customers in a reasonable way. I have discussed this approach at length
3 elsewhere. (See, for example, *Portfolio Management: Tools and Practices for*
4 *Regulators*, 9/29/2006, attached as Exhibit WS-2.) BREC's planning in regard to
5 the subject matter of this proceeding should be held to that same standard: an
6 assessment of all of its options for meeting customer needs and conducted in a
7 manner that considers all of its options on a level playing field. Specifically,
8 BREC should have done the following:

- 9 1. Identify All Currently Known Regulatory Requirements and Identify
10 Emerging and Reasonably Likely Future Regulatory Requirements
- 11 2. Identify and Evaluate All Alternatives for Compliance and Alternatives to
12 Compliance
- 13 3. Perform Correct Life-Cycle Economic Analyses, Including Sensitivity Cases
14 and other Risk Analysis of All the Alternatives
- 15 4. Make a Decision Based on the Aforementioned Information
- 16 5. Re-Evaluate the Decision as Significant Milestones Are Reached
- 17 6. Balance Cost/Risk In Implementation Method
- 18 7. Actively Manage the Implementation To Assure Budget, Schedule and
19 Performance Compliance

20 Unfortunately, BREC has failed in at least the first four of those requirements as
21 explained below.

22 **4. DESCRIPTION OF WAYS IN WHICH BREC PLANNING IS LACKING**

23 **Q Was BREC's planning and economic analysis for its Environmental Retrofits**
24 **correct? Was it consistent with least cost planning principles and good utility**
25 **management?**

26 **A** BREC's planning and economic analysis for its Environmental Retrofits was not
27 correct, nor was it consistent with least cost planning principles and good utility

1 management. Sierra Club witness Wilson summarizes the errors she identified as
2 follows:

- 3 • The load forecast, which does not include the effects of demand side
4 management (DSM);
- 5 • The input natural gas price forecast from the PACE Global modeling;
- 6 • The use of a carbon dioxide (CO₂) emissions price to determine the energy
7 market prices in the PACE Global modeling, but leaving it out of the
8 ACES production cost modeling and the dispatch of generating units;
- 9 • The resulting output energy prices from the PACE Global modeling/ Use
10 of inflated market prices;
- 11 • The assumption that capacity, heat rates, forced outages and availability
12 factors stay constant over time; and
- 13 • The use of both real and nominal dollars in calculations of net present
14 value revenue requirement (NPVRR) in the BREC financial modeling.

15 Witness Wilson also describes BREC's failure to model all controls, failure to model
16 units individually, and failure to compare to alternatives. Sensitivity analyses were
17 extremely limited and did not cover the range of important input uncertainties. None
18 of these practices is consistent with correct implementation of least-cost planning
19 principles or with good utility management. I will discuss the utility planning
20 implications of BREC's errors below.

21 **a. Piecemeal Approach to Pending and Emerging Regulations**

22 **Q Does correct least-cost planning require treating emerging and reasonably**
23 **expected regulatory requirements in a particular manner?**

24 **A** Yes. Investments necessary to meet emerging and reasonably expected regulatory
25 requirements must be considered as part of the forward going costs of any plant,
26 just as with the investments necessary to meet currently known requirements.
27 Unfortunately, BREC erred in at least two ways on this point by including in its

1 economic modeling the costs of select control technologies rather than the entire
2 suite of controls likely or reasonably expected for future compliance.

3 First, BREC chose to treat some emerging and reasonably expected regulatory
4 requirements as “speculative” and ignored the risk of forward going costs for
5 meeting those requirements. For example, BREC witness Berry states “potential
6 NAAQS [national ambient air quality standards] reductions are not expected to be
7 published until 2016 with compliance possibly due in 2018. At this time,
8 anticipated NAAQS reductions are merely speculative and will be addressed in
9 future environmental compliance plans.” He also takes a similar position
10 regarding “EPA-proposed regulations under §316(b) of the Clean Water Act -
11 Waste Water Intake Impingement Mortality & Entrainment, Waste Water
12 Discharge, and Coal Combustion Residuals (CCR).” Berry prefiled direct at 27-
13 29.

14 Second, BREC failed to treat the alternatives on a level playing field with respect
15 to potential carbon emission costs. BREC burdened market alternatives (mainly
16 natural gas energy purchases) with carbon costs, but failed to similarly burden the
17 forward going costs of the coal plants it proposes for Environmental Retrofits.
18 This is a fundamental error in least cost planning.

19 This piecemeal and biased analysis is inconsistent with the principles of least cost
20 planning and the requirements for a CPCN.

21 **b. Creation of a Bias in Favor of Additional, Future Environmental**
22 **Retrofits**

23 **Q Does BREC’s failure to comprehensively plan for least-cost solutions to its**
24 **regulatory requirements create any other concerns?**

25 **A** Yes. Once the proposed Environmental Retrofits are made, their costs are sunk
26 and not avoidable. Then, any incremental costs imposed by other regulations,
27 such as emerging and reasonably expected regulations, would be evaluated on
28 their incremental economics. However, from today’s point of view that distorts
29 the true economics of decisions about the proposed Environmental Retrofits vs.

1 the alternatives. Again, a piecemeal approach to economic evaluations distorts the
2 economic analysis of alternatives. While some emerging and reasonably expected
3 regulations are in flux and costs may be uncertain, totally ignoring those potential
4 costs biases the analysis in favor of the proposed Environmental Retrofits.

5 **Q As a general matter, how should BREC approach planning for**
6 **environmental regulation?**

7 **A** Under EPA’s multi-faceted approach, plant owners can and should
8 comprehensively plan for compliance. While BREC retained Sargent and Lundy
9 to perform the initial steps in a comprehensive plan for compliance, BREC failed
10 to follow through. As an example of this lack of follow through, BREC modeled
11 only the emission control retrofits for Cross State Air Pollution Rule (CSAPR)
12 and Mercury Air Toxics Standard (MATS) and, then only a subset of the controls
13 recommended by Sargent & Lundy to comply with these rules. Also of
14 importance, BREC did not consider forward going costs for compliance with
15 NAAQS revisions, the CCR rule, the Water Intake (316(b)) rule, and new effluent
16 limits despite its expectation that those regulations will drive further capital
17 expenditures. Berry direct prefiled at 27 ff.; DePriest direct prefiled at 10. BREC
18 stated it did not consider costs for compliance with NAAQS revisions simply
19 because they would not need to comply immediately. Berry, *loc. cit.* This position
20 of BREC’s in the face of Sargent & Lundy’s caution that “In order to achieve
21 compliance with potential NAAQS emission reductions, BMC would need to alter
22 their compliance strategy,” is not sound utility planning. S&L report at 6-4.
23 BREC implicitly admits it should use a 20-year planning horizon, but fails to
24 consider reasonably foreseeable costs for future environmental controls during
25 that period. Such shortsighted analysis stacks the deck in favor of the proposed
26 Environmental Retrofits because it only looks at subset of costs needed to go
27 down that road. As a result, its 2012 Environmental Plan fails to deliver a least
28 cost solution to meeting customer needs. Failure to consider all options in a
29 cohesive fashion makes it impossible for the Commission to find that retrofits are
30 least cost.

1 c. Errors

2 **Q** **Did any of the other errors BREC made in its economic analysis of**
3 **compliance options materially affect the outcome of its analysis?**

4 **A** Yes. Among the material errors BREC made were

- 5 • Using a natural gas price forecast that is out of date and higher than current
- 6 forecasts,
- 7 • Using a CO₂ emissions price in the determination of market energy prices, but
- 8 not in unit running costs, and
- 9 • Exclusion of ongoing operating and maintenance (O&M) costs at each of the
- 10 coal units.

11 Others are listed above and in the prefiled direct testimony of witness Wilson.

12 I am also concerned about the limited sensitivity analyses. In response to
13 discovery request KIUC 2-5, Big Rivers states that it relied on a single estimate of
14 fuel costs, market prices, allowance prices, etc., as support for its application to
15 the Commission.

16 Q. Please explain why Big Rivers used a forward energy
17 price forecast from both Pace Global (“Pace”) and APM in the
18 cases studied.

19 A. Pace’s analysis was developed to incorporate a wide
20 range of market uncertainties on key drivers such as fuel prices,
21 electric load growth, carbon compliance costs, and power market
22 prices. This approach provided the context under which Pace
23 developed a reference case hourly price projection for use in
24 further production cost models.

25 The fact that many variations of input assumptions were used to generate one or
26 more of the reference case input assumptions does not immunize that reference
27 case, itself, from uncertainty. Failure to present sensitivity cases showing whether
28 the proposed Environmental Retrofits are appropriately robust is not good utility
29 practice and should lead to the Commission not to put much weight on it the
30 Application as evidence for the retrofits.

1 **d. Failure to Model Retrofits Against Relevant Alternative Options**

2 **Q** **Did BREC compare the proposed Environmental Retrofits to a full array of**
3 **alternatives?**

4 **A** No, it did not. BREC's cost effectiveness evaluation considered three cases: a
5 Build Case (in which it installed all the Environmental Retrofits); a Partial Build
6 Case (in which it installed all but one of those retrofits) and a Buy Case (in which
7 it installed only MATS retrofits). Hite direct at 6. One of those cases considered
8 market purchases, but only as an alternative to some of the controls, not as an
9 alternative to continued operation of one or more of the coal generating units.
10 Other alternatives, such as new natural gas plant, gas conversions, retirements,
11 purchased power agreements for excess capacity, energy efficiency programs and
12 renewable resources were not modeled.

13 To illustrate the importance of this omission, Synapse compared the Build Case to
14 one of those alternatives—a new natural gas combined cycle (NGCC) unit first
15 using BREC's input assumptions and then using several combinations of more
16 appropriate assumptions. Witness Wilson explains that process and those
17 combinations of assumptions in her prefiled testimony. Those scenarios show
18 that, with reasonable input assumptions and correcting several errors made by
19 BREC in its analyses, replacement of BREC's coal units with natural gas
20 combined-cycle replacement options is more economical on an NPVRR basis
21 than the proposed Environmental Retrofits by between 12 and 20 per cent,
22 depending on the unit, for a fleet-wide savings in excess of one billion dollars
23 NPVRR.

24 **Q** **Would not reliance on natural gas generation entail some price uncertainty?**

25 **A** Yes, as with many other options, reliance on natural gas as a fuel entails some
26 price volatile over short and mid-term, perhaps somewhat more so than coal.
27 However, natural gas is not necessarily the only alternative that could be included
28 in a diversified portfolio for BREC that should include increased levels of DSM
29 and renewable resources such as wind. Further, those price fluctuations can be

1 hedged over the short- to mid-term, and the coal retrofit case brings its own suite
2 of risks including excess capacity, cost overruns (discussed below), aging plant
3 considerations, future carbon regulation, and more. Furthermore, a resource
4 portfolio so dominated by one technology and one fuel as BREC's is quite brittle
5 compared to a diverse portfolio of multiple fuels, market purchases, energy
6 efficiency, load management and renewables.

7 **Q You mentioned energy efficiency resources as one alternative not considered**
8 **by BREC. Please explain further.**

9 **A** On page 29 of his prefiled direct, witness Berry states that "the magnitude of
10 potential savings from DSM and energy efficiency is insufficient to materially
11 assist Big Rivers in complying with CSAPR and MATS."

12 **Q Are you surprised by that conclusion and do you agree with it?**

13 **A** I do not agree with that conclusion, but am not surprised that BREC would reach
14 it, as the DSM programs being implemented by BREC are nowhere near what is
15 readily achievable by a utility.

16 BREC's assertion is merely conclusory and fails to consider the possibility that
17 DSM and energy efficiency could make a difference to the economics of even one
18 of BREC's many coal units. It is also contrary to the experience of national
19 leaders in energy efficiency who have found it possible to achieve savings in
20 excess of 1% of retail sales per year consistently for a decade or more. However, I
21 am not surprised that BREC should reach such a conclusion, based on its
22 approach to DSM evidenced in its 2010 IRP. For example, on page 7-14 of that
23 IRP, BREC states that, Big Rivers and its three distribution member cooperatives
24 currently primarily provide education about energy efficiency, with the exception
25 being distribution of CFL lighting at no cost to members." In my thirty-some
26 years of experience with the design of DSM programs, I have not seen any utility
27 that took such a stance succeed in achieving substantial savings.

28 Further, In Section 8 of that IRP, BREC presents the projected savings of its future
29 DSM programs, and those savings amount to approximately 0.01% of annual non-

1 smelter sales each year. This is barely a token amount, representing a tiny fraction
2 of the sustained annual savings rate achievable by a vigorous utility DSM
3 program.¹ Such a vigorous program can also be ramped up by committed utility
4 managers within about three years, especially now that effective program designs
5 are well understood.

6 All in all, it is clear that BREC has not considered DSM and energy efficiency
7 seriously and that, if it had, it would have found that energy efficiency resources
8 would have made a difference in its ability to retire existing units and rely on
9 other resources. It is important to note that sustained savings in energy sales of
10 1% per year from DSM programs would result in a load reduction in excess of
11 10% after a decade. This is certainly an amount that can make a difference in the
12 resource needs of BREC and its customers.

13 **e. All or Nothing Alternatives**

14 **Q You mentioned that DSM resources might well have made a difference in the**
15 **economics of at least some of BREC's units. Please explain further the**
16 **modeling of individual units.**

17 **A** As witness Wilson explains in her prefiled direct, BREC's Build Case resource
18 scenario analyzed all its coal units as retrofitted. BREC did not analyze the
19 opportunities to retrofit some units and retire others in favor of alternatives. I am
20 concerned that this distorts the outcome, especially in the Smelter sensitivities. If
21 BREC had done its analysis on a unit-by-unit basis, it is likely that DSM could
22 have offset the need to retrofit or replace some units. This is especially
23 problematic given the Smelter sensitivities. In particular, BREC's assertion that

¹ For example, in 2007, states had utility and public benefit programs that saved electric energy at a rate in excess of 0.5% of retail sales (total retail sales, not excluding large industrial sales as in the above Kentucky example) included Vermont, Connecticut, California, Massachusetts, Minnesota, Washington, Oregon, Rhode Island and Iowa. Dan York, Patti Witte, Seth Nowak and Marty Kushler, *Three Decades and Counting: A Historical Review and Current Assessment of Electric Utility Energy Efficiency Activity in the States*, June 27, 2012, ACEEE Research Report U123, available at <http://aceee.org/research-report/u123>.

1 the Smelter sensitivity showed no change in the least cost strategy should be
2 given no weight due to this analytical defect.

3 **Q Did BREC consider any coal plant retirements or natural gas conversions**
4 **(aside from the Reid plant) in its economic analysis? If not, why not?**

5 **A** Apparently, BREC did not consider any coal plant retirements in its economic
6 analysis. It justified this in the following way in its Response to KIUC 1-26:

7 Because of the significant number of generating units involved and the
8 significant unamortized plant balance of the coal units that are being
9 upgraded, retirement of the coal plants or converting them to natural gas
10 would result in the need to recover, through rates, the Unamortized plant
11 balances of the coal plants in addition to any costs of converting the plants
12 to natural gas. Big Rivers believed that this cost could be avoided by
13 pursuing upgrades that would control emissions and comply with EPA
14 regulations for an average cost of about \$169 per kW compared to an
15 overnight installed cost of \$626 per kW for an advanced combustion
16 turbine and \$917 per kW for a new combined cycle unit (Assumptions to
17 the Annual Energy Outlook for 2011, DOE EIA, p. 97; see attached).
18 These differences were so large that Big Rivers did not consider it
19 necessary to evaluate the option of retiring coal plants or converting them
20 to natural gas.

21 **Q Is that justification sound?**

22 **A** No, it is not. In fact, BREC's excuse is economic nonsense.

23 I do not necessarily agree that, in the event of a coal unit retirement, the
24 unamortized values would be recoverable in rates under traditional ratemaking.
25 However, from a least cost planning point of view it is irrelevant whether the
26 unamortized costs of those plants are recoverable in rates. That is because,
27 whether or not those costs would be recoverable from BREC's ratepayers, they
28 could not "be avoided by pursuing upgrades that would control emissions and
29 comply with EPA regulations." Rather, those costs are sunk and are completely
30 unaffected by any decision regarding the proposed Environmental Retrofits. This
31 fundamental error is compounded by erroneously comparing capital resources on
32 the basis of their overnight installed cost rather than a full life-cycle revenue
33 requirement.

1 The following example should clarify this point. Assume for the sake of argument
 2 that (1) the unamortized cost of BREC’s coal plants at this time including the
 3 present value of any carrying charges (TIER, etc.) is \$1 Billion, (2) the life cycle
 4 cost of retrofitting and operating those plants is \$7.4 Billion, (3) the life cycle cost
 5 of retiring those plants and replacing them with NGCC plants is \$6.2 Billion, and
 6 (4) nothing else in BREC’s cost of service will change between those two
 7 strategies. Then the cost of service difference (NPVRR) will be:

Strategy	Build Case (Install proposed Environmental Retrofits)	Alternative Case (retire existing plants and replace with NGCC)	Difference
Amortization of existing rate base and carrying costs	\$1 Billion	\$1 Billion	\$0
Capital and operating costs of strategy	\$7.4 Billion	\$6.2 Billion	\$1.2 Billion
Total	\$8.4 Billion	\$7.2 Billion	\$1.2 Billion

8
 9 Clearly, even if we grant BREC the benefit of the doubt on whether the existing rate
 10 base would, in fact, be recoverable from customers under the Alternative Case, the
 11 amount of that existing rate base cancels out and makes no difference in which
 12 strategy is least cost.

13 **5. OTHER CONCERNS WITH THE PROPOSED ENVIRONMENTAL RETROFITS**

14 **Q In considering the cost-effectiveness of BREC’s plan, can the Commission be**
 15 **confident that the cost estimates presented for the Environmental Retrofits**
 16 **will not increase?**

17 **A** Not necessarily. First of all, there is the concern already discussed above that the
 18 costs presented do not include all of the environmental upgrade costs that BREC
 19 would need to enable its plants to continue operating, even with the proposed
 20 Environmental Retrofits. Second, as has already been discussed, BREC has not
 21 included a specific estimate of owner’s costs for the proposed Environmental
 22 Retrofits and has not accounted for future capital additions that will be needed to

1 keep the plants running. In addition, there is reason to expect the final costs of
2 such retrofits would exceed the estimates typically offered by utilities at this stage
3 of development. A recent example is the case of AEP's Big Sandy retrofit
4 proposal where there was an increase of about 130% in estimated costs from the
5 base engineering, procurement and construction (EPC) cost to total company cost
6 (from \$409 million before escalation and contingency to \$940 million after
7 "associated" costs, the cost of landfill modifications required to accept flue gas
8 desulfurization waste, a 20% contingency, American Electric Power owner costs,
9 and allowance for funds used during construction (AFUDC)). I understood that
10 the BREC cost estimate does include contingency and escalation, but describe this
11 recent experience as an illustration of what may happen to initial estimates.

12 I would also observe that Sargent and Lundy characterizes its capital cost
13 estimates as follows in Sec. 5.1.1 of its report included in the BREC Application:

14 The capital costs do not include; sales taxes, property taxes, license
15 fees and royalties, owner costs, or AFUDC (Allowance for Funds
16 Used During Construction). The costs are based on a minimal-
17 contracts lump-sum project approach. The total installed costs are
18 factored from recent projects and quotes obtained by S&L. No
19 specific quotes or engineering was completed for any of the
20 projected upgrades for the BREC units. The costs provided herein
21 reflect an approximate accuracy of +/-20% and are not indicative
22 of costs that may be negotiated in the current marketplace. These
23 costs should not be used for detailed budgeting or solicitation of
24 pollution control bonds.

25 (I have mentioned owner's costs above.) This suggests some considerable
26 uncertainty. There is some reason to believe that capital costs for such equipment
27 may increase over the next few years due to greater demand. I also note that a
28 20% margin is greater than the margin by which the proposed Environmental
29 Retrofit life cycle costs exceed NGCC life cycle costs, even in the scenarios that
30 assume BREC's input assumptions. (See Wilson Table 1.). Further, in response to
31 SC 2-4, BREC failed to provide the requested information on cost overruns of
32 prior major capital projects.

1 **6. CONCLUSIONS AND RECOMMENDATIONS**

2 **Q. Please summarize the major conclusions and recommendation from your**
3 **review of the Company's request.**

4 **A** My first conclusion is that the Company has not demonstrated that its proposed
5 CPCN for Big Rivers is reasonable and cost-effective for complying with the
6 environmental requirements the Company is facing. That conclusion is based
7 upon the results of our review, which indicates that the Company has not
8 evaluated the full range of resource options available to it, that its projections of
9 revenue requirements for the resource options it did evaluate are not correct, that
10 its evaluation of future scenarios does not include a reasonable projection of
11 carbon prices and that its risk analysis is flawed. My second, related, conclusion is
12 that allowing BREC to recover the costs of installing environmental control
13 equipment on Big Rivers from ratepayers will not result in just and reasonable
14 rates.

15 Based upon those conclusions my recommendation is that the Commission not
16 approve the Company's request for a CPCN for Big Rivers.

17 **Q. Does this complete your Direct Testimony?**

18 **A** Yes.

William Steinhurst

Senior Consultant
Synapse Energy Economics
32 Main St., #394, Montpelier VT 05602
(802) 223-2417
wsteinhurst@synapse-energy.com
www.synapse-energy.com

Synapse Main Office: 485 Massachusetts Ave, Suite 2, Cambridge MA 02139
(617) 661-3248 • fax: (617) 661-0599

PROFESSIONAL EXPERIENCE

Synapse Energy Economics Inc., Cambridge, MA.
Senior Consultant, July 2003 to Present

Consulting services to state and provincial energy regulators and public advocates, state provincial and national energy departments, and non-governmental organizations on regulatory policy, power supply procurement, electric industry restructuring, portfolio management, rate setting and rate design, economic impacts of efficiency and renewable generation programs, and other utility and energy topics. Expert witness services and litigation advice. Co-authored reports, journal articles and conference presentations on portfolio management, energy efficiency programs, and electric reliability.

Vermont Department of Public Service, Montpelier, VT.
Director for Regulated Utility Planning, 1986-2003

Preparation of long range policy plans in the areas of electric utilities, energy and telecommunications, including oversight of research, modeling, public input processes, policy analysis and writing. Development of policy positions and drafting of legislation and rules concerning utility resource planning, power supply acquisition, generation and transmission permitting, environmental costing, energy efficiency and alternative generation, utility restructuring and retail choice, distributed utility planning, rate setting and rate design, mergers, financing and acquisitions, decision analysis, power contract restructuring, Qualifying Facility contracts and permits, net metering, and other critical regulatory issues. Extensive expert testimony on those matters, as well as utility bankruptcy, prudence reviews, and critical utility policy matters. Extensive legislative testimony.

Planning Econometrician, 1981-1986

Energy demand forecasting, economic and demographic projections, economic and policy impact analysis, avoided cost estimates, and other quantitative analysis for utility and energy policy making. Development of State's basic policies regarding least cost planning and resource selection, including methods for evaluation of and program design for generation, transmission and demand-side options. Implementation of utility energy efficiency program requirements.

Vermont Agency of Human Services, Montpelier, VT.
Director of Planning, 1979-1981

Vermont Department of Social and Rehabilitation Services, Waterbury, VT.
Director of Planning and Evaluation, 1977-1979
Acting Deputy Commissioner, 1977

Vermont Department of Corrections, Montpelier, VT.
Director of Planning and Research, 1974-1977
Chief of Research and Statistics, 1973-1974

Pre-2004 Energy Consulting

Illinois Energy Office, 1986.
Massachusetts Executive Office of Energy Resources, 1986.
Northern Technology, Inc., Gorham, NH, 1983-1985.
James River Corporation, Green Bay, WI, 1985.
Newfoundland Department of Natural Resources, 1995

Teaching

University of Vermont, Burlington, Vt., 1977 to 1989
Adelphi University, Garden City, N.Y., 1980 to 1988

University of N. H., Complex Systems Ctr., Grad. Studies Comm., 1992-1994
Institute of International Education, Least Cost Planning Seminar, 1999
Community College of Vermont, 2002-2004

Miscellaneous

National Science Foundation Undergraduate Research Grant, 1965.
Wesleyan University Astronomy Prize, 1967.
Association for Criminal Justice Research (Northeast/Canada), Director, 1973 to 1981,
Secretary/Treas., 1973 to 1980.
University of Vermont Graduate Award in Statistics, May, 1980.
Contributing Editor, Current Index to Statistics, 1976-1985.
Chair, Session on Energy Economics, New England Business and Economics Association
Annual Meeting, 1983.
Member, Intl. System Dynamics Soc., Tau Beta Pi.
Northeast International Committee on Energy, New England Governors' Conference/Eastern Canadian Premieres, various
periods, 1986 to 2003
Director, Vermont Girl Scout Council, 1989-1991, 2000-2008; Secy., 1991-1997
3rd Vice President, Girl Scouts of the Green and White Mountains, 2009 to date
Editor, Intl. System Dynamics Soc. Bibliography, 1990-
Advisory Group Member, New England Project, MIT Analysis Group for Regional
Electricity Alternatives, 1991-1995.
Chair, Steering Committee & Modeling Subcommittee, New England Governors Conf.
Regional Energy Planning Project, 1991-1995.
Member, Montpelier School System Technology Steering Committee and Montpelier
High School Technology Committee, 1992-1993.
Reviewer, Vermont Experimental Program to Stimulate Competitive Research, 1993-
Invited Speaker, 3rd Intl. Conf. on Externality Costs, Ladenburg, FDR, 1995.
Member, Steering Committee, New England Governors Conference, Restructuring/
Environmentally Sustainable Technologies Project, 1996-1997
U. S. DOE Distributed Generation Collaborative, 2000-2003
Justice of the Peace, Montpelier, Vermont, 2007-

EDUCATION

Degrees

B.A., Physics, Wesleyan University, Middletown, CT, 1970
M.S., Statistics, University of Vermont, Burlington, VT, 1980
Ph.D., Mechanical Engineering, University of Vermont, Burlington, VT, 1988

Continuing Education

Seminar in Electricity and Telecommunications Demand, 1981
Advanced Workshop in Regulation and Public Utility Economics, June, 1982 and
June, 1983, Rutgers University
Transmission Reliability Assessment, Power Technologies, Inc., 1986
Regional Forecasting and Simulation Modeling, January, 1991, U. Massachusetts-Amherst

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Dockets 5108/5109 - Vt. Marble Co. Small Power Rate
Docket 5133 - Moretown Hydro Energy Co. Small Power Rate
Docket 5202 - VPPSA Refinancing
Docket 5248 - DPS Ontario Hydro Power Purchase

Docket 5270 - Least Cost Planning and Demand-Side Management
Docket 5270-GMP-1 - Highgate Apartments Fuel Switching
Docket 5270-CV-1&3 - Demand-Side Management Preapproval and Ratemaking Principles
Docket 5270-CV-4 - IRP
Docket 5270-VGS-1 - Demand-Side Management Preapproval
Docket 5270-WEC-1 - Demand-Side Management Preapproval
Dockets 5270-BRTN-1, 5270-CUC-3, 5270-HDPK-1, 5270-JHNS-1, 5270-JKSN-1,
5270-LDLW-1, 5270-LYND-1, 5270-MRSV-1, 5270-ORLN-1, 5270-RDSB-1,
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Docket 5277 - DPS Ontario Hydro Transactions Agreement
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Docket 5330E - Hydro Quebec Power Purchase, Waiver and Amendment
Docket 5372 - CVPSC Rate Increase
Docket 5491 - CVPSC Rate Increase
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Docket 5634 - NET Toll Dialing Plan
Docket 5638 - CVPSC Mack Molding*
Docket 5664 - EPACT Standards
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Docket 5826 - Vermont Marble Electric Division - IRP - externalities
Docket 5832 - Lyndonville IRP - externalities
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Docket 5857 - GMP Rate Increase*
Docket 5971 - VEC Bankruptcy Reorganization*
Docket 5980 - Proposal for Statewide Efficiency Utility
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Docket 6018 - CVPSC Rate Increase (HQ Issues)
Docket 6107 - GMP Rate Increase (HQ Issues)
Docket 6140 - Electric Industry Restructuring (various presentations)*
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Docket 6270 - Qualifying facility contract reform
Docket 6290 - Distributed Generation*
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Docket 6495 - Vermont Gas Systems Rate Increase (Deferral Account and Hedging)

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Docket 6958 - Green Mountain Power Rate Design - for AARP
Docket 6958 - Green Mountain Power Rate Design - for Conservation Law Foundation
Docket 6958 - Green Mountain Power Rate Design - for Conservation Law Foundation
Docket 7085 - CVPS Street Lighting Tariff - for Village of Woodstock
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Florida Public Service Commission

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Illinois Commerce Commission

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Oklahoma Corporation Commission

Cause No. RM 2007-007 – Demand Side Management Rulemaking – for The Sierra Club and the Oklahoma Sustainability Network (May 2008) *

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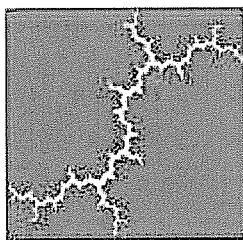
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Resume dated September 15, 2011.



Synapse
Energy Economics, Inc.

Portfolio Management: Tools and Practices for Regulators

Prepared by:
William Steinhurst, David White,
Amy Roschelle, Alice Napoleon,
Rick Hornby, and Bruce Biewald
Synapse Energy Economics
22 Pearl Street, Cambridge, MA 02139
www.synapse-energy.com
617-661-3248

Prepared for:
National Association of
Regulatory Utility Commissioners

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1. Introduction and Summary

1.1. Background and Purpose

Ensuring that reliable retail electric service is being provided at reasonable rates is more challenging than ever.

The providers of the generation component of that retail service, regardless of the presence or absence of retail competition, face a host of major uncertainties. These include high and volatile natural gas prices, uncertain wholesale power prices, uncertainty regarding the feasibility and economics of new generation capacity, and a wide range of possible environmental regulation futures, particularly with respect to greenhouse gas emissions. Providers must address those uncertainties when choosing supply strategies, resource mix, and ownership or contracting arrangements.

Regulators are faced with the difficult task of aligning resource plans and procurement strategies with the policy objectives of their particular jurisdiction. Those policy objectives may include enhancing reliability, managing risk, improving the performance of wholesale and retail markets and achieving reasonable rates. In other words, they must determine whether the proposed resource plans and procurement strategies represent “the best” choices from the full range of viable alternative plans and strategies, given their objectives.

Regulators face these challenges both in jurisdictions with retail competition and fully regulated states. Some states, such as Delaware, have recently enacted legislation mandating changes to procurement policies.¹ Others have grappled with these issues in various regulatory proceedings to institute new or updated procurement policies. Examples of recent relevant cases and proceedings in states with, or introducing, retail competition include:

- Illinois—Commerce Commission Docket 05-0159, Commonwealth Edison Auction, Dockets 05-0160, 0161 and 0162, Ameren Utilities
- Delaware—Executive Order No. 82

Examples of recent relevant cases and proceedings in vertically integrated states include:

- California—Rulemakings 01-10-024 and 04-04-003
- Oregon—Public Utility Commission Dockets UM-1056 and UM-1066 regarding IRP Policy
- Montana—Montana Administrative Rules, sub-chapter 20: Least Cost Planning—Electric Utilities. 38.5.2004

The parties to such proceedings must grapple with a number of questions at both a broad and detailed level. Broad questions that arise include:

¹ Electric Utility Retail Consumer Act of 2006, 75 Del. Laws ch. 242 (Apr. 6, 2006)

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- What level of price volatility is tolerable for customers, taking into account the means at their disposal for managing that risk?
 - How can portfolio management help address public interest concerns regarding the level and stability of electricity prices?
 - Over what timeframe will the proposed strategy apply?
 - What level and stability of prices are expected to result during that time?
 - What are the key assumptions underlying those expectations?
 - How sensitive is the expected level and/or stability of prices to a change in those assumptions?
 - What flexibility is there to modify the strategy in response to changes in demand or supply conditions; at what points in time is that possible; and what is the process for doing so?
 - What alternative strategies were or should be considered, including energy efficiency, demand response, and renewable energy resources?
 - How do those alternative strategies compare in terms of level, stability, and sensitivity of prices to changes in assumptions?

More detailed questions can also arise, such as:

- What quantity of supply should be sought in each procurement and for what contract duration(s)?
- What portions of supply should be acquired through utility-owned generation, short-term purchases (e.g. day ahead markets), short- or long-term fixed price contracts, contracts for output from renewable energy resources, and investments in energy efficiency and demand side management (DSM)?
- When and how often should auctions, RFPs, or other procurements be held?
- How should auctions or procurements be designed to attract bids from providers of energy efficiency and renewable resources in addition to traditional supply side resources?
- Will the proposed strategy limit the ability to respond to carbon emission policies in the future?
- Will the proposed strategy limit the ability to respond to newly available resources, projects, or technologies in the future?
- Will the proposed strategy result in long-term commitments that have a high probability of exposing the provider or its customers to material stranded costs in the future?

The advantage to a portfolio management (PM) approach is that it provides regulators, utilities, and other parties with a systematic process and set of tools to answer such

questions in a transparent manner. Not only can PM reveal input data and assumptions, it can also identify and quantify the trade-offs between objectives under alternative strategies.

The primary purpose of this paper is to provide regulators with an overview of PM tools and practices that could be applied to the procurement of electricity resources to serve retail customers.² As will be seen, these tools and practices are valuable both in the resource planning of vertically integrated (or partially integrated) utilities and in the development and oversight of policies for default service in retail competition jurisdictions. The report only briefly reviews the benefits of PM, as a number of other reports have described the benefits of portfolio management in detail.³ The paper then explains how PM can be implemented in states that are fully regulated as well as in states with retail competition. Finally, it presents a discussion of several key technical aspects of applying PM, including modeling tools, analytical techniques, and necessary expertise.

1.2. What is Portfolio Management?

The term “portfolio management” has a long history in the realms of finance and investment. Under that name and others, the same risk management concepts and techniques have long been applied to procurement of commodities, including electric utility procurement of fuels and purchased power and local distribution company (LDC) procurement of natural gas.⁴ In recent years, the term has begun to be used in the electric industry to describe actual or suggested approaches to default service resource planning and procurement in states that have restructured their electric industry.⁵ However, application of portfolio management concepts need not be confined to retail choice states.

First, interest in development of a set of modern planning and procurement tools for application in the electric industry has been evolving over the last several years. In its 2003 resolution on PM, the National Association of Regulatory Utility Commissioners (NARUC) encouraged state regulatory commissions to

... explore portfolio management techniques that may be applicable to their particular circumstances, under either traditional or restructured markets, and to adopt appropriate regulatory policies to facilitate effective implementation of portfolio management practices by regulated utilities.

² Many electric utilities and load serving entities are familiar with these tools and practices, as noted earlier.

³ See, for example, Bruce Biewald, et al, *Portfolio Management: How to Procure Electricity Resources to Provide Reliable, Low-Cost, and Efficient Electricity Services to All Retail Customers* Synapse Energy Economics, October, 2003. Prepared for the Regulatory Assistance Project and the Energy Foundation. Available at <http://www.synapse-energy.com/Downloads/SynapseReport.2003-10.RAP.Portfolio-Management.03-24.pdf>

⁴ Biewald, et al., and Frank C. Graves, et al., *Resource Planning and Procurement in Evolving Energy Markets*, The Brattle Group, prepared for The Edison Electric Institute, January 31, 2004.

⁵ In retail choice jurisdictions, various names are applied to this concept. Some of those are Basic Generation Service, Standard Offer Service, Provider of Last Resort service or POLR, and Basic Utility Service. Unless discussing the regime in a particular jurisdiction, we will use these terms interchangeably to mean the electric service provided to customers who do not shop.

In a 2004 report on resource planning and procurement in electricity markets sponsored by the Edison Electric Industry (EEI), the authors stated, "A synthesis is needed to meet customer needs for risk management and least-cost planning in the evolving industry structure that is a hybrid of competition and regulation."⁶

Second, there is increasing interest in meeting future electricity requirements through a diverse mix of cost-effective resources, including energy efficiency, non-traditional renewable resources, and new technologies such as distributed generation, in addition to traditional supply side resources. For example, the Energy Policy Act of 2005 (EPA) requires consideration of a fuel source diversity standard.⁷ Also, fuel diversity has been a major topic at both the 2005 and 2006 annual "Commissioners Only Summit" sponsored by National Regulatory Research Institute (NRRI). More recently, in July 2006, the President of NARUC and the Chair of EEI introduced a National Action Plan for Energy Efficiency that identifies energy efficiency as a high-priority energy resource.

This interest in applying a modern set of analytical tools to the acquisition of a diverse range of traditional and non-traditional resources is reflected in the following definition of PM, drawn from a 2006 report on clean energy policies and best practices prepared by the United States Environmental Protection Agency (EPA):

Portfolio management refers to energy resource planning that incorporates a variety of energy resources, including supply-side (e.g., traditional and renewable energy sources) and demand-side (e.g., energy efficiency) options. The term "portfolio management" has emerged in recent years to describe resource planning and procurement in states that have restructured their electric industry. However, the approach can also include the more traditional integrated resource planning (IRP) approaches applied to regulated, vertically integrated utilities.

Thus, portfolio management as applied in the electric industry may be seen as an approach to or refinement of traditional utility resource planning, which draws upon integrated resource planning, resource procurement, and risk management.⁸ As such, PM encompasses three distinct components:

- developing a resource plan,
- procuring the portfolio of resources identified in that plan, and
- managing that portfolio of resources on an ongoing basis.

⁶ Graves, p. 3.

⁷ EPA 2005 Title XII Electricity, Subtitle E, Amendments to PURPA §1251(a).

⁸ Not all concepts, tools and practices from financial markets can be applied directly to electric markets; some may not apply while others may need to be customized. Conversely, many of the products and tools relevant to electricity portfolio management are unique to that industry.

1.3. How Might PM be Applied to Particular Retail Electricity Markets?

PM can be, and is being, applied in a variety of ways. In fact, the spectrum of approaches to implementing PM ranges from a narrow, passive approach at one end of the spectrum to a comprehensive, active approach at the other.

- A narrow, passive approach might be one in which planning considers only a short time frame and few resources, there is a single annual process for purchasing 100% of requirements, and periodic reviews and updates are absent.
- A comprehensive, active approach might be one in which resources are selected from a broad range of resources based on multi-year, long-term scenario analysis, and procured under a variety of ownership and contracting arrangements. Under a comprehensive approach, decision-making would reflect the cost and risk minimization benefits of diversification – diversity of fuels, diversity of technologies, including energy efficiency and renewables, diversity of contract terms and conditions (such as start dates and durations) and diversity of financial instruments for risk management. It would also include active or ongoing management of portfolio resources in response to changes in customer requirements and market conditions from day to day, week to week and month to month.

In any given state, the policy framework and objectives that govern the retail electric market, particularly electricity supply service, will be a key factor in the choice of a PM approach from this spectrum. For example, if the explicit policy objective of a state is to strongly encourage the development of a competitive retail market for all customers, the regulator may choose to support a narrow, passive PM approach for default service so that service will be relatively unattractive or provide maximum scope for retailers to differentiate themselves. On the other hand, if the explicit policy objective is reasonable rates to all customers receiving regulated retail service, the regulator may choose a comprehensive, active PM approach for default service. Similarly, a state's policy framework may assign responsibilities in certain ways, for example relying on an Independent System Operator (ISO) or Regional Transmission Operator (RTO) to ensure reliability. The application of PM must take such divisions of responsibility into account.

Given the variation in policy objectives among the states, it is not surprising that the retail competition states exhibit a range of approaches to portfolio management. Some states have essentially no PM. In other states a narrow, passive approach is being applied to the procurement and management of resources for default service. Appendix A presents key characteristics of default service procurement in the states that we surveyed. That approach typically consists of the following components:

- a procurement strategy using fixed-price, slice-of-load contracts of one or more term lengths up to three years, possibly overlapping in a laddered sequence,⁹

⁹ In some jurisdictions, *slightly longer initial term lengths* were used to synchronize procurement with ISO or RTO planning and commitment cycles.

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- procurement via (usually) annual auctions or request for proposals (RFPs), and
 - absence of ongoing resource management between annual auctions.

There is little evidence of quantitative analysis of risks and benefits underlying the design of these procurement strategies. When contract laddering is the sole procurement tool used, it provides only limited portfolio management benefits, which are realizable only over only the length of that ladder, sometimes a very short time frame. Some states are beginning to address this limitation through new laws that explicitly try to obtain low costs over the long-term for their smaller default service customers. A variety of means have been adopted or are under discussion for this purpose. Maine, Delaware, and Maryland have each taken such steps. (See Appendix A of this report for details.) The general goal of the new policies is essentially to achieve reasonable and stable rates for default service. As a result, regulators in those states are beginning to explore ways to move to a more comprehensive, active approach.

The fully regulated states we surveyed had a comprehensive, active approach to portfolio management. Data from this survey is presented in Appendix B. In these states some form of long-term planning, which in some cases might be called "IRP," is required every few years. Procurement is not tied to an annual cycle of auctions, and ongoing management is expected. On the other hand, while planning in most of those jurisdictions included some analyses of uncertainty generally in the form of "sensitivity analyses," extensive quantitative analysis of the risks of various alternatives from a customer or public policy perspective was not the rule.

1.4. Key Conclusions

Our key conclusions are as follows:

- The providers of the generation component of retail electricity service face a host of major uncertainties, including future restrictions on emissions of carbon dioxide and future natural gas prices.
- Portfolio management, as applied to the provision of retail electric service, encompasses development of a resource plan, procurement of the portfolio of resources identified in that plan, and management of that portfolio of resources on an ongoing basis.
- Portfolio management provides regulators, utilities, and other parties with a systematic process and analytical tools for identifying a plan that will result in reliable service at reasonable rates. It offers transparency and tools for dealing with uncertainty and risk.
- Portfolio management can be applied to the generation component of retail service, regardless of the presence or absence of retail competition. Portfolio management approaches can be selected from a continuum ranging from comprehensive and active or narrow and passive.
- A narrow, passive approach to portfolio management may expose retail customers to rates that are higher or more volatile, than a comprehensive, active approach. A

strategy composed of a diverse mix of cost-effective resources, including energy efficiency and non-traditional renewable resources, may provide the best balance of expected cost and stable rates over the long-term.

- The policy framework and objectives that govern the retail electric market in a state influence the choice of an approach to PM in that state. Subject to policy constraints, regulators generally have authority to determine how portfolio management will be applied and by what entity.
- There is a range of computer models available for PM. They include planning models capable of addressing either (1) traditional cost-based engineering optimization analysis of the *expected costs of long-range* portfolios of traditional supply-side resources,¹⁰ (2) scenario-based comparisons of *long-range* portfolios of traditional resources for "robustness," or (3) short- to near-term quantitative risk analysis of a wide range of physical resources and financial instruments. Most quantitative risk analysis models are financial tools that analyze risk from the perspective of the supplier rather than retail customers.
- Most of these planning models require special effort in order to include energy efficiency and renewable energy in their evaluation of resources. In addition, these tools would benefit from improving their methodologies for analyzing long-term risks and comparing long-term decisions under uncertainty. For example, some existing optimization models require the representation of system operation to be simplified and limit the number of resources that can be considered in a model run. Such modeling constraints can prevent the long-term costs and benefits to consumers of a diverse mix of resources from being evaluated fully. Regulators may wish to promote research and development on improvements in these areas.
- Multiple modeling tools may be needed to address all three components of PM. However, integrating their results may be challenging.
- It appears that insufficient attention is being paid to development of tools for realistic analysis of long-term risks and long-term comparison of resource options that take uncertainty into account. Regulators may wish to promote research and development of open source algorithms or software in these areas.
- Staffing and resource limitations, as well as general lack of familiarity and acceptance, may be challenges to implementing or overseeing portfolio management at regulatory commissions. Regulators can do much to reduce such barriers over time.
- Portfolio management analysis and implementation will only be as good as the people who carry out and oversee those tasks. Managers and regulators need to consider the skills and abilities for doing so.

¹⁰ Models driven by optimization techniques may also lack fidelity in imperfect markets and situations where decision making and investment practices are suboptimal, as is often the case.

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- It is not clear that the data necessary for portfolio management in the electric utility industry exist in all cases. Where it does exist, the data may be private and confidential. Certainly, some historical data series are publicly available, such as fossil fuel market prices and, more recently, electricity and weather hedge prices. Other data, such as load profiles and volatility, plant outage rates, and heat rates may be less available than in the past due to competitive pressures. Regulators and utilities can begin with data that is available, publicly or under confidentiality arrangements. They also may wish to identify new information that should be developed to maximize the feasibility and usefulness of risk analysis.
 - The application of certain elements of portfolio management in the electric industry is still relatively new. Some fully regulated states and some retail choice states have begun to take action, but there is much room for improvement and certainly room for more states to implement PM. Regulators can play an important role in encouraging further improvements in, and adoption of, these concepts. Regulators may wish to promote the development of portfolio management tools that can address energy efficiency and renewable energy resources to the same degree as traditional supply-side resources at every stage of the process.
 - Screening out or winnowing down major diversification options very early in a planning study or risk assessment can seriously compromise the results. The real value of those options may not become apparent until much later in those studies or assessments, when analyses of risk and uncertainty are prepared.
 - Regulators will likely need to exercise considerably more oversight of risk mitigation, in the future. Unfortunately, clear methods for conceptualizing risk in utility portfolio management are not well developed. Regulators may wish to consider exploratory proceedings to develop and communicate risk management and portfolio management goals and criteria.

2. Portfolio Management: Objectives and Applications

Portfolio management is a process and a set of tools that can be applied in order to achieve objectives specified by the user. It needs to be informed with the goals and values regulators want pursued.

This section presents a brief overview of the public policy objectives that regulators may seek to achieve through the application of portfolio management, as well as the manner in which portfolio management can be applied under various market structures.

2.1. Portfolio Management Can Be Used to Achieve Public Policy Objectives in a Transparent Manner

The broad public policy objective that regulators traditionally sought to achieve with respect to retail electricity markets was reliable service at reasonable rates. This policy objective was typically set out explicitly, either in legislation or regulations. Some states changed these broad objectives when they implemented retail competition. More recently, some states with retail competition have passed new legislation effectively requiring default service to be provided at reasonable rates. For the purposes of this report we will focus on the objectives of reliable service at reasonable rates.

Reliable service at reasonable rates is not a new objective. Regulators have a long history of reviewing utility plans and operations to determine if they satisfy that objective. Out of that history many states have developed explicit, quantitative benchmarks for certain aspects of reliable service against which regulators can assess utility plans and operations. One such benchmark is a loss of load probability (LOLP) of one day in ten years for generating capacity adequacy.

In contrast, there are no generally accepted quantitative benchmarks for “reasonable rates.” Instead, the criteria for reasonable rates vary. This variation is driven by many factors such as differences in the availability of resources and differences in regulatory policy tradeoffs. Regulators consider a number of facts and objectives when making energy policy decisions and in determining whether rates are reasonable. Those facts and objectives vary from state to state, as do the weights that regulators apply to them.

Facts and objectives that regulators in most states consider when assessing whether retail electric service rates are, or will be, reasonable include:

- The resource options commercially available,
- The costs of those resource options,
- Whether the proposed mix of resource options minimizes costs to ratepayers (i.e., minimum rates and bills), and
- Whether the proposed mix of resource options will result in stable costs to ratepayers (i.e., stable rates and bills).

Regulators may also consider fuel diversity targets, renewable energy targets, carbon dioxide targets, other environmental goals, service to low-income customers, impacts on the local economy, and flexibility to respond to major changes in market conditions and public policies over time.

The desire to achieve multiple objectives often complicates the determination of whether rates are reasonable, because the objectives are often conflicting. For example, one strategy might be to minimize costs for the year by purchasing all generation supplies from a spot (e.g., day ahead) wholesale market. This strategy might be premised upon a belief that a strategy that included any multi-month contracts at fixed prices would incur extra risk premium costs on average in the long run. On the other hand, this hypothetical purchasing strategy could result in very volatile costs that would necessitate some sort of routine rate true-up mechanism, and, as a result, lead to highly volatile rates for customers. A second, alternative strategy might be to stabilize rates by acquiring all supplies via long-term fixed price bilateral contracts, say through a single procurement for 100% of requirements. This alternative hypothetical strategy stabilizes rates and simplifies administration, but could result in higher expected costs than the first strategy on average over time if, for example, sellers of fixed price contracts wish to and can obtain a risk premium in return for that price certainty. Neither hypothetical strategy would satisfy both objectives of minimum costs and stable costs. In contrast, a third hypothetical strategy consisting of a mix of spot purchases and fixed price contracts might partially satisfy both objectives in a balanced manner, trading off somewhat higher costs in exchange for somewhat more stable costs, and vice versa (again, assuming that fixed price term contracts require payment of a risk premium).

One major way in which states differ is the timeframe or planning horizon over which they assess the reasonableness of the rate impacts of resource decisions. In some states regulators assess reasonableness over a short-term time frame, one to three years for example. In others regulators consider the implications of the strategy and resource mix underlying the rates over the long-term of five to twenty years, as well as assess the resulting rates expected over the short-term.

Portfolio management provides regulators, utilities, and other parties to these determinations with a process, and set of tools, to select a strategy that will result in reliable service at reasonable rates and to do so in a transparent manner. Not only can it reveal input data and assumptions, it can also identify and quantify the trade-offs between objectives under alternative strategies. That transparency can, in turn, assist regulators in determining the weight to apply to each objective.

2.2. Portfolio Management Can Be Applied under Any Market Structure and Regulatory Framework

The market structures and regulatory frameworks governing electricity supply service to retail customers vary from state to state. For the purposes of this report, those structures can be grouped under one of two broad frameworks – fully regulated or retail competition. For simplicity, this discussion will consider the retail competition framework to be a fully developed one where the provider of default service (usually the distribution company) is not allowed to retain a generation or merchant power function.

One can characterize and distinguish between those two frameworks according to the entity responsible for providing generation service and the entity responsible for ensuring that those rates are reasonable. The distinctions between the two market structures according to those attributes are summarized in Table 2.1, below.

Table 2.1 Key Attributes of Alternative Retail Market Structures		
Market Structure/ Attributes	Fully Regulated	Retail Competition with no Merchant Function
Retail competition	Not Allowed	Allowed
Responsibility for providing generation service	Utility	Competitive market for customers who shop <i>Default service¹¹ for customers who do not shop</i>
Responsibility for monitoring and oversight to ensure that generation service is reliable and reasonably priced	Regulator	Regulator

Portfolio management tools and practices can be applied to the resource decisions that need to be made under either of these frameworks.

2.2.1. Application of Portfolio Management in Fully Regulated Markets

In states with a fully regulated framework, utilities employ some form of portfolio management to select and procure the appropriate resources, implicitly or explicitly. Examples from the states that we surveyed are presented in Appendix B. In these states, portfolio management is usually intertwined with resource planning procedures, such as least cost planning or integrated resource planning, where they exist. Portfolio management may also be a part of the fuel procurement practices for generation-owning utilities.

The specific procedures through which portfolio management is applied vary from state to state. However, the general approach through which the three basic steps in portfolio management are applied are summarized below.

1) Preparation and periodic updates of resource plans

Utilities are required to file a resource plan at least every two to three years. The plans cover a long-term horizon, typically at least ten years. They begin with a projection of customer electricity requirements over that period and then evaluate all options available to meet those projected requirements, including supply-side resources, transmission and distribution investments, demand-side resources and purchased power. In some cases, resource planning may encompass fuel contracting for utility-owned generators, as well as plans or policies governing

¹¹ Also known as Standard Offer Service (SOS), basic generation service (BGS), and Provider of Last Resort service (POLR)

off-system sales of power or disposal of power supply assets. That evaluation considers the reliability, economics and risk attributes of those resource options and may also address their financial, environmental and social attributes. Based upon that analysis the plan identifies a specific mix of resources and/or strategy that the utility believes will result in reliable service at reasonable rates.

Regulators review these filings. In some states, they issue an acknowledgement that the plan satisfies the filing requirements. In other states, the regulator may approve the filing, an act that *may or may not* effectively pre-approve any major new initiatives proposed in the plan, such as construction of new capacity or execution of a new long-term purchased power agreement, depending on that state's laws and practice.

2) Procurement

Utilities execute planned procurements by acquiring assets in the form of capacity and fuel, and then using those assets to meet the requirements of their customers. They do this through periodic investments in generation capacity of their own, routine purchases of fuel, or execution of fuel contracts or hedges for that generation and periodic execution of power purchase agreements. In some cases, wholesale sales of power or hedges, or disposal of power supply assets may be part of this execution phase.

Regulators review the reasonableness of the costs and revenues resulting from these utility decisions. Typically those reviews occur when the utility applies for a change in its base rates. In addition, in states which allow utilities to adjust their base rates for changes in fuel and purchased power costs, those reviews may also occur annually in “fuel adjustment proceedings.”

3) Ongoing management

By ongoing management, we mean the as-needed adjustment of plans and resulting procurement actions reacting to changes in the load requirements and market conditions. As load requirements and market conditions change, the utilities modify their use of owned generation and purchased power assets accordingly. They may increase or decrease off-system sales from capacity that is temporarily not required to serve native load, acquire new supplies, ramp up or down demand-side management programs, or take a variety of other actions.

Regulators review the reasonableness of the costs resulting from these utility decisions in the same forums as the procurement decisions.

2.2.2. Applying PM in Retail Competition Markets

Portfolio management is applicable to the procurement of resources for default generation service in states with retail competition. However, as noted earlier, any decision regarding the scope and nature of portfolio management to be applied to this service is primarily a policy issue. This decision will necessarily flow from the policy framework and objectives that govern the retail electric market in the state.

This policy issue has been the subject of debate since the onset of retail competition. When retail competition was first introduced default service was expected to be either a temporary service during the transition to full competition or a true “default” service that relatively few customers would take, and then only while they were between competitive suppliers. Based upon that expectation, some regulators felt that a basic strategy and an annual procurement would be appropriate for the acquisition of supplies for default service.

Contrary to those initial expectations, most of these states have seen almost all residential customers as well as many small commercial, institutional, and industrial customers remain on default service. Given the number of customers who continue to rely on this service, and the recent sharp increases in the rates for that service resulting from the current acquisition approaches, regulators are now faced with the question of whether to require the use of a more complete and sophisticated portfolio management approach for the acquisition of power needed for default service.

If a regulator in a retail competition state is interested in such an approach, an important first step will likely be a review of the existing legislation, regulations, and orders governing that service. For example, changes may be required in order to assign responsibility for:

- more comprehensive resource planning, in terms of both time frame and a wider range of resources (e.g., energy efficiency, renewable resources);
- more latitude in procurement, including more flexibility in the timing of procurements, the quantities procured and contract duration;
- changes in procurement to encourage bids from providers of energy efficiency and renewable resources; and
- periodic analyses and updates of the acquisition strategy.

These responsibilities can be assigned to the incumbent distribution utilities or to a third party, but what is essential is that the responsibility be assigned to *someone*.

2.3. Portfolio Management Provides a Process and Set of Tools for Examining Complex Resource Planning and Procurement Issues

Resource planning and procurement have become increasingly complex over the past 20 years. Regulators need methods and tools that can be used to determine whether a particular resource plan will result in reliable service at reasonable rates.

To illustrate this challenge, consider each of the major steps involved in developing a resource plan and procuring the necessary resources.

The first step is to choose a planning horizon. Use of a reasonably long-term horizon, e.g., 20 years or more, allows a range of resources and costs to be considered, including new renewable resources that have yet to be built and anticipated carbon dioxide emission regulations. The next step is to forecast the quantity of capacity and generation

required. These requirements can be forecast, but are obviously subject to uncertainty. In addition, the quantities that will be required from hour to hour and day to day are very difficult to forecast because they are so sensitive to weather and economic conditions. In retail competition markets there is additional uncertainty as to what quantity of load will switch to, or from, competitive suppliers.

The third step is to identify the viable resources and associated contracting and hedging options. These may include:

- Demand side management and energy efficiency
- Distributed generation
- Supply side resources (subject to resource availability)
 - Hydro
 - Wind
 - Solar
 - Gas-fired
 - Coal-fired
 - Nuclear
- Physical contracts
 - Spot
 - Term contract
- Financial instruments

The key attributes of each resource need to be projected for the planning horizon, including the quantities available at various points in time and their corresponding costs and volatility.

The fourth step is to then identify the alternative portfolios or strategies, consisting of different mixes of these resource options that could be used to provide reliable service at reasonable rates. This may entail evaluating hundreds of possible candidate plans or portfolios in light of the many potential permutations and combinations of these resources.

This evaluation and selection problem can, in many instances, be solved mathematically using computers by formulating it as an “optimization” problem. Under this approach the computer software is told to find the optimal mix of resources that will minimize risk while minimizing expected cost.¹² As one would expect, there are data and computational limits to solving this problem. For example, the assumptions for volatility and uncertainty in key inputs are notoriously difficult to characterize. Computationally, the vast number of possible resource combinations and timing of those mixes requires simplifying assumptions (such as trimming the available resource options down to a small handful of “typical generating unit types”) to enable the models to run in a reasonable amount of time. Portfolio management provides regulators, utilities, and other parties with a process and set of tools to analyze these complex resource planning and procurement issues. As

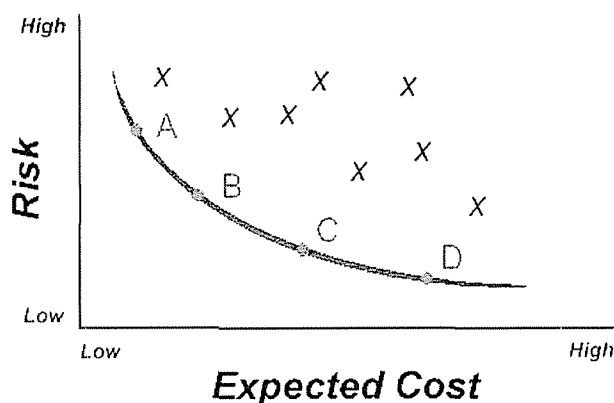
¹² This would generally be a nonlinear optimization model, likely a dynamic, multi-period one.

noted earlier, this approach can help all parties identify the assumptions to which the results are most sensitive and can also identify and quantify the trade-offs between objectives under alternative strategies. That transparency can, in turn, assist in determining the weight to apply to each objective.

Choosing Among Portfolios with Different Costs and Risks

Once candidate portfolios have been identified, their expected costs and variability can be estimated. The figure below can begin to give a sense of how candidate portfolios compare.

Example of Resource Plan Trade-off Curve



Each portfolio is represented by a symbol on the graph. The vertical axis indicates the portfolio's risk/uncertainty and the horizontal axis its expected cost. For a given expected cost, there will be one portfolio with the lowest level of risk, and vice versa. In our illustrative figure, A, B, C, and D mark four portfolios, each of which is the one that is least risky for a particular expected cost. As you move down along the curve connecting those four cases from right to left, there is a trade off in higher expected cost in exchange for less risk, i.e., more stable costs. One would always prefer a portfolio located somewhere along that line, because those portfolios represent the optimal levels of expected cost and risk.

The line connecting these "optimal" portfolios is the tradeoff curve, sometimes called the "efficient frontier." Considering only these two factors (expected cost and some particular measure of uncertainty), there is no economic reason to choose a portfolio above that frontier. However, each portfolio will have many non-economic pros and cons and there are various risk measures to consider, so the choice is never that simple. And, even along the frontier, the choice of a specific portfolio on that line will depend on what the decision-maker considers to be an acceptable tradeoff between the two objectives.

3. Confronting Uncertainty and Risk

This section will consider certain key issues regarding organization and implementation of portfolio management for regulators. The first subsection discusses why and how portfolio management applies in both fully regulated and retail choice jurisdictions. The next subsection addresses questions of organization and readiness for portfolio management approach to risk management. The third subsection highlights the challenge of making and communicating choices about risk management. The last subsection discusses in detail ways to measure and compare the risk of resource options and portfolios.

3.1. Two Contexts for Portfolio Management

As explained in Section 1 of this report, regulators from states with retail competition as well as from states with fully regulated utilities may need to address portfolio management.

Portfolio management has emerged in states that have restructured their electric utilities as an approach for acquiring resources to provide default service. In these states regulators and utilities responsible for implementing and overseeing default service procurement are faced with markets that do not always deliver stable, reasonably priced power in response to simple competitive procurements. Several states are moving towards a long-term view for delivering default service in the public interest.

In states with fully regulated generation service, vertically integrated utilities weigh various utility-owned resource options including new generation, transmission expansion, and DSM programs as well as power purchase contracts. Fully regulated utilities and their regulators now need to enhance resource planning, such as IRP, with more and better analysis and increased consideration of uncertainty and risk. Given the complexity of current markets and market products, traditional scenario analysis will no longer suffice to guide decision-making.

A sampling of some of the major new uncertainties facing regulators and utilities in all of these states help illustrate the complexity of their planning and procurement problems:¹³

- Will RTOs continue to develop?
- How will politics, pressure from the insurance industry, and fuel prices affect climate change regulation? How will "early credit" programs be treated?
- Will transmission companies proliferate and will they be able to generate enough return to gain access to capital for expansion?
- Will consumer interest in "clean power" increase or wane?
- Will the United States continue to be bifurcated into regional markets and territorial markets?

¹³ Adapted from http://www.scottmadden.com/pdfs/ScottMaddenEIUFall04_Full.pdf

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- Will wholesale market power issues cause divestitures, just mitigation activity, or continue to erode competitive pressures?
 - Will capacity expansion be driven regionally and, if so, by what mechanisms?
 - Will renewables development satisfy state targets?
 - Will fuel prices and environmental constraints strand some assets and speed development of new technologies?

Uncertainty and risk are addressed in the context of IRP as well as in financial risk management. Each of those perspectives emphasize detailed, quantitative analysis. IRP practice tends to emphasize refinement of long term expected or most likely cost and performance data for options. This is often supplemented with an engineering type bounding analysis, although in practice such bounding analyses often amount to simply running "plus or minus X%" scenarios or scenarios based on the range of estimates from different experts or studies. In contrast, quantitative analysis of the relative likelihood of various deviations or of how different risks interact to amplify or offset each other are relatively rare. Financial assessments of investment portfolios, on the other hand, currently emphasize detailed modeling the effects of variability and interactions of so-called "stable processes" by considering random variations in performance based on historical data for established products, but rarely consider longer term resource choices.

Given the strengths and weaknesses of the analytical tools and practices of each approach, and the planning and procurement problems in today's markets, we expect to see a gradual convergence of the portfolio management practices for IRP-like jurisdictions and default service procurement jurisdictions. In Section 4 of this report, we show that the current divide between the two approaches is mirrored in the software options available, too. Regulators may wish to push for a synthesis of these approaches, encouraging both rigorous detailed analysis and an understanding of the long range situation. New research and development may be necessary to accomplish this.

A portfolio management approach can also deliver side benefits to all consumers, even those who choose to shop from competitive suppliers. For example, inclusion of long term or even life-of-unit purchases from new renewable generators (or new generators not fueled by natural gas) can not only stabilize the cost of power for default service, but also lower clearing prices for all consumers by promoting new generation construction and reducing price pressure on natural gas at times of peak demand. A portfolio management approach to meeting the power needs of default service is compatible with the development of a vibrant competitive generation industry. In fact, by providing stable long term markets, a portfolio management approach for default service can enhance the health of the currently distressed generation industry by alleviating its dependence on an unfriendly project financing market.

3.2. Integrating IRP and PM Concepts

Portfolio management and integrated resource planning are not irreconcilable concepts. Rather, they are labels that emphasize different aspects of resource planning, all of which should be included in an ideal resource planning process.

Integrated resource planning involves the development of a portfolio of existing and new resources of all types that help achieve the lowest cost for consumers over the life of the plan. Each time an IRP is updated, an essentially new IRP is created, treating resources acquired since the previous update as committed and seeking the best selection of additions to form its new plan. Risks are usually assessed qualitatively or via scenario analysis, trying to find the resource plan that best combines a low cost with a reasonable degree of robustness against uncertainties. While IRPs can include fixed term purchased power contracts or consider disposing of committed resources, the emphasis is usually on permanent acquisition of resources.

On the other hand, portfolio management emphasizes assembling and managing a collection of resources, often entirely fixed-term purchase contracts. Diversification of expiration dates, vendors and, sometimes, term lengths is a typical tool in PM. Carefully designed competitive procurements are often the centerpiece of a PM approach, especially when over the counter markets are not fully developed.

PM has been applied in a narrow, passive manner in some states with retail choice and default service programs. For example, New Jersey, Maryland and Delaware limited procurement for default service generation to laddered two or three year, slice of load contracts obtained via a once-a-year auction or RFP. While such selections are implicit resource plans, they arbitrarily exclude a wide array of viable resources and limit the degree of risk mitigation provided to retail consumers. Conversely, preparing an IRP in which the focus is on identification of the least cost mix of permanent generation acquisitions and there is no assessment of risk would also represent a very limited approach to portfolio management—one with few choice points, limited diversification, and few market force effects.

Clearly, IRP can be improved by harnessing competition, by comparing resource plans using quantitative measures of risk in addition to expected cost, and by subjecting portfolios to active management. Conversely, procurement for default service (or other needs) can be improved by embracing a broad range of resource alternatives, striving for least cost service over time, and focusing on the risks borne by consumers rather than only those borne by the utility.

Applying aspects of portfolio management to the development and implementation of IRPs should be viewed as a challenging but natural enhancement of IRP for vertically integrated utilities. Several states have begun to consider such a move, especially with regard to risk management.

The descriptions of IRP and PM given above are generalizations based on typical practice among the states and may not be implemented identically in every jurisdiction. In fact, various practices can be called IRP or PM and may include some beneficial features of IRP or PM, but not fully realize either concept, much less an integration of the two. In principle, they are two ways of looking at the same problem. Ideally, resources would be planned, procured, and managed in ways that are both “integrated” and reflect “portfolio management.”

3.3. Organizational Issues

Organizational readiness and commitment are seen as critical to successful implementation of risk analysis and risk control through portfolio management.

While no one person at a major utility can (or should) make all decisions regarding portfolio management, it is the chief executive officer (CEO) who ultimately bears this responsibility. The CEO can best achieve portfolio management success by dividing up portfolio management responsibilities amongst the following types of employees: chief financial officer, chief risk officer, internal auditor, accountants (internal and/or external), chief technology officer, and others. In addition, the board of directors plays a key role in helping to define the overall risk tolerance of the organization.

It is interesting to note that, under Sarbanes–Oxley compliance requirements, the CEO is now legally responsible for ensuring that company-related risks are reported to shareholders. Not only is the CEO responsible legally, but from a practical standpoint the CEO plays a critical role in terms of setting the tone for policy implementation throughout the organization. Unless he/she makes portfolio management a key priority for the organization, it will likely be unsuccessful.

Direction and motivation are critical to success in risk management and planning for risk management. The tone for any new direction is usually set by the leadership at the top of the organization. Thus the application of these new tools in the electric industry will benefit if regulators set out clear expectations and if utility management commit to portfolio and risk management.¹⁴

With regard to PM implementation, organizations have options. A utility could choose:

- a narrow approach focused on specific resource planning activities mandated by law or regulation,
- a broad approach focused on risk analysis and management in all aspects of the firm, or
- an "optimally scoped" approach that seeks to strengthen portfolio and risk management in targeted activities, improve processes for that purpose, and establish ongoing monitoring and improvement.

Recently, under the impetus of Sarbanes-Oxley mandates, many firms have considered how best to organize risk assessment and risk control. A number of questions about a firm's readiness for risk assessment and control should be addressed. Some of these are:

- How well has the organization implemented other change efforts?
- Is the executive management supporting the effort, visibly and effectively enough to get buy-in from the entire organization?
- How well does executive management understand the effort required to implement PM and management's role in that implementation?

¹⁴ The following material draws on Anne Marchetti, *Beyond Sarbanes-Oxley Compliance: Effective Enterprise Risk Management*, John Wiley & Sons, 2005.

- Is the organization committed to providing resources (people, time, money) to both the design and implementation of the effort?

Regulators seeking to implement portfolio management and risk assessment at Commissions and utilities should ensure:

- clearly articulated reasons for implementation;
- a clear connection to the strategy of the organization;
- full implementation;
- integration with existing processes and initiatives;
- active, visible leadership;
- commitment of adequate time and resources;
- timely and thorough communication among regulators, advocates, utilities and other stakeholders, as well as throughout the affected portions of the utilities, including feedback and reinforcement;
- routine progress and performance measurement and review of corrective actions; and
- skilled, trained employees at commissions and utilities.

3.4. Making and Communicating Choices about Risk Management

Perhaps the first concept that comes up in a discussion of portfolio management is "diversification." We have devoted considerable discussion to that topic here and elsewhere.¹⁵ A second major concept that comes up in such a discussion is "risk tolerance." Risk tolerance refers to one's willingness to accept the risk of an undesirable outcome when making an investment choice.

It is natural, even traditional, for portfolio planning to determine, and take into consideration, the risk tolerance of an investment portfolio "owner" at an early stage in the process. A much more difficult problem arises in the context of applying PM to an electric utility, where the utility may be the "owner" but the costs will be paid by a large group of customers. It is difficult to express or ascertain the risk tolerance of individual customers in a meaningful way, much less whole classes of customers. While this report does not present a recipe for regulators to use in establishing the level of risk appropriate for the resource portfolio of a fully regulated utility or for a default service provider, this section attempts to clarify the issues that should be considered.

Decisions about risk should not be made in a vacuum or on a hunch. Even the sort of on-line questionnaire designed to guide personal investing decisions takes into consideration objective aspects of the investor's current situation and plans for the future. Risk tolerance discussions for individuals are driven by such life situation factors as age,

¹⁵ Biewald, et al. *Portfolio Management: How to Procure Electricity Resources to Provide Reliable, Low Cost, and Efficient Electricity Services to All Retail Customers*. Synapse Energy Economics, 2003. Available at <http://www.synapse-energy.com/Downloads/SynapseReport.2003-10.RAP.Portfolio-Management.03-24.pdf>

dependents, taxable income and projections thereof, existing assets and liabilities, commitments, fixed expenses, health status, retirement and other plans, and so on.

Regulators have been making risk tolerance judgments on behalf of ratepayers as long as they have been setting rates. Every decision to approve construction or a long term contract accepts certain risks and avoids others. Traditionally, such decisions have been made after careful qualitative and, sometimes, partially quantified consideration of the risks and uncertainties of a project under consideration and (slightly less often) the risks and uncertainties of the alternatives. However, trying to discipline or even quantify those tolerances is unbroken ground for many utilities. In fact, such discussions are typically based on evidence that amounts to the opinions of persons with a stake in the matter. An EEI report expresses the opinion that "The 'right' amount of risk-bearing for customers (in rates) is not self-evident."¹⁶ Moreover, we should not expect this job to be easy. In fact, that study calls on regulators to either specify the risk tolerance to be used or provide guidance to utilities on how it should be measured.

A finance expert might approach this question by asking regulators to name their risk tolerance (presumably something numerical, like "the probability that rates will increase by more than X% in any one year or more than Y% over five years should be less than Z%") and suggest that it would then be straightforward to determine how to deliver that level of certainty and offer to tell regulators what buying that degree of certainty will cost as of a given market day. Perhaps that could be done in theory, but there is no simple answer to the question of risk tolerance of customers. In part, this is because customers are not a homogeneous group and in part because the answer will depend on the methods used for reducing risk and their side effects.

Some would argue that rate stability is not free and all hedging comes with a cost. Others argue that long term hedges simply are not available. However, failing to hedge huge market exposure has external costs, while the absence of long-term, market-based forwards (only one of many ways to hedge risk) may be something of a self-fulfilling prophecy. Shipping companies could buy cargo and hull insurance for hundreds of years before anyone bothered to sell life insurance, but practically as soon as it was offered, life insurance was a huge success. Thus, markets for long term power contracts or other hedges may well develop if there is an adequate demand for them by buyers and sellers.

How and when the risk/cost tradeoff analysis is performed during resource planning and/or procurement processes can be just as critical to sound portfolio management as the metrics used and the preferences applied, especially when assessing longer term resources and risks. For example, as a recent national laboratory study observed,

[utility] resource plans vary considerably in how they define expected risk, and how they balance the expected cost and risk of different candidate portfolios. In selecting a 'preferred' portfolio, a utility would ideally review consumer preferences for cost-risk tradeoffs, and select the candidate portfolio that fits most closely with the risk preferences of the majority of its customers. This approach, however, is rarely used. Instead, in all of the cases we reviewed, the cost-risk

¹⁶ Graves, 2004, p. 21.

tradeoff (if made) is based on the subjective judgment of each utility, informed by any counsel provided by the utility's regulators or external stakeholders.... In other words, the cost/risk tradeoff has often been made – in part based on consideration of fuel price risk – before carbon risk is considered, in which case carbon risk is sometimes relegated to helping to distinguish between a few finalist portfolios.... As a result, some of the “renewables” portfolios in our IRP sample exhibit as much or more exposure to natural gas price risk than other portfolios.... By the time carbon risk is assessed, some renewables portfolios – i.e., those best able to mitigate carbon risk – may have already been weeded out of the process, potentially leaving the model to choose from among a number of sub-optimal portfolios.¹⁷

That study recommends "a more holistic assessment of risk, and approach to the cost/risk tradeoff" rather than a "sequential, winnowing approach." It goes on to point out that

...scenario analysis, and the risks analyzed with that technique, may end up as a mere sideshow to stochastic analysis. Related, a large and varied set of candidate portfolios should be evaluated for their ability to mitigate risks; otherwise, analysis results may be unduly affected by the pre-selection of possible candidate portfolios.

In summary, regulators will likely need to oversee or manage risk mitigation, but clear methods for conceptualizing risk in utility portfolio management are not well developed. Regulators may find it useful to consider exploratory proceedings or alternative input methods, such as deliberative polling, but in the end, regulators will need to develop and communicate risk management and portfolio management goals and criteria to generation service providers, either proactively or in response to utilities' implicit or explicit risk management choices. Further research on this point may be of value and could begin with a systematic effort to review the techniques used by institutional investors and manufacturers dependent on long lead time commodities, followed by analysis of how their methods may or may not be useful in utility planning and its oversight.

3.5. Techniques for Analyzing Risk Exposure and Uncertainty

3.5.1. Measuring Risk and Expected Benefit

Risk and uncertainty are inherent in all enterprises. But risk needs to be balanced against expected benefit. The balancing of risk and expected benefit in utility regulation differs from the balancing that occurs in business or investing. However many of the tools and metrics for measuring risk and expected benefit in business and investing can be, and have been, applied to the electric industry.

¹⁷ Ryan Wiser and Mark Bolinger, "Balancing Cost and Risk: The Treatment of Renewable Energy in Western Utility Resource Plans," *The Electricity Journal*, Feb. 2006; Ryan Wiser and Mark Bolinger, *Balancing Cost and Risk: The Treatment of Renewable Energy in Western Utility Resource Plans*, Lawrence Berkeley National Laboratory, 2005. Available at <http://eetd.lbl.gov/ea/ems/reports/58450-journal.pdf>

Business managers and investors decide how much of a return they require on a prospective investment in exchange for taking on a given level of associated risk. They then make go/no-go decisions on individual projects by measuring, implicitly or explicitly, the risk of a given project and its expected return to see if those criteria meet their investment threshold. Bond ratings are a tool commonly used for this purpose by investors. For example, an investor may choose not to invest in highly-rated corporate bonds unless the bonds bear an interest rate of, say, 3% above the interest rate for U.S. government bonds, because even highly rated firms may fail.¹⁸ The same investor might be willing to invest in the same corporation's common stock only if the expected return is 10% above the interest rate for U.S. government bonds, because common stock is the first type of security to suffer (i.e., to miss dividend payments or lose market value) when a firm is in financial trouble.

Rather than comparing expected return to perceived risk, utility regulators typically want to minimize rates or cost of service or both, while taking into account the degree of risk that ratepayers will face, as well as the risks to investors. Thus there is a need to balance the expected cost of a resource, or a portfolio of resources, with the risk that the actual cost of the resource may be more or less than expected at various times over the planning horizon, thereby introducing volatility into the cost of service during that period. It is also important to consider the risk that a resource choice will fail to provide necessary power (or save power in the case of DSM resources), triggering a need to buy at market rates. Finally one must consider how a given resource plan will impact the ability of the utility to attract capital. While the kinds of benefits and risks that regulators evaluate and balance are not exactly the same as those that businesses and investors consider, many of the tools and metrics available are suitable or may be adapted to either.

It is conceptually simple, but sometimes technically difficult, to compare different portfolios of resources based on their expected costs. Present value life cycle cost is the usual measure employed for that purpose. Unfortunately, there is currently no single, generally agreed upon measure of the risk of a resource portfolio. The accompanying text box on "Random Variables and Portfolio Management" explains portfolio risk in terms of cost uncertainty and the basic concept of comparing the riskiness of two portfolios. Appendix D of this report describes a variety of portfolio risk measures. The rest of this subsection explains a few of those risk measures and presents some key ideas about risk measurement.

¹⁸ U.S. government securities are often used as a proxy for an investment that bears no risk except for the risk that the inflation rate may change.

Random Variables and Portfolio Management

What is a random variable? A *random variable* is a number whose value changes, say over time, in a way that cannot be predicted in advance. Planning risk for utilities is often a result the random variability of weather, inflation, economic growth, power plant availability, the market price of gas and the like. These and similar factors have a big influence on the cost of a portfolio, but forecasts and trends of them are subject to unpredictable fluctuations. Often we are most interested in the long term average cost of a portfolio of resources; that cost, itself, is usually a random variable because it is determined by interaction of the random variables just mentioned and others, too.

What is a probability distribution? We usually know *something* about the behavior of a variable, even if it is random. The high temperature in Chicago on July 4 next year maybe impossible to predict, but we have lots of data about past temperatures. Using that data, we can say with some confidence that the most likely value is the long term average for that place on that day of the year. Using that data, we can also find the *probability* that the temperature will 90° or 101° or any other particular value. If we draw a graph showing temperature values on the horizontal axis and their probability of occurring as the vertical axis, we have a picture of that variable's *probability distribution*. (The figure below shows two examples.) In many cases, the graph may look like a bell curve; for others, it may not. If a variable can have only a few different values, such as yes or no or 0% to 100%, the graph will be a bar chart with one bar for each possible value.

What is an expected value? For a random variable, the *expected value* is the value we expect to see *on average* over time, but not necessarily the single most common value.

How is variability measured? Appendix C to this report describes a number of ways to put a number on the uncertainty of a portfolio's cost, but they are all ways of expressing the width of the probability distribution.

Where do we get probability distributions for resource planning variables? If historical data is exists, such as for weather or fuel market prices, we can rely on that data *if* we are confident that the systems that produced those data will not change. For example, we might believe that a manufacturer's historical data on the availability of the generators of a certain type will be representative of the units we need to model. On the other hand, we may feel that weather data need to be adjusted for the impact of climate change. Finding good data for the probability distributions of resource planning variables is challenging, especially for long-term planning.

How do probability distributions relate to portfolio management? The riskiness of a portfolio of resources is related to the variability or uncertainty of its cost. For example, a portfolio consisting of only two resources, a single generating plant and spot market purchases, would have at least four sources of uncertainty. One is the uncertainty in the plant's fuel cost. Another is the variability in the market price paid for any extra power needed or earned for an excess sold. The third would be variation in the load to be served, because that determines how much power is available to sell on the market or how much extra needs to be bought. Lastly, the availability of the plant helps determine how much market power needs to be bought or sold. If we know (or can assume) the probability distribution of those four variables, we can compute the probability distribution of the portfolio's projected cost. The probability distribution of the cost for this hypothetical portfolio might look like Curve A in the figure in this text box.

How are probability distributions used in comparing portfolios? Suppose we wanted a portfolio with a more stable cost. Then we might consider adding a fixed price purchase contract to cover some of the excess power need. This would reduce variability as some or all of the purchases would be at a known price. We might also purchase options for the generator's fuel. The options would cost us a certain amount whether we exercise them or not, but would ensure that the fuel price does not exceed a certain value and also reduce the variability of the portfolio's cost. We could use this new information to compute the probability distribution of the revised portfolio's projected cost. The distribution of the cost for this revised portfolio might look like Curve B in the figure below.

Curve B is much narrower, illustrating the reduction in uncertainty about portfolio cost, but is shifted to the right, reflecting the extra fixed cost of some of the risk mitigation measures. So, comparing these hypothetical probability distributions, we would have to make what may, or may not, be a difficult decision, i.e., is it worth paying a somewhat higher expected cost to avoid exposure to the possibility of a very high cost. If the differences in costs under the two approaches are minimal the decision may not be difficult. If the differences in costs are large, the decision becomes more difficult. Or, we might decide to look harder for cost effective ways to reduce risk, such as adding less volatile renewable generators or ramping up energy efficiency to reduce the need for market purchases.

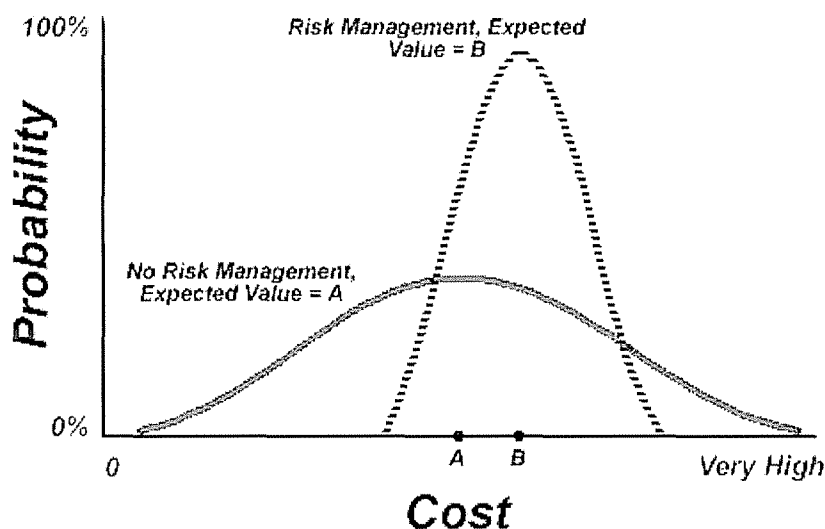


Figure 3.1. One view of the possible impact of hedging on risk exposure for the cost of a portfolio of resources.

One straightforward way to measure the riskiness or robustness of a portfolio is to compare its expected cost to its worst-case cost. Northwest Energy and the Northeast Power Coordinating Council (NPCC) compare portfolios using this type of metric. They measure each portfolio's risk as the difference between its expected cost and an average

of the costs in the last 10% of the high end of its probability distribution, which they consider to be the worst-case cost.¹⁹

Another approach for quantifying risk is to calculate the increase in cost over a given planning horizon (the selected risk level) for a specified probability or risk level. This approach, Value at Risk (VaR), was developed in the financial sector to evaluate the downside risk of an investment. It is always calculated in the context of a risk level and a planning horizon. Value at risk is widely used by banks, securities firms, commodity merchants, energy merchants, and other trading organizations, who often monitor it on a daily basis. In the case of an electricity resource portfolio VaR can be applied to measure the cost increase that has a certain probability (the selected risk level) of occurring over the selected planning horizon. For example, a regulator might be interested in the VaR of a proposed resource portfolio over a one year planning horizon at the 99% risk level. That VaR would tell us the amount of extra cost that would have a 1% chance of occurring over the next year. Or, a VaR at the 90% risk level for a ten year planning horizon would tell us the amount of extra cost that the portfolio has a 10% chance of incurring over the next ten years. Utilities in California compare portfolios using this type of metric and variations on it.²⁰

Value at Risk and estimates of extreme values like the metrics used in Montana are two measures of the risk of a specific portfolio. There are several possible measures of risk available for regulators to consider. These are listed in Table 3.1 and discussed in Appendix D of this report. The goal of monitoring and managing each of these risk measures is to identify sources of and changes to risk and to enable managers and regulators to reduce overall utility risk for both utility customers and shareholders. Consistency and transparency should be considered in choosing a measure to use. It may also be necessary to require validation of the computer models used for this purpose, especially proprietary or in-house models. It is also important to exercise care in the development of the probability distributions used to generate the risk measurements.

¹⁹ Not surprisingly, the mechanics of computing this measure of uncertainty are far from simple. This approach is discussed further in Appendix B of this report and in the *NorthWestern Energy 2005 Electric Default Supply Resource Procurement Plan*, available at <http://www.montanaenergyforum.com/plan.html>

²⁰ See Appendix B of this report and CPUC Energy Division, *Workshop Report on Value at Risk, Cash-Flow at Risk, and Other Measures of Portfolio Risk*. June 6, 2003.

Table 3.1 Possible Measures of Risk

Value at risk	Estimates the likelihood that a given portfolio's losses will exceed a certain amount.
Component value at risk	Measures the marginal contribution to value at risk of each element within the overall portfolio.
Credit value at risk	Measures potential credit exposure on individual transactions as well as the total credit value at risk for the portfolio.
Enterprise-wide risk measures	Aggregates market, operational, credit, and regulatory risk.
Costs at risk	Measures probability that a portfolio's costs will go up or down.
Rates at risk	Measures potential change in end customer's rates as a result of generation supply portfolio.

3.5.2. Considering Risk in the Assessment of Resource Choices

The various parties involved in long-term planning, fuel and purchased power procurement, and ratemaking will have a range of perspectives and goals. From a regulatory perspective the goals may be to achieve a reasonable balance of cost and risk. In order to prepare a quantitative comparison of alternative resource portfolios relative to those goals, a regulator may wish to know the expected retail rates over the next two years *and* the amount by which retail rates could increase over that same period at a 90% risk level for each portfolio. Adaptations of the VaR measure discussed above can be used for this purpose.

Expected cost and value at risk could be used to help evaluate and compare three alternative strategies, e.g., (1) the status quo plus purchased power from the wholesale market, (2) building a particular new generating plant, or (3) a combination of increased DSM and smaller purchases of power from the market. These metrics would allow comparison of the three resource choices on their expected present value revenue requirement (PVRR), the usual measure looked at in IRP, as well as on the risk of rate increases. Regulators have always done such risk assessments mentally or implicitly; now they have tools for making these assessments quantitatively and explicitly.

This notion, of course, is based on the assumption that one can actually quantify the risk. As discussed earlier, future probability distributions are typically estimated based on an analysis of historical data. If the historical data is inadequate or does not represent current or future fundamentals, then the probability distribution will not be accurate. Some types of risk are well represented in historical data, such as interest rate fluctuations, returns on financial investments, and some commodity prices. Other risks are not well represented in historical data. For example, the additional price risk for fossil fuels due to potential carbon regulations would have to be analyzed separately, perhaps through a scenario analysis, and added to the underlying uncertainty in fossil fuel market prices.

There are of course ways to reduce the level of risk identified in any such analysis. For example one might sign a long-term fixed-price contract or purchase commodity futures. That would eliminate, or nearly so, the risk associated with increases in material costs, but it would also eliminate the potential benefits if those costs fell. There are also more sophisticated approaches using call and put options which can limit the downside risks but still capture the upside benefits. The most neutral approach is a “costless collar” in which the purchase and sales costs of the options net to zero. In essence, this is trading some of the upside potential to protect against some of the downside risk.

Thus, to summarize, all of the “at risk” calculations attempt to determine the likelihood and magnitude of the downside risks. The results are based on statistical models, usually reflections of historic performance of a given investment or market, and predict a “loss” threshold at a given probability level over a specified time period. The methodologies are most robust in the short to intermediate term for normal economic conditions. Unusual or new conditions can be factored in through additional analysis, but these require special studies.

3.5.3. Tools for Mitigating Risk

The goal of monitoring and managing each of these risk measures is to identify sources of and changes to risk and to enable managers and regulators to reduce overall utility risk for both utility customers and shareholders.²¹

Many kinds of risk can be protected against with insurance, although there is a usually an increase in the expected cost for doing so. This is true for some resource types, but not all. For example, if one wishes to reduce exposure to the risk of possible climate change mitigation costs or emission permit costs, one could choose renewable resources over fossil fuels as a portfolio addition. At the current time, the expected cost of power from many renewable resource plants may be greater than the expected cost of fossil fuel plants over their respective lives. Hence, choosing that kind of renewable generation insures against a possible future cost at the expense of accepting an increase in the power cost that will occur if those climate change costs do not arise or arise late. However, there are possible “insurance” resources that do not incur extra costs. Many DSM resources are known to be cheaper in terms of lifetime revenue requirement than traditional fossil fuel generation (and the associated transmission costs and line loss costs), but also provide insurance against possible CO₂ emission costs. In addition, reducing a utility’s riskiness by making lower risk portfolio choices may reduce its cost of money and hence its overall cost of service.

²¹ For additional discussion of ways in which portfolio management can address electricity resource risk for regulated service or default service procurement, see Biewald, et al., 2003 cited above.

4. Tools and Data for Portfolio Management

4.1. Overview

Portfolio management activities can be grouped into three major applications or stages, as discussed earlier. These activities as indicated in the Introduction are

- developing a resource plan,
- procuring the portfolio of resources identified in that plan, and
- managing that portfolio of resources on an ongoing basis.

Some of the questions to keep in mind when considering the appropriate tools are:

- Over what timeframe will the proposed strategy apply?
- What level and stability of prices are expected to result during that time?
- What flexibility is there to modify the strategy in response to changes in demand or supply conditions, at what points in time is that possible, and what is the process for doing so?
- What alternative strategies were, or should be, considered?

The nature and scope of each activity may vary according to the entity responsible for portfolio management and its particular objectives, constraints and circumstances. For example:

1. Type of organization, e.g., vertically integrated utility or a load serving entity.
2. Scope of consideration, e.g., total cost of delivered services, generation service cost.
3. Planning objectives, e.g., rate minimization, rate stability, balance of rate minimization and rate stability, rates tied to day ahead prices.
4. Time frame for planning, e.g., decade or more, one to five years, less than a year.
5. Planning constraints, e.g., all new resources to be acquired from wholesale market, renewable energy target.

This section provides an overview of the data and software tools available for each major application and a brief discussion of the issues associated with each.

4.2. Tools Available for Portfolio Management

The software tools that are available come from two different perspectives (1) financial planning and investment and (2) traditional utility supply-side planning. The former flow from a highly developed quantitative practice and focus on the management of various financial instruments such as future contracts, laddering, and options. The software tools

available in this category offer fairly sophisticated methods for evaluating risk. Contrastingly, those models and tools coming from the utility side represent the unique aspects of the electric utility industry, but are *much less sophisticated* in risk analysis. The sections below describe the types of tools and Appendix C describes specific software tools in more detail. Table 4.1 provides an overview.

Table 4.1 Overview of software models for risk analysis and management

Application	Time Horizon	Input Data and Forecasts	Capacity expansion models	Procurement and scheduling models (no capacity expansion)
1. Integrated System Plan (analytics)	10 to 20 years (long-term)	Forecasts of <ul style="list-style-type: none"> • customer load, • price elasticity, • resource availability, • fuel costs, • resource costs, • risk premiums, • fuel price volatility, • reliability requirements and policies, • environmental policies and costs. 	<i>Optimization Models</i> Electric Generation Expansion System (EGEAS) EnerPrise Capacity Expansion	<ul style="list-style-type: none"> • PLEXOS for Power Systems
			<i>Screening, scenario, and risk analysis models</i> PowerBase Suite AURORA RISKMIN	
2. Procurement (Trading and Risk Management)	1 to 3 years (short-term)	Energy and fuel price forecasts and market futures. Load requirements.		BookRunner; Edur Epsilon & Entegrate ICTS Symphony Planning and Risk
3. Management (Generation and Scheduling)	Daily to annually (day ahead or near-term)	Short term load forecasts. Resource and transmission availability Fuel and energy prices Environmental conditions		Monaco Predict! Kiodex Risk Workbench

4.2.1. Load Forecasting

Load forecasting has been done since the beginning of the electric utility industry. The approaches used vary by the time scale involved. Short-term forecasts of a day or less are based on typical hourly load patterns for the season and weather forecasts. Forecasts of a few years are generally derived from recent historic data and extrapolated with

adjustments for weather and simple external drivers such as population growth and planned DSM programs. Common current practice is to incorporate weather variability in computing confidence intervals for peak load levels. The greatest change has occurred with long-range forecasts. The old practice was to plot the historic load values on log graph paper and then draw a straight line into the future. More modern practices look at load growth by customer class and apply econometric methods to develop future values. In some cases the load components are broken down by end-use category. That approach is especially useful for designing and evaluating Demand Side Management (DSM) programs. Over the years, most entities have developed and refined their own custom tools for load forecasting.

4.2.2. Price Forecasting

With the move in recent years to wholesale markets, a number of tools have been developed that integrate load and price forecasting. Some of these are quite sophisticated and consider transmission constraints and locational prices.

There is considerable academic and professional literature on this topic. In recent years most efforts have been focused on short-term forecasting using such techniques as neural networks.

4.2.3. Integrated System Planning

Integrated system planning is about finding the right mix of supply and demand side resources that provide low cost and reliable electricity service, while also minimizing risks. This is much like the Integrated Resource Planning (IRP) that was done by utilities before deregulation. The goals are similar but the available components have changed somewhat.

4.2.4. Risk Analysis

In this category are applications focusing on various aspects of risk. The short-term products look at the more quantifiable risks associated with futures contracts and energy markets. A few of the more utility focused tools try to represent in some way the longer term risks. But that is conceptually a more difficult task since there is much greater uncertainty. For longer-term analysis, a scenario-based approach is most commonly used, but the challenge always is to make those scenarios diverse enough to capture a reasonable range of possibilities.

4.2.5. Managing Financial Resources and Contracts

An important aspect of portfolio management is organizing and managing contract information.

Some of the types of products that could be monitored with software tools include spot purchases, forward contracts, option contracts, and flexibility contracts. Each of these product types offers a different type and degree of pricing and flexibility.

The goal of portfolio management may be thought of as finding the optimal trade-off between price and flexibility through an appropriate mix of low price/low flexibility (long-term contracts), reasonable price but better flexibility (option contracts), or unknown price and supply but no commitment (the spot market.) Varying durations as well as contract types can help create an even mix. The role of software for managing contracts and options is to monitor (perhaps on a daily basis) the cost and risk of the inventory of such products and to analyze purchases and sales that might improve the tradeoff. If a portfolio includes short positions or options, frequent analysis is needed to choose the best time to fill short positions or to exercise options (if at all).

There are many vendors offering various applications for this purpose and below we list a few of fairly wide use in the energy sector. Note also that this category also overlaps some with the risk management tools in the next section.

4.3. Strengths and Deficiencies of Tools for Resource Planning and Procurement

Some points to keep in mind with regard to software tools for IRP and PM:

1. Traditional electric industry tools have a utility cost-based engineering optimization perspective. This is also true of nearly all IRP tools whose goal is to determine the least-cost plan given various fairly fixed expectations about the future.
2. Most traditional planning models are deterministic and do not incorporate uncertainty. Thus their results, while optimal for a specified set of assumptions, may not be so if circumstances change. Traditionally scenario analysis has been used deal with these limitations, but the range of scenarios needs to be wide enough to adequately represent the range of possible futures. There is a general human tendency to expect the future to be a smooth continuation of the present, but a look at the past shows that that is not always the case. One approach is to double the range of what conventional wisdom says. Another approach is to consider some “far out” scenarios as stress testers for the plans that are developed.
3. Short-term uncertainty can be more easily quantified via statistical methods than long-term uncertainty. Thus sophisticated statistically based methods used in trading and risk management tools are more appropriate for shorter terms of up to one or two years, but are harder to apply to long-range analysis and planning, at least at the current state of the art. This is mainly because of the increasing uncertainty of projections as time spans grow.²²

²² The ENERGY 2020 platform takes a somewhat different approach that may be helpful in analyzing the risks of long-term uncertainties and strategies. Originally developed as a premier load forecasting model, it is one of the few end use models commercially available. However, its endogenous and bottom up approach to representing the performance of the utility and its load and resources through time allows it to offer an integrated system for IRP analysis including representation of various supply-side and demand-side options. It does not presume optimal functioning of the utility’s dispatch, or

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4. Most financial tools are focused toward the shareholder/manager perspective and not toward customers. Thus when such tools are used for utility PM there needs to be a refocusing on the implications for customers.
 5. Demand-side options and non-traditional resources (such as wind and solar) are not well represented in most models. Thus *special effort*, depending on the model used, may need to be taken to adequately include these choices.
 6. Societal benefits such as environmental externalities and employment impacts are not generally represented. If they are to be considered, they may have to be calculated externally to the PM models themselves.

It is important to remember what the model was designed to do and what necessary simplifying assumptions are built in to it. Careful review of key input data is always necessary and it is wise to remember that even the best of models fed the best available forecasts can provide only informed approximations of the future.

4.4. Things to Consider Before Selecting Software

Whenever selecting software, it is important first to prioritize the objectives and then to evaluate the available options in that context.²³

- Objectives: How well the software meets the designated goals.
- Involvement: The ultimate users of the software need to be closely involved in its selection.
- Transparency: Are modeling methods and algorithms well documented and visible to users and regulators?
- Software Characteristics:
 - Monitoring capabilities
 - Facilitation and documentation of risk assessment, testing, and remediation
 - Built-in version controls
 - Security and access controls
 - Electronic sign-off functionality
 - Audit trail documentation and traceability
 - Ability to customize input fields, reports, and templates
- Reporting Capabilities: Are the model results available in reports and formats that are easily understood and used?

resource expansion as many models do, but can represent imperfections in planning and their results. For risk analysis, it provides a broad, integrated platform to analyze a wide range of long-term uncertainties via Latin Hypercube sampling (an efficient type of Monte Carlo simulation).
<http://www.energy2020.com/energy.htm>

²³ Some of these criteria are from Anne Marchetti, *Beyond Sarbanes-Oxley Compliance: Effective Enterprise Risk Management*, John Wiley & Sons, 2005.

- Flexibility: How easily can the software be applied to meet new needs?
- Support: Does the vendor provide training, fix problems and update the software as needs change?
- Implementation costs: software, licensing fees, hardware requirements, implementation time, training costs, customization efforts/consulting. Complex models severely tax even high end computer hardware. Investments in the fastest computers and largest storage devices available are likely to result in considerable labor savings and faster, more responsive answers to modeling questions. In summary, regulators considering PM or IRP software acquisition, whether for their own use or by utilities they oversee, should focus on the prioritized goals and be aware that the largest expense is likely to be for the personnel to properly use the software.
- Staffing Requirements: The biggest investment may actually be in hiring and training people to properly use the software for the desired objectives.

4.5. Data Requirements for PM

Depending on the type of PM activity chosen there will be different data needs. Some of this can be based on historic information, but the essence of PM entails making decisions about a future in the face of uncertainty. Thus, the data used in each PM activity are primarily forecasts or assumptions. Moreover, as with most forecasts, the longer the planning horizon the more uncertain the forecast. In some cases the PM tools may themselves generate these forecasts based on historic data, or other methods and tools may be used. But in either case, the development of the input data is as least as important as the modeling itself and should be carefully scrutinized.

Some major general categories of data required for PM are forecasts of:

- customer load;
- reliability requirement policies;
- customer price elasticity;
- resource availability (including energy efficiency and renewable energy);
- resource costs, both fixed capacity costs and variable operating costs including fuel prices;
- fuel price volatility;
- environmental policies.

Procurement and/or portfolio management decisions that are made in the short- and near-term require more detailed data than resource planning decisions made for the long-term. The types of detailed data required for those short- and near-term decisions are listed in the box below.

Requirements

- Load forecasts
- Customer price elasticity (reduced consumption, switching)
- Capacity requirements

Fuel Markets

- Historical fuel prices and volatility
- Forward market prices

Self- Generation, Efficiency and Renewables

- Production costs from own generation
- Energy efficiency availability and costs
- Renewable energy availability and costs

Wholesale Electricity markets

- Forecast costs of capacity, transmission, and ancillary services
- Forecast costs of congestion and of FTRs to hedge congestion risk
- Historical wholesale electricity prices and volatility in the region of interest—both on and off-peak
- Forward market price data for electricity
- Probability and impact of new environmental regulations, e.g., CO₂ controls
- Probability and impact of new reliability requirements, e.g., RPM policy in PJM

Financial Instruments

- Financial instruments and associated costs

Depending on the specific circumstances not all of these may be required, or other kinds of information may be required. Each situation needs to be analyzed considering the objectives and what data is relevant and available.

5. Expertise and Staffing for Portfolio Management

5.1. Staffing and Expertise for Portfolio Managers

Overall, the expertise of the organization should include the following knowledge, skills, and abilities relating to portfolio management, risk analysis and management, and IRP:

Knowledge:

- Detailed knowledge of the natural gas markets, electricity markets, regional transmission organizations, and FTRs
- Full understanding of the range of available supply and demand options (including renewables, energy efficiency, etc.)
- Working understanding of the engineering and operations functions required to get those supply and demand options on-line
- Full understanding of transmission related options, including RTO/ISO rules and costs
- Working knowledge of relevant accounting rules (including rules for transactions in derivatives and Sarbanes Oxley compliance)
- Full understanding of environmental regulation costs and risks

Technical Skills:

- Ability to develop or select and implement quantitative models for power trading, power marketing, and fuels hedging
- Ability to utilize statistical and modeling tools, which may require programming expertise, as well as standard spreadsheet and database applications
- Ability to perform quantitative analysis of risk exposure on a periodic (possibly daily) basis and a long-term basis regarding both financial and physical positions
- Ability to identify, evaluate, and understand actual and potential changes in markets to assess overall portfolio risks
- Ability to develop and evaluate risk mitigation options
- Ability to take part in financial trades, potentially on a daily basis
- Ability to translate the outcome of the portfolio into utility rates

Other Abilities:

- Ability to communicate complex issues and options to internal staff and external parties (regulators, shareholders, etc.) regarding the overall risks associated with the current portfolio, as well as modifications that can be made to decrease such risks
- Ability to develop and maintain a system to provide detailed, traceable records regarding all trades and risk management strategies

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- Ability to prepare reports regarding the portfolio's valuation
 - Ability to report activities to FASB, the SEC, rating agencies, regulators, shareholders, and the public.

While it is definitely possible, and perhaps preferable, for a utility to take on all of the above responsibilities with regard to portfolio management, there is an alternative solution, which is to outsource the portfolio management function.

5.2. Staffing and Expertise for Regulators

Regulators can and do play multiple roles with regard to portfolio management strategies.

The four major roles, which may not all be performed by a given commission, can be broken down into the following:

1. Design of the portfolio (choice of supply/demand side resources, T&D resources, types of suppliers, types of contracts, hedging mechanisms, etc.)
2. Actual procurement of products (solicitation of contracts, making trades, hedging, etc. and regular oversight of the portfolio)
3. Ongoing oversight and adjustment of the portfolio design and procurement, either as regulator or as implementer of procurement
4. Audit and other regulatory oversight of the utility (or other responsible parties) regarding each of the above.

How involved regulators are in each of the above is state dependent. In Maine, for example, regulators are intimately involved in each of the four roles described above, whereas in other jurisdictions regulators simply oversee the utilities' activities after the fact. Most states with competitive retail procurement fall in between these extremes. For example, in New Jersey, the Board of Public Utilities *approves* the portfolio and procurement plan, as well as the results of procurement, while the utilities execute those plans.

Naturally, the skill set required of regulators involved in electric portfolio management varies considerably with the extent that they are involved in each of the roles. Regulators generally need to be highly analytical, knowledgeable about financial products (hedging instruments, forward markets, etc.), knowledgeable about the range of resources available at any given time and their general cost. As far as timing, the role that regulators play is on-going or cyclical. From first assessing key risk areas to developing options to mitigate that risk to implementing a strategy and monitoring that strategy, regulators play a dynamic role in managing utility risk practices. For a graphic to demonstrate the full range of roles, see Figure 5.1, below.



Figure 5.1. The role of the regulator in risk management is dynamic in nature.²⁴

6. Conclusion

Traditionally, utilities performed integrated resource planning by evaluating a wide variety of available (or expected to become available) supply-side and demand-side resources in order to meet current and future needs. The usual emphasis was on finding the combination of resources added gradually over a planning period that was *expected* to meet the need at the lowest present value cost to the utility and its ratepayers over the planning period. While IRP processes have strong similarities from state to state, the detailed requirements specified by utility commissions vary. These differences include details for treatment of energy efficiency programs, whether and how to include treatment of environmental and societal costs, mechanisms for public input, and treatment of the way risk and uncertainty are treated.

Wise investors and commodity purchasers generally employ some kind of portfolio management (PM) and an organized procurement process to choose from the huge variety of products available. Portfolio managers must choose from contracts of various lengths and starting dates, decide whether and how to use options and hedging products, and evaluate many other possible strategies. This task, as a whole, has features in common with the job of a mutual fund manager, who takes responsibility for investing money for others, such as the assets of a retirement fund or an individual investor. In that setting, some of the available choices are cash, stocks of various kinds, bonds of various

²⁴ Lucienne Robillard, "Integrated Risk Management Framework," presented by the President of the Treasury Board, Canada, April 2001.

lengths and maturities from various issues (companies, governments, special purpose entities, etc.), interest rate futures, mutual funds, and so on. State-of-the-art PM uses detailed quantitative analysis to understand the uncertainty of cost and returns from different investment choices. The goal of this quantitative analysis is to assess and manage how different combinations of investments with varied kinds of uncertainty affect the return and risk profile of the portfolio as a whole.

Obviously, this is a very general concept. When applied to electric power procurement, there are specialized constraints and additional options such as building one's own generation or reducing one's need through procurement of DSM options. Up until the mid-1990s, vertically integrated utilities focused on building or buying generation and on DSM programs, so adding PM to IRP would have made a difference only in emphasis. More recently, two things have changed. First, the appearance of market trading in wholesale power and options for power, natural gas, weather, and emission permits have begun to widen the choices a utility can make in its resource planning to look more like the type of PM seen in financial and commodity markets. Indeed, some "vertically integrated" utilities have de-emphasized owning generation and instead concentrate on power purchasing. Secondly, competitive procurement of power for default service has begun to use PM-like features, such as contract laddering and purchasing from purely financial brokers who do not own generation.

A few state PUCs now require utilities to apply portfolio management with the goal of achieving reliable electric service at reasonable rates to customers over the long term, either for vertically integrated service or for default service procurement.

Arguably all electric utilities—vertically integrated and distribution-only—could benefit from placing greater emphasis on PM. The recent developments in the competitive wholesale electricity markets create greater opportunities but also greater pitfalls. A passive or inactive utility is more likely to suffer from the pitfalls than benefit from the new opportunities. Regulatory guidance and oversight will be critical to achieve the goals of portfolio management, and to ensure that all utilities have clear direction regarding their roles as portfolio managers. Utilities, even in states with restructured electricity industries, may need to take another look at how and why to manage resource portfolios.

The great variety of new electricity and electricity-related products and tools available for managing resource portfolios and rapidly changing market conditions means that regulators have an opportunity to reassess their roles and expectations regarding the scope and nature of portfolio management applied in their state, regardless of whether it is a retail choice state or a fully regulated state. This report has reviewed the reasons for this conclusion, explained the key analytical and policy-making challenges, and reviewed the software and skills necessary to perform those functions. It should be emphasized, however, that markets, market rules, and product offerings have shifted and changed frequently for some time now, and show no signs of stabilizing anytime soon. Regulators should continue to monitor such changes and update their policies and practices accordingly.

Most of these planning models discussed in this report require special effort in order to include energy efficiency and renewable energy in their evaluation of resources. In addition, these tools would benefit from improving their methodologies for analyzing

long-term risks and comparing long-term decisions under uncertainty. For example, some existing optimization models require the representation of system operation to be simplified and limit the number of resources that can be considered in a model run. Such modeling constraints can prevent the long-term costs and benefits to consumers of a diverse mix of resources from being evaluated fully. The availability of the data these models require to do sound risk analysis is also problematic in some competitive situations, while the institution of competitive wholesale markets has improved data transparency in others. Regulators may wish to promote research and development on improvements in these areas.

Appendix A: Supply Acquisition Strategies For Default Service In States With Retail Access

A.1. Overview

For this report, we examined competitive processes for procurement of power for default service in several states and the District of Columbia, representing a range of approaches to default service procurement. Specifically, we looked into actions that states are currently taking to manage risk—primarily price risk—for default service customers. The common approach to managing that risk is through defining and overseeing the procurement process used by default service providers (also known as basic service providers and providers of last resort).

States using auction or RFP procurement typically procure different products for different classes of customers. For example, a fixed price, all requirements service, including energy, capacity and ancillary services, might be procured for residential and small commercial default service customers, while large commercial and industrial customers might be served under a procurement for fixed price capacity, with energy billed at spot market prices. In states that procure default service power for small customers under multi-year, fixed-price contracts, power for medium-sized commercial customers may be procured under fixed price, but shorter contracts.

In this Appendix, we focus on procurement approaches for residential and the smallest commercial customers, as such approaches present the most challenging concerns for risk mitigation policies.

A.2. Risk Management Approaches Used in Default Service Procurement

Having surveyed a number of deregulated states, we find that many, but not all, retail access states have adopted one or another form of contract laddering to manage price volatility. Contract laddering means that power is procured in staggered, multi-period contracts, instead of through a single contract, or several contracts, that expire all at once. When such a ladder of contracts is put in place, only a fraction of the total portfolio of electric generation contracts expires each cycle, and only a fraction of the supply needs to be replaced and re-priced. In practice, this means that the majority of a customer's generation rate is already locked in by pre-existing contracts; the full effect of trends or spikes in electric generation prices is buffered for default service customers. In most jurisdictions that use contract ladders, the cycle period is one year, and the most common choice for contract lengths has been three years. Figure A.1 shows a pattern of procurement over time for a simple ladder of three-year contracts with one-third of the load rolled over annually. A contract ladder of this type, whatever the length of its contracts and number of cycles, may require odd contract lengths when being initialized to allow for synchronizing contract expirations and future procurements with ISO or RTO planning years and the like.

Laddering is the main procurement strategy used by a number of states and utilities that pursue competitive procurements for their default service, particularly on the East Coast. Table A.1 presents the specifics of procurement schemes in the jurisdictions studied.

<i>Procurement Year</i>	<i>Year 1</i>	<i>Year 2</i>	<i>Year 3</i>	<i>Year 4</i>	<i>Year 5</i>	<i>Year 6</i>	<i>Year 7</i>	<i>Year 8</i>
1/3 load								
1/3 load								
1/3 load								

Initial 1-year contracts	
Initial 3-year contracts	
Rollover 3-year contracts	
Subsequent 3-year contracts	

Figure A.1. Illustrative 3-year procurement ladder with phase-in. In this example, by Year 3, only 1/3 of the contracts expire and must be replaced each year. In other words, 2/3 of the load prices are locked in earlier years.

Specific laddering terms, such as those described above, are established via commission orders. In many cases, the framework used to establish such terms was a negotiated settlement amongst some of the parties to a rulemaking or other proceeding. Settlements have included varied parties, including some or all of the utilities, wholesale bidders, retail suppliers, regulators, consumer advocacy groups, and others. Generally, once the contract procurement ladder and process is established, adjustments have been made for a period of several years before it is revisited.

A.3. Observations on Procurement Approaches

A.3.1. Procurement Process

A few retail choice states rely primarily or in part on spot market purchases for default service procurement (e.g., Texas and New York). In New York, supply procurement for default customers is essentially a portfolio-based approach where utility supply portfolios typically consist of "legacy hedges" (i.e., long-term contracts entered into at the time the power plants were sold), short-term contracts, spot purchases from the NYISO market, and financial hedges. The majority, however, use either a Request for Proposal (RFP) or an auction format to procure power for default service customers. New Jersey led the way with auctions for default service power, using a descending clock auction to determine final prices. Illinois has recently adopted a similar process, but has not yet executed an auction. A number of other jurisdictions, including Maryland, the District of Columbia, Maine, and Delaware, use RFPs soliciting bids of various lengths for fixed price blocks of default service power.

Table A.1: Competitive procurement strategies for procurement of default service power in selected jurisdictions.

<u>Jurisdiction</u>	<u>Procurement Process Type</u>	<u>Contract Durations</u>	<u>Effective Date of First Procurement</u>	<u>Timing of Procurements</u>	<u>% of Annual Requirement s Procured</u>
New Jersey	Auction	3-year	2002	Annually, in February	33%
Maine ¹	RFP	3-year	2005	Annually, in December	33%
Illinois	Auction	3-year	2006 (pending)	Annually, in September	33%
Maryland ²	RFP	Mix of 1,2 and 3-year	2005	Annually, in 3 rounds, approx. 3 weeks apart. Previously began in Dec., but MD, DE and DC expect to reschedule so that bid periods do not overlap.	Varies. Currently 25% annually.
District of Columbia	RFP	Mix of 1,2 and 3-year	2005	Same as Maryland	Varies. Currently 25% annually.
Delaware ³	RFP	3-year	2006	Same as Maryland	33%
Massachusetts ⁴	RFP	1-year	2004 ⁵	Semi-annually, in April and October	50%
Texas	Spot market	N/A	2002	Daily	Actual daily requirement
New York	Utility-specific portfolio approaches along with the use of financial instruments	Varies, some pre-existing long-term contracts, short-term contracts, spot purchases, and financial instruments.	1999	Varies	Varies

¹ New legislation (May 2006: 36 MRSA §3203) establishes the possibility of using longer-term contracts.

² The MD PSC is currently exploring changes to SOS procurement: [case number 9064](#).

³ New legislation (April 2006: [H.B. 6](#)) calls for sweeping changes, including integrated resource planning, consideration of both short- and long-term contracts, owning and operating generation facilities, and demand side management program to serve default service customers. At least 30% of the requirements are to be procured competitively from the regional wholesale market. IRP aspects of this bill will be implemented over time, but a proceeding is under way to consider revisions to the RFP procurement process (PSC Docket No. 04-391).

⁴ While Massachusetts has revisited contracting mechanisms multiple times over the last several years, most of the state's basic service providers continue to procure 50% of their load every 6 months, using 1-year contracts. However, in a December 2005 settlement, NSTAR agreed to begin using a mix of 1, 2, and 3-year contracts for its generation contracts going forward.

⁵ Effective date of semi-annual procurements. Standard offer service began in 1998.

Advantages and disadvantages are claimed for each approach. State regulators or default service providers who utilize RFPs can readily adjust the RFPs annually to address specific needs or concerns over time. Smaller jurisdictions perceive an advantage in the RFP format due to reduced transaction costs and shorter lead times, viewing a more formal auction process as burdensome. Meanwhile, advantages of the auction include a perception of greater transparency, especially since bidders receive feedback about the level of interest expressed in each round of bidding as the price descends from round to round. To date, there is not enough data to clearly indicate which approach is better from either the generator or consumer perspective. Theoretical arguments have been offered about which one, if either, will produce the lowest prices, greatest bidder participation, etc., but, in practice, each approach has been able to attract a sufficient number of bidders to satisfy the various commissions that monitor the processes.

Some states (e.g., New Jersey, Maine, Illinois) have a single annual procurement to replace expiring contracts. Maryland, the District of Columbia, and Delaware each spread the annual procurement over three separate bid dates, spaced approximately three weeks apart in time. This is perceived to reduce the risk that a temporary market disruption will dominate the overall result. On the other hand, the smaller size of each procurement might make the RFP marginally less attractive to bidders and slightly increases the administrative cost.

The different approaches have advantages or disadvantages for both the buyers and suppliers, but there is not enough data available to reach firm conclusions on which approaches are better and under what circumstances. Clearly, however, timing plays an important role in the outcome of procurements. Default service procurements are typically scheduled farther in advance and are not easily moved. Market events and the timing of their procurements hit the 2006 generation contracts in Maryland, the District of Columbia, and Delaware particularly hard. These jurisdictions each held the first of their three intra-year procurements in December 2005, when natural gas price futures were at an all time high. Even a six week delay would have resulted in prices on the order of 20% lower. In this regard, New Jersey was fortunate, because its last procurement was held in February 2006, at which point natural gas prices (and electricity futures) had already begun to subside. Thus, the specific timing of procurement processes can significantly affect generation rate outcomes. Jurisdictions attempting to initialize a multi-year ladder procurement are particularly vulnerable. Whether results can be improved by introducing flexibility in the timing of procurements is a recent topic of controversy.

A.3.2. Contract durations in default service procurement

We see that not all states have chosen to implement the same contract laddering terms. New Jersey, Illinois, Delaware, and Maine have chosen a simple 3-year contract laddering approach.⁶ The District of Columbia and Maryland use a combination of one-

⁶ New Jersey began with unlayered one-year contracts and began phasing in a three-year ladder with its 2003 procurement. In its 2005 RFP, Maine began to phase in a three-year ladder, but did so by procuring separately priced contracts for each off years one, two and three of the ladder, rather than single, flat-priced bids for the whole three years.

two- and three-year bids in their 2005 and 2006 RFPs. Meanwhile, Massachusetts utilizes only 1-year contracts in overlapping procurements every six months. In New York, some utilities use the laddering approach for a portion of their supply portfolios with the remainder of their portfolios consisting of longer-term contracts and spot purchases. Texas relies on spot markets.

The duration of contracts and the number of overlapping contracts in a ladder portfolio has a major affect on the degree to which customers are protected from price fluctuations; those procurements using spot market purchases or unladdered contracts (100% of contracts expire together) expose customers to greater price volatility than ladder procurements. Contracts for longer periods of time protect customers from price fluctuations longer, but if they are not ladder to roll over, create the risk of larger price jumps when they do expire.

In general, jurisdictions that use a three-year ladder with annual roll over of one-third of the supply have chosen to optimize their ladder to provide protection against fluctuations of price ranging from short-term spikes to highs and lows of up to a few years. With regard to the longer-term risks (say, price trends over five to ten years or longer), a ladder of three years or less is inadequate to mitigate those risks for customers. A three-year ladder results in generation rates that are, in effect, a three-year moving average of market prices. So, if generation prices gradually rise over ten years or if a market change results in a sudden long- term shift in prices, the risk mitigation obtained from early procurements fades out after three years and the full force of those market trends or events is fed into rates at that time. Price risks due to long-term trends or sudden permanent market shifts may be mitigated only with correspondingly long-term procurements (or other types of long-term hedging). In order to accommodate longer-term stabilization goals, a long-term ladder or longer-term resources would be needed.

It is important to note that a *single* long-term purchase stabilizes rates for the life of the contract, but at the risk that the contract may turn out to be higher than market prices that actually occur in the future *and* at the expense of total exposure to market conditions prevailing at the end of that purchase. Alternatively, the aspect of laddering that produces *risk mitigation* as well as *price stability* is that it divides the supply up into small increments, each of which is priced separately at a different time and only one of which expires at any given date.

It is also important to highlight the fact that states may have different policy objectives with regard to portfolio management. For example, states that have chosen contract laddering may have a goal of trying to stabilize prices for customers who do not switch to a competitive supplier or they may anticipate that small customers are unlikely to switch to a competitive energy supplier.

New York specifically desires to encourage development of competitive retail markets but requires utilities to provide stable prices for mass market customers until volatility mitigated products are available from the competitive market. The NY PSC's 2004 policy statement requires that utilities that provide default service, at least for the present, should "prepare plans to foster the development of retail markets" and "continue to maintain a

balanced contract portfolio for residential customer commodity" in the "near term."⁷ Pricing of default commodity service varies by utility and by customer class. Some utilities pass through average monthly NYISO spot prices in the supply charge but with an offsetting adjustment to delivery charges based on the "value" of hedges, so that, on average, the utility's commodity price is based on its overall portfolio cost.⁸ Texas has chosen a similar strategy to encourage competition. Most deregulated states, however, have opted to focus procurement policy on the needs of customers who do not shop.

A.4. Beyond Laddering

When contract laddering is the sole procurement tool used, it provides only limited portfolio management benefits, which are realizable only over the length of that ladder – sometimes a very short time frame. Some states are beginning to address this limitation through new laws that explicitly try to obtain low costs over the *long-term* for their smaller default service customers. A variety of means have been adopted or are under discussion for this purpose.

Maine is one state that has taken this approach. The Maine Legislature recently enacted legislation requiring the PSC to “adopt by rule a long-term plan for electric resource adequacy for this State to ensure grid reliability and the provision or availability of electricity to consumers at the lowest cost.” The new legislation allows the Commission to include in that plan "cost-effective demand-side measures" as part of the supply of standard-offer service. It authorizes the Commission to enter into various standard-offer service contract lengths and terms for residential and small commercial customers and directs the Commission to consider developing one or more demand response programs for medium nonresidential customers.”⁹

Delaware now also requires expanded portfolio management practices embracing full scale integrated resource planning for default service including energy efficiency, renewables, and the option of utility construction of new generation units.

On or after May 1, 2006, it is the policy of the State that Electric Distribution Companies subject to the oversight of the Commission and as part of their obligation to be Standard

⁷ Quotations from pages 48, 52 and 28-29 of the *Statement* cited in this footnote, respectively. However, the Commission also declined to provide for further acquisition of hedges for medium to large commercial and industrial customer service as existing hedges expire. *Statement* at 32. Further, the Commission ordered that, "When new rate cases or rate plan extensions are filed, the utilities will be expected to include specific proposals to encourage migration of customers and to otherwise further the development of retail competitive markets.... We are not endorsing the New Jersey [auction] model because it unnecessarily prolongs the utilities' commitment to multi-year wholesale contracts and their role as a commodity supplier.The sooner customers experience pricing variations, the sooner competitive markets will provide alternatives, including fixed-price options and peak and off-peak pricing, possibly accompanied by interval metering." NY PSC Case 00-M-0504, Proceeding on Motion of the Commission Regarding Provider of Last Resort Responsibilities, the Role of Utilities in Competitive Energy Markets and Fostering Development of Retail Competitive Opportunities. *Statement of Policy on Further Steps toward Competition in Retail Energy Markets*, August 25, 2004.

⁸ Personal communication, Raj Addepalli, NY PSC, 7/30/2006

⁹ 36 MRSA §3203, enacted May 2006.

Offer Service Suppliers shall engage in Integrated Resource Planning for the purpose of evaluating and diversifying their electric supply options efficiently and at the lowest cost to their customers...As part of the initial IRP process, to immediately attempt to stabilize the long-term outlook for Standard Offer Supply in the DP&L service territory, DP&L shall file on or before August 1, 2006 a proposal to obtain long-term contracts. The application shall contain a proposed form of request for proposals (“RFP”) for the construction of new generation resources within Delaware for the purpose of serving its customers taking Standard offer Service. Such proposed RFP shall include a proposed form of output contract..., which contract shall have a term of no less than ten (10) years and no more than twenty-five (25) years. Such RFP shall also set forth proposed selection criteria based on the cost-effectiveness of the project in producing energy price stability, reductions in environmental impact, benefits of adopting new and emerging technology, siting feasibility and terms and conditions concerning the sale of energy output from such facilities.¹⁰

Similarly, Maryland is considering modifications to its standard offer service policy. Objectives and strategies are currently being considered in Commission Case Number 9064: a major policy review proceeding covering the provision of standard offer service (“SOS”) to residential and small commercial customers.

In sum, some states that deregulated electric generation and adopted retail competition in the last decade are returning to an IRP-type of portfolio management, as opposed to relying solely on contract laddering with terms of one to a few years. This may provide a more robust form of portfolio management than is currently being utilized.

A.5. Resources on state procurement practices

For more information on the basic service procurement processes and results in the states that use a competitive process for procurement of their default service, see:

- NJ: www.bgs-auction.com
- DE: http://www.state.de.us/delpsc/documents/dp_sos_022806.pdf
<http://www.state.de.us/delpsc/documents/vantage030106.pdf>
- MD: <http://www.psc.state.md.us/psc/AboutUs/Press/SOS2004.htm>
http://webapp.psc.state.md.us/Intranet/Casenum/NewIndex3_VOpenFile.cfm?ServerFilePath=C%3A%5CCasenum%5C8900-8999%5C8908%5C462.pdf
- ME: http://www.maine.gov/mpuc/industries/electricity/standard_offer/closed_so_solicitations.html
- MA: <http://www.mass.gov/dte/restruct/competition/defaultservice.htm#Fixed%20Default%20Service%20Prices>

¹⁰ Electric Utility Retail Customer Supply Act of 2006, HB 6, enacted April 2006.

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- <http://www.mass.gov/dte/restruct/competition/index.htm>
 - DC: http://www.dcpsc.org/pdf_files/hottopics/PEPCO_Press_Release_030306.pdf
http://www.dcpsc.org/pdf_files/hottopics/Q&A_PEPCO_New_Price.pdf
 - IL: ICC Final Order Dockets 05-0159 through 0162, January 2006.
<http://www.illinois-auction.com/index.cfm?fa=bid.reginfo>
 - NY: PSC Case 00-M-0504. Proceeding on Motion of the Commission Regarding Provider of Last Resort Responsibilities, the Role of Utilities in Competitive Energy Markets and Fostering Development of Retail Competitive Opportunities. *Statement of Policy on Further Steps toward Competition in Retail Energy Markets*, August 25, 2004.
[http://www3.dps.state.ny.us/pscweb/WebFileRoom.nsf/Web/0717FE125899AD1985256EFB006253F2/\\$File/201b.00m0504.pdf?OpenElement](http://www3.dps.state.ny.us/pscweb/WebFileRoom.nsf/Web/0717FE125899AD1985256EFB006253F2/$File/201b.00m0504.pdf?OpenElement)

Appendix B: Integrated Resource Planning Practices in Regulated States

In contrast to the practices seen in the deregulated states covered in Appendix A, the fully regulated states we surveyed generally had an integrated, active approach to portfolio management.¹ Frequently these processes consider many factors affecting the need for electric resources, such as generation and transmission siting, system reliability, efficiency and renewable energy, rate design, and fuel diversity.

California, Montana, Washington, and Oregon, for example, explicitly require consideration of price or environmental risk management in planning and procurement. However, each state's approach to regulating risk management practices differs. More than any other state in the survey, California prescribes how utilities treat regulatory (environmental and cost recovery) and price risk in utility resource plans and is actively involved in utilities' decisions about risk metrics and models. California is also the only state we interviewed that explicitly defines consumer risk tolerance in the context of procurement planning. With both regulated and deregulated utilities, Montana is an interesting case study of how risk management policy can translate from one regulatory construct (vertically integrated) to another (deregulated). Washington and Oregon require utilities to consider risk, but they leave risk management squarely in the hands of the utilities. Because cost recovery depends in part on the company's risk management practices, utilities have a large incentive to keep up with developments in risk management theory and methods. In Oregon, specific regulations concerning risk are currently unfolding. Although Washington has generally taken a hands-off approach to risk management policy, incentives to account for risk in procurement planning and acquisition processes have spurred extensive and sophisticated modeling of stochastic variables, providing a solid foundation for least-cost/least-risk decision making.

B.1. California

In 2003, following a tumultuous two-year period of testing customer choice in retail markets, the California Public Utilities Commission (CPUC) ordered the state's investor owned utilities to resume planning and procuring resources to meet consumers' electric load. The state's Long-Term Procurement Planning process (LTPP) is one part of overall resource planning, which is being coordinated and integrated with previously separate processes under the following headings: Community Choice Aggregation, Demand Response, Distributed Generation, Energy Efficiency, Qualified Facilities, Renewable Portfolio Standards (RPS), Transmission Assessment and Planning proceedings and Resource Adequacy requirements. Every two years, utilities are required to submit LTPPs detailing their projections of demand and laying out how they propose to meet

¹ For this survey, we reviewed background literature, regulations, and legislation on risk management practices and policies in fifteen US states and one Canadian province. We contacted the state public utility commission where we found indications that the state makes some explicit consideration of price or environmental risk management in its planning and procurement processes. In all, we contacted eleven and interviewed eight commission staff members.

that demand over a 10-year horizon.² Analysis underlying and presented in the plans must include sensitivity analyses for load growth as well as for gas and market prices,³ and the proposed resource mix must meet the criterion of least cost–best fit.⁴

California requires utilities to consider environmental factors, including the cost of future carbon reduction regulations, in their long-term planning and resource comparisons. Utilities are instructed to add \$8 per ton of CO₂ to the cost of fossil-fired resources for planning purposes (i.e., the adder is not used in ratemaking) to reflect the cost of climate change to California and to incorporate some of these resources' financial, regulatory, and environmental risks into resource decisions.⁵ The goal of this requirement is to reduce California's dependence on fuel sources that pose considerable and increasing environmental risks.

Also addressing the environmental externalities and regulatory risk associated with fossil fuels, California directs utilities to prioritize demand-side and renewable resources in the planning process. Utilities are to follow the “loading order” established in the state's Energy Action Plan (EAP), which seeks to optimize energy conservation and resource efficiency while reducing per capita demand.⁶ The EAP established the following priority list:

1. Energy efficiency and demand response
2. Renewable energy (including renewable DG)
3. Clean fossil-fueled DG and clean fossil-fueled central-station generation

The state and its utilities are meeting their goals for energy efficiency, suggesting that the planning process and loading order may have had some affect on procurement decisions. For example, SCE requested an additional \$38 million for efficiency programs, to meet an anticipated energy shortfall. However, goals for demand response and renewables have been somewhat elusive, in part due to perceived increased risk of contract failure by

² Liz Baldwin, *Regulatory Assistance Project Electric Resource Long-range Planning Survey: California*. May 20, 2005.

³ Demand forecasts must include three levels of demand, with a high load forecast that is set at the 95th percentile. Scenario analysis of energy and gas costs is likewise to be evaluated at the 95th percentile. (CPUC, *Ruling and Scoping Memo 37116 in Rulemaking 04-04-003*, Jun 4, 2004)

⁴ Liz Baldwin, *op. cit.*

⁵ U.S. EPA. *Clean Energy-Environment Guide to Action: Policies, Best Practices, and Action Steps for States*, April 2006. Available at <http://epa.gov/cleanenergy/stateandlocal/guidetoaction.htm>.

⁶ State of California. *2003 Energy Action Plan*. May 8, 2003.
http://www.energy.ca.gov/energy_action_plan/2003-05-08_ACTION_PLAN.PDF

The loading order originates in the 2003 *Energy Action Plan*, proposed by a joint subcommittee of the California Energy Commission, the CPUC, and another agency that is now defunct. These agencies approved the final plan, which required the State Energy Resources Conservation and Development Commission to conduct assessments to address public-interest energy strategies including “identification of policies that would permit fuller realization of the potential for energy efficiency, either through direct programmatic actions or facilitation of the market.” The *Energy Action Plan* was required under SB 1389 (Signed Sep 14, 2002. Available at http://www.leginfo.ca.gov/pub/01-02/bill/sen/sb_1351-1400/sb_1389_bill_20020915_chaptered.html, accessed July 12 2006).

renewables, as well as transmission development and cost recovery risks. In part to address these problems, the CPUC combined long-term RPS planning with its general procurement planning proceeding (R.04-04-003). Also, it directed utilities to identify and conduct contingency planning addressing impediments towards meeting the RPS.⁷

Procurement plans are required to incorporate one or more procurement process features that, if adhered to, reduce the utility's risk of cost disallowances. These features include a competitive procurement process,⁸ a benchmark-driven incentive mechanism,⁹ and a pre-established set of criteria on the acceptability and eligibility of procurement contracts for rate recovery.¹⁰

Taking into account the parties' positions, the CPUC analyzes each plan and may approve, modify, or reject the plans. The Commission may require compliance filings to resolve any deficiencies in the plans. Inclusion of an element in an approved LTPP does not constitute pre-approval, per se; the IOUs must get separate authorization for turn-key projects, self-build, and supply contracts of five years or longer.¹¹

Procurement strategy is overseen by utility-specific Procurement Review Groups (PRG), which comment on (but neither approve nor disapprove) the details of each utility's proposed procurement processes and contracts (prior to their submission to the PUC for expedited review). PRG members include the PUC Energy Division, Office of Ratepayer Advocates staff, and interested parties who are not market participants, all subject to a non-disclosure agreement.¹² The Commission monitors procurement decisions via quarterly reports submitted by the companies. Utilities must also file monthly risk reports assessing consumer exposure to market risk.¹³

Guidance on specific risk measures evolved from the time of the energy crisis. Citing VAR's widespread use in financial markets, in commercial software, and in utility holding companies' annual reports, the CPUC adopted SDG&E and PG&E's

⁷ U.S. EPA, op. cit.; Center for Resource Solutions Team, *Achieving a 33% Renewable Energy Target*, Nov. 1, 2005. Prepared for the California Public Utilities Commission. Available at http://www.cpuc.ca.gov/word_pdf/misc/Achieving_33_Percent_RPS_Report.pdf, accessed July 12, 2006.

⁸ The Commission, not the utility, specifies the format of that procurement process, as well as criteria to ensure that the auction process is open and adequately subscribed. If purchases are in compliance with the authorized process, they will be recovered in rates. (California SB 1037. Signed Sept. 6, 2005. Available at http://info.sen.ca.gov/pub/bill/sen/sb_1001-1050/sb_1037_bill_20050929_chaptered.html, accessed July 12, 2006.)

⁹ If approved, this incentive mechanism would authorize the utility to procure from the market, depending on how the company performs relative to commission-authorized benchmark(s). The incentive mechanism should be clear and achievable. In addition, it should contain quantifiable objectives and contain balanced risk and reward incentives. (California SB 1037, op. cit.)

¹⁰ Under this mechanism, the CPUC will conduct an expedited review of the proposed transaction's compliance with the approved procurement plan. (California SB 1037, op. cit.)

¹¹ Liz Baldwin, op. cit.

¹² CPUC, Decision 02-08-071 in Rulemaking 01-10-024, Aug. 22, 2002; CPUC, Resolution E-3857, ID# 2979, Dec. 18, 2003.

¹³ U.S. EPA, op. cit.

recommendation for reporting portfolio cost risk using TEVAR, the value at risk to expiration.¹⁴ Further, it required that the utilities file monthly portfolio risk reports reflecting estimated portfolio risk for each month on a rolling 12 month basis, on a quarterly basis for months 13-24, and on an annual basis for months 25-60. Seeking transparency and consistency in risk management reporting, the CPUC required validation of SCE's proprietary, in-house portfolio risk model.^{15,16}

Consumer risk tolerance, defined as the price that an average consumer would be willing to pay to reduce the risk of higher prices in the future, is specifically addressed in the context of procurement planning. For example, PG&E set a consumer risk tolerance level, measured by portfolio TEVAR, at one-cent per kWh over a rolling 12 month period in its 2004 short-term procurement plan.¹⁷

More recently, SB 1037 emphasized the role of risk management in procurement plans. Objectives of the plans were clarified and redefined to include providing an appropriate balance of price stability and price level in rates, and to allow utilities to enter into financial and other electricity-related product contracts for the purpose of moderating price risk associated with serving retail customers. This law requires utilities to assess their portfolio price risk and risk management policy, strategy, and practices, including specific measures of price stability, and to include these assessments in their proposed procurement plans.¹⁸ Furthermore, the utility must demonstrate that the procurement plan

¹⁴ VAR stands for Value at Risk, a measure of the uncertainty of the value of resource portfolio. VAR is discussed in Section 3.5 and Appendix C of this report. TEVAR, or Value at Risk to Expiration, is a measure of risk over the entire holding period of the positions. It is of some interest that the confidence levels (e.g., 95% or 99%) to be used in these analyses were controversial. The CPUC has ultimately approved use of 85% levels on the understanding that more extreme confidence levels may be beyond the ability of the existing data to estimate in a stable manner.

¹⁵ The Commission stated, "while we continue to believe that it is unwise to be overly prescriptive in directing utility risk management practices, we need to balance our preference for an "even-handed" treatment on procurement policy with an emphasis on transparency and consistency in risk management reporting. We recognize the importance of standardized risk reporting in order to measure ratepayer risk on an "apples-to-apples" basis and to ensure that utility procurement decisions will benefit all IOU ratepayers in an equitable and unbiased manner. Establishing a common benchmark is one way of ensuring that California's ratepayers, regardless of utility, are equally protected from adverse risk, and thereby can reap the benefits of reliable energy at low and stable rates." (CPUC Interim Decision D.03-12-062, in R 01-10-024, Dec. 18, 2003)

¹⁶ The CPUC allowed SCE to use its model temporarily, contingent on the Company reporting on the methodology, assumptions, and formulas of the model. Validation would require an independent audit. If the model did not receive an unqualified model certification, SCE would be required to use a commercially available risk measurement model. SCE later questioned the ability of an independent reviewer to assess the internal validity of its model but was overruled. The Commission clarified that certification required a determination that all the features of the model work as advertised, that the model is mathematically sound, and that the assumptions utilized by the model are reasonable. (Interim Decision D.03-12-062 in R 01-10-024, Dec. 18, 2003)

¹⁷ PG&E's STPP was essentially subsumed into its LTPP. (CPUC, Resolution E-3951. Sept. 22, 2005)

¹⁸ A portfolio should include "any utility-retained generation, existing power purchase and exchange contracts, and proposed contracts or purchases under which an electrical corporation will procure electricity, electricity demand reductions, and electricity-related products and the remaining open

will “create or maintain a diversified procurement portfolio consisting of both short-term and long-term electricity and electricity-related and demand reduction products.” SB 1037 also allows the commission to use funding to obtain independent consulting services to evaluate risk management and strategy.¹⁹

B.2. Montana

In 1992, the Montana Public Service Commission (MPSC) enacted IRP guidelines that encourage electric utilities to develop and implement least cost planning. Five years later, restructuring legislation established customer choice and mandated the functional break up of Montana Power Company. Montana Power Company was later purchased by NorthWestern Energy (NWE), which became the default supply utility (DSU) in most of the state. The other major investor-owned utility, Montana-Dakota Utilities (MDU), which provides power in eastern Montana, was exempted from restructuring and remained a vertically integrated utility.²⁰ In 2003, the PSC enacted guidelines on long-term portfolio planning, management, and resource procurement for default service electricity supply. As a result, there are two separate planning processes applying to the two major service territories: traditional integrated resource planning (applicable to MDU) and electricity resource planning and procurement for default service customers (applicable to NWE).

IRP guidelines

Montana’s IRP guidelines provide a fairly comprehensive framework for conducting least cost planning and addressing a variety of costs and risk factors. The guidelines place strong emphasis on managing and reducing risks associated with resource choices in a manner that addresses environmental, societal, and ratepayer risks as well as risks to shareholders. The IRP rules require that utilities consider all available resource options, including DSM, and evaluate these options based on a broad range of resource attributes. Using “best available” methodology, resource plans should explicitly evaluate quantifiable and non-quantifiable environmental externalities, including the uncertainty and risk associated with future environmental regulations, uncertainty regarding the size and importance of external environmental costs, and environmental costs associated with continued operation of existing resources.

Although utilities determine the sources of risk using their own techniques and judgment, the IRP guidelines suggest that utilities consider these potential sources of risk:

- resource lead-time,
- water availability,
- future load growth,

position to be served by spot market transactions.” (California SB 1037, signed Sept. 29, 2005. http://info.sen.ca.gov/pub/bill/sen/sb_1001-1050/sb_1037_bill_20050929_chaptered.html)

¹⁹ California SB 1037, op. cit.

²⁰ PacifiCorp was also affected by restructuring. PacifiCorp sold its Montana service territory to Flathead Electric Cooperative. Rural electric cooperatives opted not to open their territories to competition.

- shortcomings of various forecasting methods,
- performance and useful lives of existing resources,
- costs and performance of future demand- and supply-side resources,
- the rate of technological change,
- future fuel availability and price,
- the existence and social evaluation of environmental externalities, and
- the future sociopolitical and regulatory environment.

The IRP guidelines also present a list of potential planning techniques for utilities to consider for managing risks associated with the above sources:

- assessing the risk of resource alternatives,
- developing resource options that increase scheduling flexibility,
- developing small, short lead-time resources that better match loads with resources and reduce the amount of, and period over which, capital must be invested to meet future load growth,
- diversifying the resource portfolio to allow adaptation to a range of future outcomes,
- managing loads to increase utility control over resource requirements,
- encouraging the acquisition of resources through competitive processes,
- incorporating consumer response to rate design into forecasting models,
- providing for public involvement and education in resource decisions, and
- maintaining a transparent integrated least cost resource planning and acquisition process (i.e., one which produces resource plans that can be reasonably understood by the public and the commission).²¹

The guidelines require that demand-side resources be given special consideration in resource evaluation.²² Utilities are required to weight and rank existing and potential

²¹ Montana Administrative Rules, sub-chapter 20: Least Cost Planning – Electric Utilities. 38.5.2004

²² The IRP guidelines also include provisions on sizing and evaluating demand side resource options. The impact of price-induced conservation (i.e. conservation undertaken by customers in the absence of any utility-sponsored program) should be accounted for either in the load forecast or as part of the total available resource. The revenue impacts of decreased sales resulting from demand-side resources are not added to cost of acquiring such resources. Also, in considering demand-side resources, until a point at which there are no market barriers or market failures that may interfere with investment in demand-side resources, as opposed to supply-side resources, demand-side resources are considered cost-effective up to 115% of the utility's long-term avoided cost. The total societal cost test and the total resource cost test are required elements of an IRP. (Montana Administrative Rules , sub-chapter 20: Least Cost Planning – Electric Utilities. 38.5.2004; Liz Baldwin, *Regulatory Assistance Project Electric Resource Long-range Planning Survey: Montana*. Sept. 29, 2005)

resources on the basis of, in part, their environmental impacts. In evaluating potential resource options, utilities should recognize protected areas and any areas inhabited by protected wildlife. Utilities are encouraged to recognize the positive externalities associated with resources that correct or reduce existing environmental damage. Furthermore, utilities should conduct sensitivity analyses to determine if more environmentally benign resource alternatives can provide equivalent benefits at a lower societal cost.²³

Special attention is given to consistency between the IRP and rate making processes in the IRP guidelines. The importance of this consistency is particularly emphasized for rate stability. In addition, IRPs must explicitly recognize rate design opportunities to develop demand-side resources.

While the determination of how to assess environmental externalities and risk factors is left to the utility, the guidelines do require that the utility clearly and thoroughly document the decision process for choosing resource options.

Default electric supplier procurement guidelines

Montana's largest restructured IOU, NorthWestern Energy, is subject to Montana's default electric supplier procurement guidelines.²⁴ These guidelines were developed with the following stated objectives:

- Provision of adequate, reliable default supply services, stably and reasonably priced, at the lowest long-term total cost
- Pricing that is both equitable and promotes rational, economically-efficient consumption and retail choice decisions
- A balanced, environmentally-responsible portfolio of power supply and demand-side management resources, coordinated with economically-efficient cost allocation and rate design
- Diversity with respect to resource types and contract durations
- Dissemination of information to customers regarding the mix of resources in the supply portfolio and corresponding level of emissions and other environmental impacts

²³ The screening process in Montana's IRP guidelines requires that the cost assigned to each resource reflect all relevant attributes. Attributes generally include those that influence utility costs as well as long-term societal costs, including risk and uncertainty. Other attributes to be considered are environmental externalities, the overall efficiency with which the resource produces energy services, administrative costs of acquisition programs, the cost effectiveness of the resource within the context of the utility system, reliability, and associated transmission costs. (Montana Administrative Rules, subchapter 20: Least Cost Planning – Electric Utilities. 38.5.2004)

²⁴ In NorthWestern Energy's territory, there is currently no competitive supply available for residential and small business customers. A statutory change in 2005 will allow entities to aggregate residential and small business customers, subject to regulatory approval. The Commission lacks authority to adopt portfolio rules for aggregators, but it may be approving some sort of planning guidelines in the future.

Each DSU is required to develop an Electric Default Supply Procurement Plan (EDSPP) to comply with these objectives. This plan is based on a comprehensive resource needs assessment, considering all aspects of customer load, resource availability, and product type availability. The plan must assess the resource diversity and flexibility of the existing portfolio, as well as the effect of cost allocation and rate design on future resource needs. To evaluate these factors independently of resource options, DSUs must employ rigorous computer modeling and analysis in the portfolio management and resource procurement processes. Analyses must also be used to develop least-cost scenarios and conduct risk sensitivity analyses for the various options. Table B.2.1 shows the risk factors that DSUs are required to consider.

Table B.2.1. Sources of risk that should be considered in prudent default supply resource planning and procurement (MT 38.5.8219)

Underlying Risk Factor	Price Uncertainty Risk	Load Uncertainty Risk
Fuel prices and price volatility	X	X
Environmental regulations & taxes (including carbon regulation)	X	X
Default supply rates	X	
Competitive suppliers' prices	X	
Transmission constraints	X	
Weather	X	X
Supplier capabilities	X	X
Supplier creditworthiness	X	
Contract terms and conditions	X	X

DSUs must apply cost-effective resource planning and acquisition techniques to manage and mitigate the risks posed by the factors shown in Table B.2.1, above. Such techniques include contingency planning, portfolio diversification, and transparency in the planning and procurement process. These utilities must balance environmental responsibility with other portfolio objectives, including lowest long-term total cost, reliability, and price stability.

The guidelines require DSUs to develop methods for incorporating portfolio objectives into the resource procurement, for example by weighting resource attributes and ranking bids in competitive solicitation processes. The guidelines suggest that weights may be given to reflect, among other things, contributions to achieving optimal resource diversity; project feasibility (and risk) with respect to engineering, development, and financing; supplier creditworthiness (counterparty risk); and fuel source, associated price volatility, and regulatory risk (including regulations on carbon emissions).

A default service provider should evaluate the performance of alternative resources under various loads and resource combinations through scenario, portfolio, sensitivity, and risk

analyses. As an example of these modeling efforts, for its 2005 EDSPP, NWE conducted a 20-year horizon resource planning analysis involving the following steps:

1. Define the load obligation
2. Accumulate data on resource options and model inputs, including expected carbon costs and gas and electricity price forecasts
3. Create portfolios of resources that are representative of the feasible possibilities that NWE could pursue
4. Conduct intrinsic analysis²⁵ of the portfolios to identify key risk drivers, and employ scenario analysis for gas and electricity prices, load, and CO₂ regulations²⁶
5. Select the most robust portfolios, considering the major risk factors inherent in the portfolios
6. Conduct the final screening of the most robust portfolios using stochastic analysis using thousands of simulations
7. Select the best portfolios based on their placement on a risk-adjusted mean efficiency frontier²⁷
8. Conduct qualitative analysis of the best portfolios
9. Create an Action Plan outlining how the selected resource characteristics will be acquired over the time frame of the Plan

NWE ran PCI GenTrader®, an energy supply portfolio modeling and generation dispatch model, for steps four, six, and seven (listed above).²⁸

For approval of a power purchase and sale agreement, NWE employed somewhat different methodology. NWE used GenTrader® to model both the current portfolio of resources and the best portfolio mix going forward. Also, it evaluated portfolio performance by a different measure of portfolio risk measure, calculated by adding 70

²⁵ Intrinsic analysis employs fixed market prices and static resource assumptions. (NorthWestern Energy, 2005 Electric Default Supply Resource Procurement Plan)

²⁶ The analysis considers the potential implementation of a CO₂ tax using forecasts of medium, high, and zero taxes. The expected case (medium) was drawn from NPCC's estimate of a 67% chance of a \$6.00/ton-CO₂ charge starting in 2010 and rising to \$14/ton in 2017. *Ibid.*

²⁷ For step seven, NWE employed a risk metric that compares the expected outcome (the mean) to the difference between the mean and the average of the worst 10% of stochastic draws. NPCC also uses this metric. *Ibid.*

²⁸ GenTrader® is a "widely used" tool that evaluates complex power portfolios of both generators and energy contacts. In the MPSC's Comments, it noted that other models might be more useful in this context—for analyzing and evaluating dynamic resource portfolios—because it does not employ iterative modeling techniques. *Ibid.*

percent of the stochastic mean portfolio cost to 30 percent of the 95 percent confidence level portfolio cost.²⁹

The default electric supplier procurement guidelines also address staffing and tools for risk management and mitigation, but only briefly. They recommend that utilities seek upfront and substantive input from an independent advisory committee of technical and public policy experts, for the purpose of mitigating risk and optimizing resource procurement outcomes relative to portfolio objectives. The guidelines also advise utilities to employ “adequate” staffing and technical resources for risk management; other suggested tools include using diversity (fuels, technology, contract terms) and contingency planning. Transparent planning and procurement process is also considered a cost-effective resource planning and acquisition technique for managing and mitigating risks.

As a requirement of providing default electric supply service, a default supplier is required to also provide customers with the option of choosing a “green” product composed of or supporting power from certified environmentally preferred resources such as wind, biomass, solar, or geothermal resources. Further promoting resource diversity, the Montana PSC recently adopted a rule establishing a Renewable Energy Resource Standard.

The Montana PSC is not required to explicitly “approve” resource plans filed by restructured or traditional utilities, therefore recoverable costs associated with an implemented plan are not guaranteed in rate cases.

B.3. Washington

The Washington Utilities and Transportation Commission (UTC or Commission) considers utility portfolio and risk management practices in three interrelated processes: integrated resource planning (IRP), competitive resource acquisition, and, more tangentially, in cost recovery.

In 1987, Washington implemented an IRP process with filings required every 24 months. As a part of the IRP process, utilities must conduct a “detailed and consistent” analysis considering, at a minimum, resource cost, dispatchability, and effect on system operation; market-volatility and risks imposed on ratepayers; uncertainties regarding demand-side resources; regulation or policy change at the state and federal level; and environmental policy risks, including the cost of CO₂ emissions.³⁰ The Commission does not require that IRPs consider externalities explicitly, although these issues may be considered in other proceedings.³¹

²⁹ MTPSC Docket 2004-3-45, Order 6557c.

³⁰ WAC 480 100 238.

³¹ Utilities that have service areas in other states that require consideration of externalities generally include these factors in their Washington IRPs. Liz Baldwin, Regulatory Assistance Project, *Electric Resource Long-range Planning Survey: Washington*. Sep 2005. Available at <http://www.raponline.org/>.

In the IRP process, utilities must consider a wide range of commercially available, conventional and non-conventional supply- and demand-side options.³² This directive for an inclusive review of resources, together with risk evaluation requirements, spurred utilities to begin conducting extensive simulation analyses of many different resource portfolios, each over many different futures. For their IRPs, utilities compare the performance of these portfolios, allowing selection of one with minimal cost and risk for a given price and risk tolerance.

Although utilities are not specifically required to include DSM in resource portfolios, they have begun to do sophisticated analyses to more accurately represent the cost reduction and risk mitigation benefits that DSM brings to a portfolio.³³ For example, in its 2005 IRP, Avista analyzed conservation measures using hourly avoided costs (as opposed to the more common use of annual figures), load shifting, and on-peak versus off-peak value.³⁴

Risk management practices in Washington have improved greatly in the last five years, due to use of stochastic (and other) models and the availability of computing power to produce more robust results. Generally, the present value of revenue requirements is computed over many trials (200-300 iterations), and the mean of the variants provides a measure of risk.³⁵ For example, Puget Sound runs an enterprise-wide database management tool—KW3000 by Kiindex—as its core risk management software that is used to run large numbers of scenarios and to evaluate the firm's position.³⁶ While many risk factors, including weather and price variability, are evaluated using stochastic analysis, some risk factors are generally not considered stochastically; potential policy changes, for example, are generally evaluated using scenario analysis.³⁷

The purpose of the IRP is largely for dissemination of information within the company and to the UTC, ratepayers, investors, and other stakeholders. If the Commission finds

³² Although transmission and distribution are not explicitly evaluated in IRP, they are generally considered if they are impact or are impacted by other measures. Liz Baldwin, *op. cit.*

³³ The risk mitigation benefits that energy efficiency, other DSM, or renewable resources provide are accounted for in the IRP through a "consistent" comparison of all resources and extensive analysis of the performance of portfolios with different resource mixes under varying conditions. Washington does not confer special status to these resources in the resource planning and acquisition processes on the ground that their effects on risk vary. For example, while renewable resources may provide an excellent hedge against the price of fuel, they may have less value in terms of reliability, price, supply, and strategic risk mitigation. Phone interview, Hank McIntosh, WA Utilities and Transportation Commission, Integrated Resource Planning. Jan. 27, 2006.

³⁴ Linda Anderson, "Avista Utilities aims high on efficiency," *nwcurrent*. Nov 29, 2005.
<http://www.nwcurrent.com/efficiency/industrial/1978117.html>

³⁵ Phone interview, Hank McIntosh, WA Utilities and Transportation Commission, Integrated Resource Planning. Jan. 27, 2006. See also Northwest Power and Conservation Council. (NWPPCC) 2003. *Power Supply Adequacy Forum: State IRP Requirements and Issues*. Available at <http://www.nwcouncil.org/energy/powersupply/adequacyforum/>

³⁶ Possibly relating to the large number of scenarios, the software has been cumbersome and slow in practice. Moreover, it needs a lot of input and time. (Phone interview, Hank McIntosh, WA Utilities and Transportation Commission, Integrated Resource Planning. Jun. 28, 2006.)

³⁷ Liz Baldwin, Sep 2005(b), *op. cit.*

that an IRP is consistent with its rule, it issues an acknowledgment during a public, non-litigated process. This formal acknowledgment does not, however, represent a determination that a plan is reasonable, nor does it reduce the utility's regulatory risk in future proceedings, *per se*. Utilities are expected to justify resource procurement decisions in rate cases in light of any new opportunities or conditions that occurred after the IRP was issued.

Utilities are given a great deal of leeway in the methodology and assumptions used in developing their IRPs. A utility may, for example, choose the planning horizon (although long-run and short-run components are required), the assumed cost of compliance with CO₂ regulations, and acceptable levels of reliability and price escalation risks.³⁸ Utilities can choose to reject Staff's technical advice on modeling methods³⁹ but rarely do so. To the extent that decisions subject to prudence review are founded on the IRP, it is in the utility's interest that Staff and other interested parties understand the proposed plan, including underlying modeling and assumptions, sufficiently well to participate in the plan's development. For this reason, the utility usually involves these parties the plan's development and may revise the plan multiple times based on their feedback.

While risk over the long term is generally dealt with in the context of the IRP, short term risk may be considered in other ways. At Avista, risk management policies focus on an 18-month horizon; consistent with available product terms and the uncertainty associated with hydro conditions.⁴⁰

Following submission of its IRP, the utility submits a draft request for proposals (RFP), consistent with the resource needs and preferences identified in the IRP but open to all resources, as well as a set of bid evaluation criteria for Commission approval or suspension. The evaluation criteria and ranking process for proposals must also be consistent with the stated goals of the IRP and include consideration of a resource's cost, dispatchability, and effect on system operation. In addition, RFP evaluation should consider risks to both shareholders and ratepayers with, for example, criteria for credit and financial risk, price volatility, climate change regulatory risk, and resource preference under federal or state policy. Finally, ranking criteria must consider unique risks posed by different technologies, fuel sources, financing arrangements, and contract provisions.⁴¹

Bidder response to the RFP provides data for verifying the accuracy of resource cost and availability models and assumptions used in the IRP, such that these models and assumptions can be improved for future planning purposes.⁴² The RFP data inform the utility's decisions going forward, and the Commission may use this information when evaluating utility performance during rate cases.⁴³

³⁸ WUTC General Order No. R-526, Jan. 4, 2006, Docket UE-030311.

³⁹ Liz Baldwin, *Ibid*.

⁴⁰ Phone interview, Rich Stevens, Director of Corporate Risk Management, Avista. Jun. 30, 2006.

⁴¹ WAC 480-107-015, -025, -035

⁴² The results of the RFP are also used to determine the utility's avoided cost, which serves as the price to be paid to qualifying facilities under PURPA.

⁴³ WAC 480-107-015, -025, -035

Risk and risk management policy are also considered during prudence reviews. Utilities bear the full weight of their decisions regarding risk and price-risk tradeoffs, and they must later defend these choices during prudence review. There is no pre-approval.⁴⁴ Utilities have risk management policies, but they are voluntary⁴⁵ and produced within the companies. For example, Avista's risk management policy is written and approved by its portfolio management committee, comprised of upper management at Avista. Avista shares risk management policies with certain regulators subject to the confidentiality agreements. Although regulators provide comments, they have taken a hands-off approach to the development of these policies.⁴⁶

B.4. Oregon

Since 1989, Oregon has required investor-owned gas and electric utilities to file individual integrated resource plans with the Oregon Public Utilities Commission (OPUC) every two years.⁴⁷ The primary goal of Oregon's IRP process is to acquire resources at the least cost to the utility and ratepayers in a manner consistent with the public interest. These resource plans must consider risk and cost-risk tradeoffs. Utilities have employed risk factors such as price volatility, weather, and the costs of current and potential federal regulations, including regulations that address CO₂ emission standards.^{48,49} In recent years, the utilities have considered non-quantifiable issues that impact planning, such as potential changes in market structure, the establishment of renewable portfolio standards, changes in transmission operation and control, and the effect of PacifiCorp's multi-state process on regulation and cost-recovery.⁵⁰

⁴⁴ NWPCC 2003

⁴⁵ Phone interview, Hank McIntosh, WA Utilities and Transportation Commission, Integrated Resource Planning. Jan. 27, 2006.

⁴⁶ Phone interview, Rich Stevens, Director of Corporate Risk Management, Avista. Jun. 30, 2006.

⁴⁷ The original IRP order, No. 89-507, was modified in 1993 in Order No. 93-695, which set out guidelines for utilities to quantify external societal costs. In 93-695, the PUC found that mandating consideration of externalities was outside of its jurisdiction unless these costs are likely to be internalized in the future. Accordingly, the guidelines recommend that utilities incorporate cost adders to account for potential federal-level carbon regulations.

⁴⁸ In its most recent IRP, PacifiCorp looks at four primary risks: load variation, natural gas and electric price variation, hydro variation, and forced outage rates. It also conducts scenario analysis for some "what if?" risks. For example, CO₂ risk was considered in a scenario analysis, which employs simpler models than are used for analysis of the primary risks. (Phone interview, Maury Galbraith, OPUC Energy Division. Feb. 3, 2006)

⁴⁹ Although Oregon is covered by the federally-mandated Northwest Power and Conservation Council (NWPCC) plan, Oregon utilities only consider this analytically sophisticated plan peripherally in the IRPs. Northwest electric power and conservation plans are available at <http://www.nwccouncil.org/library/Default.htm>.

⁵⁰ U.S. EPA. *Clean Energy-Environment Guide to Action: Policies, Best Practices, and Action Steps for States*, April 2006. Available at <http://epa.gov/cleanenergy/stateandlocal/guidetoaction.htm>.

In docket UM 1056, the OPUC is currently considering changes to its IRP requirements and guidelines. The most recent proposal, put forth by Staff in docket UM 1056 includes these requirements and guidelines, in part:⁵¹

- Utilities should evaluate all supply- and demand-side resources on a consistent and comparable basis, using consistent, clearly defined assumptions and methods for evaluation of all resources. Utilities should provide a comparison of resource fuel types, technologies, lead times, in-service dates, durations, and locations in portfolio risk modeling. Demand side resources should be evaluated on par with supply side resources, and any potential savings in distribution system costs from these resources should be identified.
- Uncertainty and risk must be considered in the IRP. At a minimum, utilities should address uncertainty due to load requirements, hydroelectric generation, plant forced outages, natural gas prices and electricity prices. Utilities should identify in the plan any additional sources of uncertainty. The analysis should recognize the historical variability of these factors as well as future scenarios. Discussions on specific risk evaluation metrics are ongoing.⁵²
- The primary goal is the selection of a portfolio of resources with the best combination of expected costs and associated risks and uncertainties for the utility and its ratepayers.⁵³ To this end, utilities should consider all costs with a reasonable likelihood of being included in rates over the long term, which extends beyond the planning horizon and the life of the resource. The plan should include analysis of current and estimated future costs for all long-lived resources (such as power plants) as well as short-lived resources (such as short-term power purchases) for a planning horizon of at least 20 years. Utilities are required to address risk by analyzing resource alternatives using measures of cost-variability and the severity of bad outcomes, and by evaluating portfolios for a range of discount rates. These plans must analyze the effect of potential compliance costs related to global warming on costs and risks for the resource portfolios under consideration, as well as risk mitigation strategies.⁵⁴ The plans should also consider how costs and risks are affected by the use of physical and financial hedges.

⁵¹ Staff's Reply Comments, filed Sept. 30, 2005 in docket UM 1056 (Public Utility Commission of Oregon)

⁵² Currently, the risk techniques employed in IRP are not consistent with those used in ratemaking processes. That could change in the future. Staff and PGE are investigating whether IRP tools could be used to normalize costs for ratemaking purposes. Phone interview, Maury Galbraith, OPUC Energy Division. Feb. 3, 2006 and Jun. 28, 2006.

⁵³ To achieve the best combination of resources, utilities trade off cost and risk, with the understanding that it might be worth it to pay more for a portfolio that displays less volatility. (Phone interview, Maury Galbraith, Jun. 28, 2006. Op. cit.)

⁵⁴ Utilities are including a CO₂ adder as a base-case assumption, in addition to running CO₂ cost scenarios for a range of prices (\$0 to \$40/ton, 1990\$). In its 2006 planning cycle, PacifiCorp is looking at phase-in strategies where the CO₂ adder ramps up over time.

Additionally, the Staff's proposal continues the requirement that the public be allowed adequate involvement in development of the plan.

A parallel docket, UM 1182, is updating competitive bidding guidelines for resources above a certain size, including how bids should be evaluated and how bidding should mesh with IRP processes and criteria. Price-risk tradeoffs are also at issue in yet another open docket, UM 1066, which is reviewing whether the Commission should modify its requirement that all new generating resources go into rates at market price (undefined), rather than in the utility's rate base at cost. The current rules include a waiver process.

Currently, the Commission reviews the filed IRP—including its treatment of risk—and either acknowledges it, in whole or in part, or sends it back to the utility for modification and resubmission. Although the OPUC does consider IRPs in future rate-case proceedings, a formal acknowledgment of an IRP does not ensure favorable rate-making treatment for costs associated with resource acquisition.^{55,56} The significance of acknowledgment for future prudence review has been raised in UM 1056.⁵⁷

Risk is also considered during rate cases on power costs, and adherence to companies' risk policies has made an impact on rate treatment. For example, the OPUC determined that PGE imprudently deviated from its risk policy when it contracted for power before forward markets demonstrated liquidity. The OPUC disallowed the difference between

⁵⁵ Oregon PUC Order No. 89-507 set forth the Commission's role in reviewing and acknowledging a utility's least-cost plan. The Commission reviews the plans submitted by utilities and either acknowledges them, in whole or in part, or returns them for modification, based on its assessment of the plans' adherence to the principles set forth in this and more recent orders. Legally, the Commission is required to reserve judgment on rate-making issues. However, the Commission considers the IRP and ratemaking processes to be linked. In ratemaking proceedings, the Commission gives weight to actions that are consistent with an acknowledged IRP, and utilities are expected to explain actions that are inconsistent with acknowledged plans. (OPUC Staff Report. April 18, 2003. Docket No. LC 33. <http://www.oregon.gov/PUC/meetings/pmemos/2003/050703/reg3.pdf>)

⁵⁶ Acknowledgment of specific risk management practices have been proposed. For example, PGE's Action Plan Supplement in case LC 33 requested acknowledgment of PGE's continued reliance upon ratemaking tools, including internal insurance, reserve funds, and deferred accounting, for managing risks that have a low probability but a high cost to insure externally. Staff opposed acknowledging this practice, because "different risk mitigation tools are appropriate for different resource acquisition strategies," further stating that Staff "cannot assess how PGE should mitigate risk because it will not be requesting acknowledgement of specific resource acquisition actions until it files its Final Action Plan." PGE later withdrew this request. (OPUC Staff Report. Op. cit.; OPUC, Partial Plan Acknowledgment, Order No. 03-461, Aug. 1, 2003)

⁵⁷ In UM 1056, Staff initiated discussion on the significance of acknowledgment for a prudence hearing or rate case regarding an investment or purchase. Both PGE and PacifiCorp (and other parties, including Idaho Power) submitted comments. PacifiCorp maintained that what is known or knowable by the utilities is appropriately considered in the IRP planning cycle and asked the Commission to clarify that it won't revisit what was known or knowable at the time the IRP was acknowledged in later proceedings. (PacifiCorp's Opening Comments. Sept. 9, 2005. Docket UM 1056, p. 21-22) Staff opposes PacifiCorp's proposal. (Staff's Reply Comments, filed Sept. 30, 2005, in OPUC docket UM 1056.)

the actual purchased power costs and what costs would have been, had PGE followed its purchasing guidelines.⁵⁸

Although Oregon does not require utilities to have risk management policies, all investor-owned utilities (Idaho Power Co., PGE, and PacifiCorp) have them. Generally these policies are developed and approved by risk management committees consisting of company staff.

Risk metrics employed vary from utility to utility, although value at risk (VAR) and the variance of portfolios' PVRP is commonly used for resource planning. In its 2004 IRP, PacifiCorp evaluated resource portfolios using the following measures of PVRP variability: stochastic average PVRP (stochastic variable costs plus the deterministic fixed cost), upper tail PVRP (average of five worst results), and standard deviation and variance. As with metrics, risk management software also varies from utility to utility. Portland General Electric has just begun using Aurora for resource planning models. PacifiCorp uses Planning & Risk by Global Energy Decisions and adds on internally-developed, system-specific models for its IRP.⁵⁹

Formal treatment of risk allocation between shareholders and ratepayers generally occurs during rate cases. In these proceedings, a company's recovery of costs hinges on the prudence of its decisions based on information reasonably available to it on, among other things, the risk those decisions pose to consumers.⁶⁰ In theory, rate cases deal with risk to shareholders through the rate of return, but in practice this relationship is not specifically modeled. In recent filings, some intervenors argue that there should be reduction in the rate of return if the companies are granted purchase cost adjustment eligibility or other measures that reduce utility risk.

Most staff members at the Commission who deal with energy risk management are economists, with skills and experience in economic and financial analysis, return on equity, and cost of capital.⁶¹

⁵⁸ OPUC Order 02-772. Oct 30, 2002. Case docket UE-139.

⁵⁹ Our respondent has not used Planning & Risk but notes that the training provided by the software developer was excellent. (Phone interview, Maury Galbraith, June 28, 2006)

⁶⁰ Allocation of risk was also considered in docket UE 165, specifically with respect to PGE's request for a power cost adjustment mechanism (PCAM) to help it deal with the fluctuations in earnings due to hydro availability and power market prices. Under a rejected stipulation, the PCAM would have created an asymmetrical band around System Dispatch Cost Variance, in which consumers would have been charged for these costs in excess of \$15 million, whereas shareholders would return excess earnings greater than \$7.5 million to ratepayers. Among other things, this stipulation would have required PGE to obtain consultation services for analyzing the statistical distribution of net power costs as well as the variability and correlations between hydro generation, electricity prices, natural gas prices, system load, and forced outages. In its order rejecting elements of the stipulation, the Commission cited the stipulating parties' failure to provide analysis on how often the PCAM would likely be triggered and that it would be revenue-neutral. (Order No. 05-1261, Dec. 21, 2005).

⁶¹ Cathie Murray, Regulatory Assistance Project, *Electric Resource Long-range Planning Survey: Oregon*. September 2003. Available at <http://www.raonline.org/>.

Appendix C: Models and Tools for Portfolio Management

C.1. Overview

This appendix discusses several computer models for portfolio management and some practical issues concerning the selection and use of such models. The particular models presented are some of the better known ones, but an exhaustive list is beyond the scope of this report.

In considering available tools for portfolio management in the context of electricity, several factors must be considered:

1. Type of organization, e.g. integrated utility or a load serving entity
2. Time frame for planning, e.g. less than a year, several years, decade or more
3. Scope of consideration, e.g. management of energy and fuel contracts or total cost of delivered services
4. Perspective, e.g. shareholders, customers, or society—or a combination thereof

The tools that are available come from two different perspectives (1) finance/investment and (2) traditional utility planning. The former flow from a highly developed quantitative practice and focus on the management of various financial instruments such as future contracts, laddering, and options. The software tools available in this category offer fairly sophisticated methods for evaluating risk. Contrastingly, those models and tools coming from the utility side tend to focus on fully representing the unique aspects of the electric utility industry, but are generally much less sophisticated in risk analysis.

Regulators should keep in mind what the model was designed to do and what necessary simplifying assumptions are built in to it. Careful review of key input data is always necessary and it is wise to remember that even the best of models fed the best available forecasts can provide only informed estimates of future results.

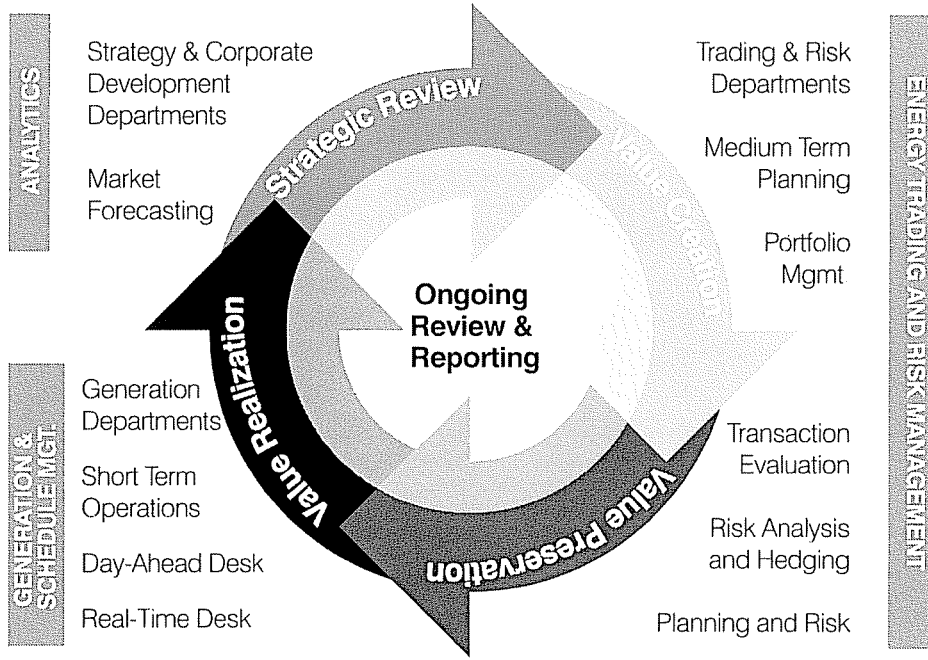
To give some idea of the range of tools for different aspects of electricity portfolio management, we reproduce in Fig. C.1 the product diagram from Global Energy Decisions showing their products and their applicability.¹

New Energy Associates also offers a suite of products that breaks out the process in a slightly different way. (See Table C.2.)²

¹ <http://www.globalenergy.com/solutions.asp>

² <http://www.newenergyassoc.com/products/>

Fig. C.1. Conceptual Approach of a Sample Portfolio Management Software System (Global Energy Decisions)



SOURCE: Global Energy Decisions

Global Decisions graphic, used by permission

Table. C.1. Conceptual Approach of a Sample Portfolio Management Software System (Global Energy Decisions)

Global Energy Decisions Tools by Category		
<u>Analytics</u>	<u>Energy</u>	<u>Operations</u>
Market Analytics	Front Office Solutions	Generation Management
Market Analytics LMP	Middle Office Solutions	ISO Management
Planning & Risk	Back Office Solutions	Load Forecasting
Capacity Expansion		Plant Management
Strategic Planning		Maintenance Scheduling
		Tariff Analysis

Table. C.2. Conceptual Approach of a Sample Portfolio Management Software System (New Energy Associates)

Strategy and Planning	Trading and Market Operations
PowerBase Suite	Monaco
PROMOD IV Strategist MarketPower	MarketManager Retail Office NOSTRADAMUS
IMPACT	
SENDOUT	Generation Management
	Cockpit

C.2. Load and Price Forecasting

Load forecasting has been done since the beginning of the electric utility industry. The approaches used vary by the time scale involved. Short term forecasts of a day or less are based on typical hourly load patterns for the season and weather forecasts. Forecasts of a few years are generally derived from recent historic data and extrapolated with adjustments for weather and simple external drivers such as population growth and planned DSM programs. Common current practice is to incorporate weather variability in computing confidence intervals for peak load levels. The greatest change has occurred with long range forecasts. The old practice was to plot the historic load values on log graph paper and then draw a straight line into the future. More modern practices look at load growth by customer class and apply econometric methods to develop future values. In some cases the load components are broken down by end-use category. That approach is especially useful for designing and evaluating Demand Side Management (DSM) programs. Over the years most entities have developed and refined their own custom tools for load forecasting.

With the move in recent years to wholesale markets, a number of tools have been developed with integrate load and price forecasting. Some of these are quite sophisticated and consider transmission constraints and locational prices.

There is considerable academic and professional literature on this topic. In recent years most efforts have been focused on short-term forecasting using such techniques as neural networks.

Other sources of information

NERC Load Forecasting Working Group: www.nerc.com/~pc/lfwg.html

Electric Power Research Institute: www.epri.com

Spatial Electric Load Forecasting by H. Lee Willis, Marcel Dekker, Inc.

Table. C.3. Load Forecasting Models

Model	Description	Company
TRM	Time Related Modeling System for time series data in a deregulated market.	Economic Sciences Corporation www.econsci.com
LOADCASTER	Comprehensive load analysis, modeling, forecasting, and settlement software system.	
ESM - ENERGY SERVICES MANAGER	Prospect load analysis, cost of service estimation, bid pricing. DSM project valuation and planning.	
EnerPrise Load Forecasting	Short to mid-term load forecasts for scheduling resources, communicating commitments with an ISO, and planning energy purchases/sales.	Global Energy Decisions www.globalenergy.com
NOSTRADAMUS	A neural network-based short-term demand and price forecasting system	New Energy – Siemens www.newenergyassoc.com
MetrixND	Forecasting techniques, such as neural networks, multivariate regression, ARIMA and exponential smoothing.	Itron www.itron.com
AURORA Price Forecasting	Electric market forecasting tool that captures dynamics and economics of energy markets. Short and long-term forecasts.	EPIS www.epis.com

C.3. Integrated System Planning

Integrated system planning is about finding the right mix of supply and demand side resources that provide low cost and reliable electricity service, while also minimizing risks. This is much like the integrated resource planning that was done by utilities before deregulation. The goals are similar but the available components have changed somewhat.

Table. C.4. Integrated System Planning Models

Model	Description	Company
Electric Generation Expansion System (EGEAS)	Least cost capacity expansion analysis.	Electric Power Research Institute www.epri.com
PowerBase Suite	Power supply and transmission planning with market and risk analysis.	New Energy – Siemens www.newenergyassoc.com
EnerPrise Capacity Expansion	Screening and evaluation of generation capacity expansion, transmission upgrades, strategic retirement, and other resource alternatives. It is an economic optimization model that considers resource expansion investments and external market transactions.	Global Energy Decisions www.globalenergy.com
AURORA	Price forecasting, portfolio analysis, capacity expansion, risk and uncertainty analysis.	EPIS www.epis.com
PLEXOS for Power Systems	Operational issues such as scheduling power, optimized unit commitment, transaction and risk evaluation, power station valuation, market analysis, transmission analysis.	Plexos www.plexosolutions.com
Energy 2020	The ENERGY 2020 model is an integrated multi-region energy model that provides complete and detailed all-fuel demand and supply sector simulations.	www.energy2020.org

C.4. Managing Forward Prices & Contracts

An important aspect of portfolio management is organizing and managing market and contract information.

Some of the types of products that could be monitored with software tools include:

Spot purchases involve paying market price on the day that the commodity is needed.

Spot market pricing can be quite volatile, but requires no commitments. Spot market reliance protects against both falling demand and falling prices, but exposes the portfolio to risks from rising demand or prices.

Forward contracts: agreements between buyers and suppliers to trade a specific amount of a commodity at a pre-agreed upon price at a given time or times.³

Payment is on the delivery date. Forward contracts avoid exposure to spot market volatility, but accept the risk that market prices may fall, that the counter-party may default, and that demand may fall.

Option contract: the buyer prepays a (relatively) small *option fee* up front in return for a commitment from the supplier to reserve a certain quantity of the good for the buyer at a pre-negotiated price called the “strike price.” The cost of the option may increase the total price compared to the price (offered at *that time*) of a long-term contract, but one does not need to commit to buying a specific quantity. Typically, the option is *exercised* only when the spot price (on the date of need) exceeds the strike price of the option. This type of option contract is known as a “call” option; a similar option contract that gives the buyer the right to sell a certain quantity of the good to the seller (of the option) at a pre-negotiated price is known as a “put” option.

Flexibility contracts: like a forward contract, but the amount to be delivered and paid for can differ based on a formula, but by no more than a given percentage determined upon signing the contract. Flexibility contracts are equivalent to a combination of a long-term contract plus an option contract. (Simchi-Leve 2002)

Each of these product types offers a different type and degree of pricing and flexibility. The goal of portfolio management may be thought of as finding the optimal trade-off between price and flexibility through an appropriate mix of low price-low flexibility (long-term contracts,) reasonable price but better flexibility (option contracts) or unknown price and supply but no commitment (the spot market.) Varying durations as well as contract types can help create an even mix. The role of software for managing contracts and options is to monitor (perhaps on a daily basis) the cost and riskiness of the inventory of such products and to analyze purchases and sales that might improve the

³ The term or time period of a forward contract can be of whatever length the parties choose. It often begins sometime in the future. For example, power contract can be for one month, one year or for the life of a generator and may start immediately on signature, the next month, or one or more years into the future. Forward contracts for less than one year are often called “short-term” contracts. To be “long” in a futures contract means that one has the obligation to buy at a later date, thus coming out ahead if the asset price goes up. To be “short” in a futures contract means that one has an obligation to sell at a later date, thus coming out ahead if the asset price goes down.

tradeoff. If a portfolio includes short positions or options, frequent analysis is needed to choose the best time to fill short positions or to exercise options (if at all).

Many vendors offer applications for this purpose. Table C.5 lists a few fairly widely used in the energy sector. Note also that this category also overlaps some with the risk management tools in the next section.

Table C.5. Software for Forward Price and Contract Management

Model	Description	Company
BookRunner	Analysis for various transaction types and all energy commodities including oil, natural gas, and electricity.	Risk Advisory www.riskadvisory.com
Edur	Application for trading, risk management and operations needs in various commodity markets.	OpenLink www.olf.com/energy/
Epsilon & Entegrate	Integrated risk management, trading and physical commodities scheduling system.	SunGard www.sungard.com
ICTS Symphony	Comprehensive transaction management system to capture, manage, track and process all over-the-counter and exchange traded instruments.	Trade Capture www.tradecapture.com
GasBuyer	Price analysis and decision support tool used for purchasing and hedging natural gas.	Planalytics Inc. www.planalytics.com

C.5. Risk Analysis

In this category are applications focusing on various aspects of risk. The short-term products look at the more quantifiable risks associated with futures contracts and energy markets. A few of the more utility focused tools try to represent in some way the longer term risks. But that is conceptually a more difficult task since there is much greater uncertainty. For longer-term analysis, a scenario-based approach is most commonly used, but the challenge always is to make those scenarios diverse enough to capture a reasonable range of possibilities.

Table C.6. Software for Risk Management

Model	Description	Company
RISKMIN	Least cost capacity expansion analysis.	Electric Power Research Institute www.epri.com
Planning and Risk	Portfolio management to analyze, report, and actively manage assets, including power plants, customer loads, fuels and contractual positions.	Global Energy Decisions www.globalenergy.com
Monaco	Deal capture, advanced risk analytics, multi-commodity portfolio management, real-time credit monitoring and analysis.	New Energy – Siemens www.newenergyassoc.com
Predict!	Database application for recording and managing risks, opportunities, issues and mitigation strategies	Risk Decisions www.riskdecisions.com
Kiodex Risk Workbench	Commodity risk management software.	Sungard Kiodex www.sungard.com/kiodex
NWPCC Portfolio Model	An Excel based model that calculates energy and costs associated with meeting regional requirements for electricity. The model evaluates the cost and risk relationships for a number of alternatives.	Northwest Power and Conservation Council www.nwccouncil.org

C.6. Selecting software:

C.6.1. Selection issues

When selecting software, it is important first to prioritize the objectives and then to evaluate the available options in that context.⁴

- Objectives: How well the software meets the designated needs of the user.
- Involvement: The ultimate users of the software need to be closely involved in its selection and committed to its use.
- Transparency: Are modeling methods and algorithms well documented and visible to users and regulators?
- Software Characteristics:

⁴ Some of these criteria are from Marchetti, Anne, Beyond Sarbanes-Oxley Compliance: Effective Enterprise Risk Management, John Wiley & Sons, 2005.

- Monitoring capabilities
 - Facilitation and documentation of risk assessment, testing, and remediation
 - Built-in version controls
 - Security and access controls
 - Electronic sign-off functionality
 - Audit trail documentation and traceability
 - Ability to customize input fields, reports, and templates
- Implementation Costs: software, licensing fees, hardware requirements, implementation time, training costs, customization efforts/consulting.
 - Reporting Capabilities: Are the model results available in reports and formats that are easily used and understood?
 - Flexibility: How easily can the software be applied to meet new needs?
 - Support: Does the vendor provide training, fix problems, and update the software as needs change?

C.6.2. Non-Software Cost Considerations

Staffing Costs

When implementing software systems for portfolio management, the biggest cost may very well be labor and training costs for staff using the software. Portfolio management presents a trio of staffing requirements: information technology demands; ability to understand and apply complex economic, statistical, and financial concepts relating to risk management; and understanding any specialized characteristics relating to the electric industry. That last category is quite broad, encompassing, for example, power supply needs, specialized energy products and markets, ISO/RTO requirements, and utility cost recovery or ratemaking. Careful attention to budgeting for staff, staff training (and regular update training), and startup time will be critical.

Hardware Costs

Our experience is that complex models severely task even high end computer hardware. Investments in the fastest computers and largest storage devices available are likely to result in considerable labor savings and faster, more responsive answers to modeling questions. Attention should be paid to backup hardware, as well; large capacity RAID storage devices with hot-swappable drives for off-site backup appear to be the most cost effective solution at this time for high volume data storage. For team use, network attached storage and high speed networking are helpful. The costs for these items are very small compared to the labor and software expenses, but shortchanging them can waste considerable staff time and put critical work at risk.

In summary, regulators considering PM or IRP software acquisition, whether for their own use or by utilities that they oversee, should focus on the prioritized goals and be aware that the largest expense is likely to be for the personnel to properly use the software.

Summary Table

Time Horizon	Input Data and Forecasts	Capacity Expansion Models	Procurement and Scheduling Models (No Capacity Expansion)
1 to 20 years (long-term)	Forecasts of <ul style="list-style-type: none"> • customer load, • price elasticity, • resource availability, • fuel costs, • resource costs, • risk premiums, • fuel price volatility, • reliability requirements and policies, • environmental policies and costs. 	Optimization Models <ul style="list-style-type: none"> • Electric Generation Expansion System (EGEAS) • EnerPrise Capacity Expansion 	<ul style="list-style-type: none"> • PLEXOS for Power Systems
		Screening/scenario/risk analysis models <ul style="list-style-type: none"> • PowerBase Suite • AURORA • RISKMIN 	
1 to 3 years (short-term)	Energy and fuel price forecasts and market futures Load requirements		<ul style="list-style-type: none"> • BookRunner • Edur • Epsilon & Entegrate • ICTS Symphony • Planning and Risk
Monthly to quarterly (short-term)	Short term load forecasts Resource and transmission availability Fuel and energy prices Environmental conditions		<ul style="list-style-type: none"> • Monaco • Predict! • Kiindex Risk Workbench

Appendix D: Risk Measures

Perhaps the most commonly used family of risk measure in portfolio management is Value at Risk and related measures discussed in Section 3 of this report. Others that have been used and which may be of value are summarized in Table 3.1 and explained further here. All depend on development of probability distributions for the cost of the portfolio.

COEFFICIENT OF VARIATION (CV)—This measure is the ratio of the distribution's standard deviation to its mean. It is one way to measure risk relative to return, or in this case, variation in price relative to mean price, measured over a defined period. Tolerance bands can be established around CV.

BETA—Beta is a measure of the systematic risk of a single instrument or an entire portfolio and describes the sensitivity of an instrument or portfolio to broad market movements. A portfolio with a large beta will tend to benefit or suffer from broad market moves more strongly than the market overall, while one with a small beta will swing less violently than the broad market. It is defined as the ratio of the portfolio's covariance with the market divided by the market's variance or $\text{Covariance}(\text{portfolio, market}) / \text{Variance}(\text{market})$. Beta is used to measure volatility of stock returns relative to an index like S&P 500 returns, and one could consider measuring volatility of a resource portfolio's cost relative to volatility of spot market prices. However, it must be remembered that beta does not capture specific risk (the riskiness of the portfolio itself, irrespective of market risk). A portfolio can have a low beta but still be very volatile if its variations are simply not correlated with those of the market.

EXTREME VALUE MEASURES—We use this term as a catch-all for a variety of conceptually straightforward measures of portfolio riskiness. In general, this type of measure is the difference in cost between a portfolio's expected cost and some estimate of its worst-case cost. For example, Northwest Energy and the NPCC measure portfolio riskiness by the difference between its expected cost and average of the worst 10% of its cost's probability distribution.¹

VALUE AT RISK (VaR)—A traditional approach for quantifying risk of investment portfolios.² VaR measures the downside risk of a portfolio. It is always calculated in the context of a risk level and a planning horizon. In the case of an electricity resource portfolio, VaR would be a measure of the dollar cost increase that has a certain probability (the selected risk level) of occurring over a certain time period (the selected planning horizon). For example, a regulator might be interested in the VaR of a proposed resource portfolio over a one year planning horizon at the 99% risk level. That VaR would tell us the amount of extra cost that would have a 1% chance of occurring over the next year. Or, a VaR at the 90% risk level for a ten year planning horizon would tell us the amount of extra cost that portfolio has a 10% chance of incurring over the next ten

¹ NorthWestern Energy 2005 Electric Default Supply Resource Procurement Plan, available at <http://www.montanaenergyforum.com/plan.html>

² Harry M. Markowitz, "Portfolio selection," *Journal of Finance*, 7(1), 77-91, 1952.

years. Utilities in California compare portfolios using this type of metric and variations on it.³

REVENUE AT RISK (RAR)—Related to VaR, RaR considers a firm that needs a resource to produce a product over the next year. If the cost of that resource increases dramatically and the firm cannot pass on that cost increase to its customers, say because the price had already been agreed upon, then the net revenues could take a big hit. Because of the cost uncertainty of that resource, they have Revenue at Risk (RaR). This firm might want to study the historical price volatility of the resource in question. Suppose this examination of history shows that the one-year 10% RaR is equal to the maximum amount of extra resource cost that the manufacturer can afford to pay without severe damage to its finances, it might choose to purchase a (long) forward contract for all its anticipated resource need for the next year at today's futures price, giving up possible extra profit that would be earned if the commodity price drops, but eliminating that 10% chance of grave damage. Alternatively, the firm might purchase a call option for its resource needs with a strike price that leaves it in the black. The purchase price for that option would be the "insurance premium" for eliminating this risk.

COMPONENT VALUE AT RISK — This measures the marginal contribution to value at risk of each element within the overall portfolio. For a utility's purposes, this could mean the risk that each additional coal plant, for example, adds to environmental regulation risks. This approach can be especially valuable as a way to provide insight into the risk analysis analogue of avoided cost analysis.

STRESS EXPOSURES — While value at risk might tell a company how much they could lose under the kind of random market fluctuations that make up the broad history of their industry, stress tests help a company understand the larger risks they may also face. (This type of analysis must take into account volatility and correlation spikes.) In general, there are two approaches used. First, one can test the portfolio relative to shocks that have been observed historically and see how the portfolio being considered might fare under a similar shock. The second approach is to brainstorm extreme scenarios and test their affect on the portfolio. The problem with these approaches is that history is unlikely to repeat itself exactly, and nobody can predict the future. Nonetheless, stress testing allows the portfolio manager to better understand how much loss might occur during a catastrophic event. It could be especially informative if there are certain large events identified that may or may not occur. An example of a stress exposure would be to test the expected cost and riskiness of various strategies with and without implementation of a proposed market reform or with and without implementation of CO₂ emission limits.

LIQUIDATION VALUE AT RISK — One question many companies wish to answer is the total potential loss that could occur if an asset had to be liquidated. For instance, a utility might try to determine what would happen if it were forced to retire an old coal plant.

MARGIN AT RISK — This measure helps companies understand what margin requirements they may need to provide due to margining agreements. This is important for cash flow management.

³ CPUC Energy Division, *Workshop Report on Value at Risk, Cash-Flow at Risk, and Other Measures of Portfolio Risk*. June 6, 2003.

CREDIT VALUE AT RISK — A firm's potential credit exposure on individual transactions is the cost of complying with changes to the amount of credit security the firm must supply to creditors. This can be affected by individual transactions or by external conditions that affect the credit obligations of the firm as determined by its total portfolio. For example, long-term contracts that utilities enter can be viewed as liabilities on their books. A credit value at risk calculation can be done to determine how different transactions might affect the utility's return on equity, for instance.

ENTERPRISE-WIDE RISK MEASURES — This is a measure that appropriately aggregates market, credit, regulatory and operational risk for the firm as a whole. Enterprise risk management seeks a balance amongst the various risk components.

COSTS AT RISK – This measures the probability that a portfolio's costs will go up or down by certain amounts over certain time periods. It is of particular interest from a consumer protection perspective.

RATES AT RISK — This measures the potential change in the retail customer's rates as a result of how external fluctuations affect the cost of generation supply portfolio as a whole. This measure, too, is of particular interest from a consumer protection perspective.