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November 27, 2013

Via Personal Delivery

Mr. Jeff Derouen, Executive Director
Case No. 2013-00259
Kentucky Public Service Commission 211
Sower Blvd.
Frankfort, KY 40601

Re: Case No. 2013-00259 Direct Testimony of Jeffrey Loiter (Public Version)

Dear Mr. Derouen,

Enclosed please find one (1) original and ten (10) copies of the public version of the Direct Testimony of Jeffrey Loiter, filed today in the above-referenced matter via personal delivery. One (1) copy of the confidential version will be filed with the Commission on December 2, 2013 via personal delivery by Joe Childers, local counsel. Page 13 includes information that is subject to a petition for confidential treatment filed by Mark Gross and Michael Kurtz, counsel for East Kentucky Power Cooperative. By copy of this letter, all parties listed on the Certificate of Service have been served via USPS and e-mail. Please place this document of file.

Sincerely,

Kristin A. Henry

Kristin A. Henry
Senior Attorney
Sierra Club
85 Second Street
San Francisco, CA 94105
Phone: (415) 977-5716
kristin.henry@sierraclub.org

COMMONWEALTH OF KENTUCKY
BEFORE THE PUBLIC SERVICE COMMISSION

AN APPLICATION OF EAST KENTUCKY POWER COOPERATIVE, INC. FOR A CERTIFICATE OF PUBLIC CONVENIENCE AND NECESSITY FOR ALTERATION OF CERTAIN EQUIPMENT AT THE COOPER STATION AND APPROVAL OF A COMPLIANCE PLAN AMENDMENT FOR ENVIRONMENTAL SURCHARGE COST RECOVERY	))))))	**CASE NO. 2013-00259**

Direct Testimony of

Jeffrey Loiter

On Behalf of

Sonia McElroy and Sierra Club

Public Version

27 November 2013

(I.) Introduction

Q. Please state your name and business address.

A. My name is Jeffrey Loiter and my business address is Optimal Energy, Incorporated, 10600 Route 116, Hinesburg, Vermont, 05461.

Q. On whose behalf are you testifying?

A. I am testifying on behalf of Sonia McElroy and Sierra Club.

Q. Mr. Loiter, by whom are you employed and in what capacity?

A. I am employed as a Managing Consultant by Optimal Energy, Inc., a consultancy specializing in energy efficiency and utility planning. In this capacity, I direct and perform analyses, author reports and presentations, manage staff, and interact with clients to serve their consulting needs. My clients include non-governmental organizations, state energy offices and efficiency councils, utilities and third-party program administrators. For example, I participate on the consultant team supporting the work of the Massachusetts Energy Efficiency Advisory Council, which guides the development of energy efficiency plans by the state's investor-owned gas and electric utilities and energy providers and monitors the implementation of these plans.

Q. Please summarize your work experience and educational background.

A. I have 15 years of experience in environmental and economic consulting. For the past 7 years, I have been engaged in a variety of work at Optimal Energy related to energy efficiency program design and analysis. For example, I prepared two documents for inclusion in EPA's *National Action Plan for Energy Efficiency (NAPEE)*: a guidebook on conducting efficiency potential studies, and a handbook describing the funding and administration of clean energy funds.[1]

In my capacity as a Managing Consultant at Optimal, I also advise clients on efficiency program design and implementation. I have assisted with the design and development of statewide and utility-specific efficiency programs in Maine, Maryland, New York, Massachusetts, and Tennessee. I currently support program

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[1] These documents can be found at http://www.epa.gov/cleanenergy/documents/suca/potential_guide.pdf and http://epa.gov/cleanenergy/documents/clean_energy_fund_manual.pdf, respectively.

implementation and on-going program design and development for Orange and Rockland Utilities in New York and the Connecticut Municipal Electric Energy Cooperative. I have submitted written testimony to and/or testified before public utility commissions in Arkansas, Virginia, West Virginia, Ohio, Kansas, and Maryland on topics such as demand-side management, integrated resource planning, and efficiency as a resource in state energy plans.

Prior to joining Optimal Energy in 2006, I was a Senior Associate at Industrial Economics, Inc. in Cambridge, Massachusetts. I have a *B.S. with distinction* in Civil and Environmental Engineering from Cornell University and an *M.S.* in Technology and Policy from the Massachusetts Institute of Technology. My resume is provided as Exhibit JML-1.

Q. **Have you previously testified before the Kentucky Public Service Commission ("the Commission" or "PSC")?**

A. No, I have not.

Q: What is the purpose of your testimony in this proceeding?

A: The purpose of my testimony is to comment on Eastern Kentucky Power Cooperative's ("EKPC" or the "Company") application for a certificate of public convenience and necessity ("CPCN") and approval of an environmental surcharge compliance plan amendment and environmental surcharge cost recovery. Specifically, I will comment on EKPC's purported need for capacity, discuss alternative means of acquiring capacity and energy resources through demand-side management ("DSM"), and explain the benefits of DSM as compared to the proposed investment in Cooper unit 1.

Q. What are your main conclusions?

A. I have five main conclusions. First, EKPC has not identified a reliability need for 300 MW of capacity. Second, the cost of the proposed retrofit of Cooper unit 1 does not accurately capture the full cost of maintaining the capacity of the unit. Third, EKPC failed to consider DSM as a resource option. Fourth, EKPC could support far greater levels of DSM rather than retrofitting Cooper unit 1. Fifth, DSM provides substantial economic and non-economic benefits to member-owners and their ratepayers.

Q. Are you submitting exhibits along with your testimony?

A. Yes. I have attached my resume as Exhibit JML-1. I have also attached a 2012 study on energy efficiency potential in Kentucky completed by ACEEE for Oak Ridge National Laboratory and the US Department of Energy as Exhibit JML-2.

(II.) <u>EKPC has not identified a reliability need for 300MW of capacity</u>.

Q: What evidence does EKPC present regarding the need to maintain the capacity from Cooper unit 1?

A: Pages 1 and 2 of the Application state that the Company's 2012 IRP identified a need for 300 MW of additional capacity if Cooper unit 1 and Dale Station units 1 through 4 were retired or idled.

Q: Did you review the IRP with respect to this claimed need, and if so, what are your findings?

A: Yes, I did review the IRP and associated discovery responses from PSC Case No. 2012-00149. This review leads me to conclude that EKPC does not in fact require the capacity from Cooper unit 1.

Q: What evidence do you have that EKPC does not require the capacity from Cooper unit 1?

A: Julia Tucker, Director of Power Supply Planning at EKPC, states on page 4 of her direct testimony that "[i]t is possible that the 300 MW could be retired without any replacement capacity, those impacts will be reflected in EKPC's cost to serve its load. The replacement capacity issue became strictly an economic issue when EKPC joined PJM, and no longer had reliability impacts."

Q: How do you interpret Ms. Tucker's phrase "strictly an economic issue?"

A: First, that the project contained in the CPCN is not needed to ensure that EKPC can safely and reliably meet its customers' capacity or energy needs, but rather is an attempt to pursue the least cost means of retaining a portion of the Company's generating capacity in isolation, regardless of other potential impacts on its generation mix (such as increasing their reliance on coal-fired generation), risk to ratepayers, or overall risk-adjusted least cost planning. Second, that in viewing the proposed project strictly through the lens of the relative cost of supply-side projects that provide a similar level of capacity, EKPC may not have included important factors that the Commission may wish to consider, such as benefits not directly related to EKPC's assessment of the Net Present Value of the project.

Q: Does EKPC have a reliability need for energy?

A: No, it does not appear to. Data in the IRP shows that EKPC will have excess supply (composed of generation and purchase) beginning in 2014 (Table 8.(4)(b)1-4, p. 168). Even if Cooper unit 1 and Dale Station 1-4 were retired in 2015, EKPC would have surplus supply beginning in 2016 and extending through at least 2026. Thus, there is no need to retrofit Cooper unit 1 to provide capacity or energy for reliability purposes.

(III.) <u>The cost of the proposed retrofit does not accurately capture the full cost of maintaining the capacity of the unit</u>.

Q: What is EKPC's estimate of the cost of retaining the 116 MW of Cooper unit 1 capacity?

A: EKPC estimates capital costs of $15 million and annual variable operating and maintenance ("O&M") costs of $2.6 million. It is important to realize that these costs, including the annual O&M costs, are NOT the full cost to generate electricity from Cooper unit 1. These are just the capital and ongoing costs for the environmental compliance project that is the subject of the CPCN application.

Q: Why is it important to consider overall operating costs rather than only the cost of operating the proposed environmental controls?

A: Because, as Ms. Tucker has stated, EKPC is now part of PJM. As such, EKPC must "either supply or purchase in the capacity market" sufficient capacity. (Tucker, p. 4). System operators like PJM typically have requirements that specify how and when resources must be available in order for their capacity to be "counted" towards a load-serving entity's obligations. It is not sufficient for the capacity to exist, it must actually deliver that capacity at the required times.

Therefore, the true cost of maintaining Cooper unit 1's capacity also includes the cost of running the unit in such a manner as to meet PJM's requirements.

Furthermore, according to an exhibit submitted by Mr. Block Andrews, when Cooper unit 2 is not in service, Cooper unit 1 will have to increase its minimum load in order to produce enough exhaust flow to operate the dry scrubber. Exhibit BA-1 at 13. In particular, Cooper unit 1 will have a minimum load of 100 MW when Cooper unit 2 is not running. *Id.* Therefore, any consideration of the costs of maintaining the capacity provided by Cooper unit 1 should include a consideration of the costs of operating the plant in a manner that meets the above-mentioned requirements.

Q: Did you develop an estimate of these additional operating costs for Cooper unit 1?

A: No, I did not. The testimony of Mr. Tyler Comings addresses the costs and expected benefits of the proposed project.

(IV.) <u>EKPC failed to consider reasonable levels of DSM as a resource option</u>.

Q: Did you review EKPC's proposed level of Demand Side Management (DSM) resources?

A: Yes, I reviewed the assumptions and information on DSM contained in the IRP, the Application and Testimony, and associated discovery.

Q: What were your findings?

A: My findings are that 1) EKPC did not consider DSM as a resource to cover part or all of the purported 300 MW capacity for which they propose the Cooper unit 1 project; and 2) the Company presents inconsistent information and data concerning the future levels of DSM in EKPC's plans. Both of these findings raise concerns regarding the way the Company views and utilizes the DSM resource in meeting customers' demand and energy needs, particularly in light of the pending application in this case to invest a substantial amount of ratepayer dollars in a resource with uncertain future costs and risks. I will explain each finding in turn.

Q: Please explain your findings regarding EKPC's failure to consider DSM as a resource to cover part or all of the purported capacity need.

A: This finding comes from the Company's testimony in this case and the RFP it issued for capacity. First, on page four of his direct testimony, Mr. Read states that EKPC was willing to consider proposals "to purchase new or existing power plants, to enter into intermediate- or long-term power supply contracts, and to purchase power from renewable or conventional resources." DSM does not fall into any of these categories. Second, the RFP explicitly states that "EKPC is not soliciting and will not accept capacity from PJM Demand Response resources." Exhibit JJT-1 at 3.

Q: Did EKPC provide any explanation for accepting supply-side resource bids but excluding bids for DSM?

A: Only to a minor extent. When asked to explain why the RFP was limited to supply-side resources, Ms. Tucker responded simply that EKPC "was evaluating the loss of large, central station supply." (SC 1-58b). Attempts to clarify this response in subsequent discovery and to address whether or not demand response ("DR") and energy efficiency ("EE") beyond what is currently planned in EKPC's territory could reduce the need for capacity and energy currently provided by Cooper unit 1 yielded similarly vague responses, with EKPC stating that they will "seek cost-effective and beneficial" demand response and energy efficiency, as "driven by PJM market prices." (SC 2-40b and c).

Q: How do you interpret these responses?

A: The response to Sierra Club's first request demonstrates the Company's bias against DSM and preference for central station generation, preferably its own. The second responses fail to bring any clarity to the Company's decision process, because the RFP process conducted to identify a replacement for the Cooper unit 1 capacity did not in fact "seek cost-effective and beneficial" demand response and energy efficiency.

Q: Should the Company have solicited and accepted bids for DSM in response to the RFP?

A: Yes. The RFP was issued in response to the Company's determination in their IRP that they were in need of 300 MW of capacity. The IRP process did not identify the least-cost or preferred option for meeting that purported need. For example, the IRP analysis did not indicate that a combustion turbine or power-purchase agreement was the best strategy for meeting the Company's claimed needs. In fact, the IRP includes analysis of DSM as part of the Company's resource mix. Therefore, the RFP for the needed capacity should not have been prejudiced against DSM.

Q: Is DSM eligible to participate in PJM's capacity market ?

A: Yes. DSM in the form of both DR and EE has been and continue to be part of the resource mix in PJM. For example, over 14,800 MW of demand response and over 920 MW of energy efficiency are included in the resources procured by PJM to meet 2015/2016 capacity needs, representing almost 10% of total cleared capacity.

Q: Is EKPC aware that EE and DR can participate in meeting their capacity requirements and be supplied to PJM?

A: Yes. In its reply to Sierra Club's comments on the 2012 IRP, EKPC stated that it intends to offer its DR programs into the PJM capacity market and that it is considering the possibility of doing the same for EE. Reply at 7; Staff Report at 28.

Q: Did the Company present inconsistent information and data on future levels of DSM resources in its 2012 IRP?

A: Yes. The Company's 2012 IRP present two different levels of DSM savings. For example, page 15 of the IRP presents DSM impacts growing by nearly 384,000 MWh and over 130 MW (winter) from 2013 through 2017, more than the capacity of Cooper unit 1. These resources were determined to be cost-effective. Despite this, the IRP also notes that "an aggressive and reasonable DSM goal" would be only 50 MW over that same period (IPR, p. 4). In response to a discovery question, the Company stated that the "forecasted practical impact savings" during this period is slightly more than 109,000 MWh, less than one-third of what is presented in the IRP as cost-effective, a significant difference (EKPC Response to Intervenors' Data Request 57).

Q: **Do you agree that the DSM goal of 50 MW over the five-year period is "aggressive but reasonable?"**

A: No. The 50 MW represents just 1.6% of EKPC's projected winter peak and 2.0% of summer peak projected for 2017 (based on the data presented in Table 8.4.a on page 165 of the IRP). The energy savings represent less than 0.8% of the forecast energy requirements in 2017 (Table 8.(4)(b)1-4, p. 168 of IRP), or about 0.15% per year. For a five-year portfolio of efficiency programs in a territory where DSM programs have been offered "for more than 30 years," (IRP, p. 73), this is far from aggressive and is unreasonable.

Q: **Are you aware that Commission Staff have previously opined that the approach EKPC has taken with its DSM analysis is "aggressive and flexible?"**

A: Yes, I have reviewed the Staff's report on the IRP proceeding dated September 2013. While the Staff disagreed with some of the Sierra's Clubs contentions in that case, it also recommended that "EKPC should endeavor to work with its Collaborative and steering committee in ramping up the deployment of the DSM portfolio so that the theoretical modeling contained in the IRP that can be implemented on a cost-effective basis can achieved [sic] to the greatest extent possible." Staff report, p. 31. I agree that EKPC should work to implement cost-effective DSM to the greatest extent possible and, with all due respect to Staff's previous findings, believe the planned level of DSM savings falls far short of this.

Q: **What is the basis for this finding?**

A: The main argument made by EKPC as to why the modeled level of DSM is not feasible is that they were modeled as "mature programs," and therefore do not represent a feasible level of achievement in the near term (Response to SC 1-57, referring to Response to Staff 1-1 in 2012-00149). This reasoning was echoed by the Staff (Staff report, p. 30). Yet EKPC claims to have been engaged in DSM for three decades and notes a broad range of existing programs. While the DSM modeling in the IRP contemplates a large number of new "programs," I note that in many jurisdictions, these would not be considered individual programs, but components of larger, more comprehensive strategies to serve customers' efficiency needs. That is, rather than represent entirely new approaches, these "new" programs should represent expansions of current efforts. As a result, there need not be a substantial amount of time required for them to begin delivering substantial savings. Even beyond the issue of "maturity" of programs, I disagree with many of the statements made by EKPC regarding the ability of DSM programs to achieve higher levels of savings (Response to Comments of Intervenor Sierra Club on the 2012 Integrated Resource Plan, dated 11 February 2013).

Q: With which statements do you disagree?

A: First, EKPC notes "willingness or ability of retail customers to participate" (Id. p. 1) as a limiting factor in DSM achievement. This statement indicates a potential flaw in EKPC's assessment of DSM potential. As long as the Company assumes it has no ability to influence how its customers view efficiency investments, its achievement will fall short of potential. EKPC and its member-owners must consider efficiency a product that they market to their customers, not an option that they make available and hope the customers will purchase. One of the primary objectives of efficiency programs is to inform customers of the benefits of investment in efficiency, and thereby increase their willingness to participate rather than accept the current status as a given. That is how other businesses sell their products; efficiency is no different.

EKPC also notes that its customers' income levels make it unrealistic for them to invest in efficiency. At the same time, EKPC acknowledges that these customers also have higher energy consumption and higher bills, and therefore spend a greater percentage of their income on energy, than the US average and several other states with higher electric rates than Kentucky. (Response to Intervenor Request 56). Taken together, this indicates a GREATER opportunity for efficiency in EKPC's territory, not less. The objective of efficiency investment is to lower customer bills; the Company has clearly indicated that this is needed in Kentucky. And in relation to my previous point, if Kentucky customers were provided with information concerning the benefits of efficiency and how it can reduce the disproportionately high share of their income that goes towards paying electric BILLS, their willingness to invest in efficiency would likely increase.

Next, noting a high proportion of low-income customers, EKPC states that to achieve efficiency savings with these customers "the only effective solution is to increase the customer incentive or provide another subsidy such that the low income ratepayer has zero cost of participating." (Response to Comments of Intervenor Sierra Club, p. 4). EKPC goes on to state that this "requires funding at levels that make the programs no longer cost-effective." This ignores decades of experience from many other jurisdictions that provide a variety of program approaches to service low and moderate income customers, including the availability of cash-flow positive financing, leveraging other sources of funding such as Low Income Home Energy Assistance Program (LIHEAP) and weatherization programs, working through the supply chain to lower cost differences between standard and efficiency products (and achieve savings at lower cost to the utility, as well), and others. These strategies make it possible to deliver efficiency programs that involve small but meaningful contributions from the customer themselves, which can increase the trust and confidence customers have in the programs and the savings they are likely to receive. I also note that the Company confuses the issue of the cost-effectiveness of programs for low income customers. While increasing incentive payments does reduce a program's cost-effectiveness from the utility's perspective, it has NO effect on the Total Resource Costs or overall TRC benefit/cost ratio. Incentive payments are a transfer payment from the TRC perspective, so a program that covers 100% of measure cost is no different from one that covers 25% of measure cost from the TRC perspective, all else equal.

EKPC also implies that because a high percentage of their customers rely on electric heating and have no other fuel choices, the savings they can achieve are less than in areas where lighting represents a higher proportion of residential energy use. Once again, this is an opportunity for potentially GREATER savings, as measures to reduce heat loss in buildings will be MORE cost-effective than in areas where fossil-fuel is the baseline heating technology. Rather than simply focus on air sealing measures, for example, the higher bills of electric heat customers may support more aggressive support of insulation upgrades and other investments such as switching from electric resistance heating to high-performance heat pumps.

(V.) <u>EKPC could support far greater levels of energy efficiency and demand response instead of retrofitting Cooper unit 1</u>.

Q: Taking the factors and evidence you have presented, what do you conclude about the level of DSM savings presented by the Company as "aggressive and reasonable?"

A: I believe that far greater levels of efficiency are reasonable. Based on data from the recently published ACEEE State Energy Efficiency Scorecard, the Company's planned savings, on the order of 0.15% per year, are less than half of recent accomplishments in neighboring Tennessee (0.33%) and nearby North Carolina (0.39%), one-quarter of neighboring Indiana (0.58%), and only one-eighth of neighboring Ohio (1.22%).[2] Even the levels of DSM included as "theoretical" in the IRP modeling are far from aggressive. On an annual basis, the modeled savings for the period (i.e., 384,000 MWh) represent just 0.5% savings per year. This closely matches the level found by an EPRI study that the Company used as "an overall reasonableness sanity check." Request 18, Supplemental Request for Information, 2012-00149. Second, it is only half of the cost-effective potential identified by a study completed in 2012, using data specific to Kentucky (Exhibit JML-2).

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[2] http://aceee.org/files/pdf/state-sheet/2013-spending-and-savings-tables.pdf.

As another example, I note that utilities in Michigan have been able to quickly ramp up their savings from 0.3% in 2009 to over 0.75% in 2011.[3] There is no reason why EKPC's programs should be limited to 0.15% each year for five years.

Q: **If EKPC's arguments for not pursuing more DSM are flawed and greater levels of DSM are achievable, what is the impact on this proceeding?**

A: The impact is that there is substantially more DSM resource available to EKPC than they plan to acquire and that the ratepayer dollars that would be spent on the proposed project and on continuing to operate Cooper unit 1 could be used instead to support additional DSM, particularly energy efficiency. This would provide tangible economic benefits for their member-owners and their ratepayers.

Q: **Have you estimated the amount of DSM that could be acquired using the funds requested for the Cooper unit 1 project in this proceeding?**

A: Yes. I developed an estimate of the potential EE and DR that could be acquired using both the $15 million capital cost of the Cooper unit 1 project and the on-going annual maintenance costs of $2.6 million. In addition, I considered the other O&M costs required to generate electricity from Cooper unit 1, which I estimate at between [redacted] as a lower bound using the Company's projected fuel costs and capacity factor.

Q: **What did you assume about how these amounts could be spent on energy efficiency and demand response?**

A: Because efficiency is nearly always cheaper than traditional supply, I assumed that the annual operating costs of Cooper unit 1, both the stated O&M cost of the environmental controls plus my estimated fuel-based operating costs, would fund energy efficiency. The capital cost, amortized over the next 15 years, would be allocated to demand response.

Q: **How much energy could EKPC help its customers save by investing in efficiency instead of the Cooper unit 1 retrofit?**

A: Using the O&M spending for the environmental controls and fuel-based operating costs, more aggressive efficiency programs could acquire over 244,000 MWh of

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[3] http://www.michigan.gov/documents/mpsc/2012_EO_Report_404891_7.pdf

cumulative annual savings by 2017, more than double the amount proposed by EKPC as "aggressive." I developed this estimate on an average cost per annual MWh for a selection of EKPC's "new" efficiency programs as described in the IRP. This would represent 1.7% of EKPC's forecast load in that year, or incremental annual achievement of slightly more than 0.4%, a level that is certainly reasonable. Note that I assumed spending beginning in 2014, and therefore only four years of program activity as compared to the five years contemplated in EKPC's stated goal. Looking farther into the future, EKPC could achieve savings of over 533,000 MWh by 2021.

Q: The need for Cooper unit 1 has been framed in terms of needed capacity. How much peak demand reduction could be accomplished?

A: Achieving the above-stated energy savings from efficiency programs would also generate peak demand savings. Using the relative peak savings from the existing programs presented in the IRP (Table DSM-1, Appendix Vol. 2, p. 10), summer peak reduction of 36 MW would result by 2017 and 78 MW by 2021. Again, these are just the impacts from efficiency programs with budgets equal to an estimate of the annual O&M costs of operating Cooper unit 1. These impacts would be in addition to the 50 MW of summer peak reduction currently planned by the Company.

Q: What other options exist for peak demand reductions besides energy efficiency?

A: Demand response programs are designed to reduce on-peak energy consumption, which reduces the peak load that a utility must serve and lowers consumption of higher-priced energy during peak times. EKPC's IRP included several demand response programs covering all sectors. If the $15 million capital cost of the Cooper unit 1 project was amortized over 15 years at 7.5%, the resulting $1.7 million per year cost could produce a sustained additional 22 MW of summer peak demand reduction, again based on an average per-kW cost of the a selection of the Company's demand response programs. In 2017, therefore, total peak demand reduction would equal 58 MW (summer) in addition to the Company's planned 50 MW.

(VI.) DSM provides substantial economic and non-economic benefits to member-owners and their ratepayers.

Q: Why should EKPC look to invest in DSM for its resource needs?

A: First and foremost, DSM is typically the least-cost resource available to a utility. EKPC's own program assumptions demonstrate this. While the IRP does not present DSM cost estimates directly, selecting a few example programs from both the existing and new programs groups indicates a levelized cost of savings of about $24/MWh. This is in keeping with other estimates of efficiency, including those from the Kentucky study, in which levelized costs ranged from $17 to $40/MWh, depending on the sector (Exhibit JML-2).

Q: Are there benefits to DSM beyond cost savings as compared to supply-side resources?

A: Yes, there are several. First, DSM helps mitigate forecasted load and fuel price risk. Investing in the proposed project (or any other large, central generating station) is an all-or-nothing proposition. Once a project is built (or even before completion) the Company's ratepayers are committed to paying for its entire cost and, eventually, operation. This is true whether or not the project ends up being needed to serve customer load and regardless of the price of fuel or any future environmental control or compliance costs that may come into effect in the future.

In contrast, DSM resources can be developed and deployed incrementally to match actual conditions. This trades a larger risk (i.e., a risk of a large revenue requirement over a long period of time for an unnecessary or uneconomic capital investment) for a smaller one (i.e., the potential need to acquire potentially more expensive resources through market purchases or other shorter lead-time supply-resources for a short period of time until additional resources can be developed). The Company itself acknowledges the risk-reduction value of reducing the size of investments. In response to PSC Request 14 (1st set), it states that "by splitting the 300 MW into multiple projects,...the risk of incurring a 'fatal flaw' has less impact from a total capacity basis." If this is true of splitting the 300 MW into a 116 MW piece and a 174 MW piece, it would certainly be true of splitting the 300

MW into tranches of DSM or renewables, distributed generation, or non-coal resources.

Second, DSM promotes local jobs and spending. Investments in energy efficiency create jobs directly through the implementation of efficiency upgrades to buildings and equipment and indirectly through subsequent spending of both job income and bill savings from reduced energy consumption.

Third, the ability to target DSM to areas of transmission and distribution needs can reduce the cost of reliability upgrades where growth or equipment age has created a need for capital investment. By slowing load growth or even eliminating it in targeted areas, DSM generates additional benefits that may not be reflected in current avoided cost estimates based on current energy market prices.

Fourth, DSM savings lower the market clearing price of energy and capacity, thus benefitting ALL customers, not just program participants. This is referred to as Demand Reduction Induced Price Effects ("DRIPE"). In New England, where efficiency has made substantial reductions in load growth, this effect has been quantified and is now included in cost-effectiveness tests as an additional benefit of load reduction from DSM.[4]Even if the effect is smaller in Kentucky and PJM overall, it represents another benefit of efficiency over traditional supply-side options and one that has not been valued in the Company's analysis.

Fifth, increasing DSM program participation means fewer non-participants and more equity. Distributional equity is an important issue with regards to efficiency programs. Greater levels of investment in efficiency programs make it more feasible for all customers to participate at some level in efficiency programs that all customers are paying for.

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[4] For information on how DRIPE is estimated in New England, refer to http://www.synapse-energy.com/Downloads/SynapseReport.2013-07.AESC.AESC-2013.13-029-Report.pdf.

Q: **Please summarize your conclusions.**

A: I conclude that EKPC has not identified a reliability need for 300 MW of capacity, nor has it demonstrated a need for additional energy resources. In describing the costs necessary to maintain Cooper unit 1 as a capacity resource, the Company has not accurately captured the full cost of maintaining this capacity. Furthermore, EKPC failed to consider DSM as a resource option for the purported capacity need. Where it did consider DSM in its previous resource planning, it dramatically underestimated the potential size of the DSM resource. Using the ratepayer funds requested for the proposed Cooper unit 1 project to instead invest in DSM would provide economic and non-economic benefits for the Company as well as its member-owners and ratepayers.

CERTIFICATE OF SERVICE

I certify that I had filed with the Commission and served via U.S. Mail and electronic mail the foregoing Direct Testimony of Jeffrey Loiter (Public Version) to East Kentucky Power Cooperative on November 27, 2013 to the following:

Mark David Goss
Goss Samford, PLLC
2365 Harrodsburg Road, Suite B325
Lexington, KY 40504

Patrick Woods
East Kentucky Power Cooperative, Inc.
4775 Lexington Road
P. O. Box 707
Winchester, KY 40392-0707

Michael L. Kurtz
Kurt J. Boehm
Boehm, Kurtz & Lowry
36 East Seventh Street, Suite 1510
Cincinnati, OH 45202

Anthony Raduazo

JEFFREY M. LOITER

MANAGING CONSULTANT

Mr. Loiter has over 14 years of consulting experience in energy and natural resource issues. His energy experience includes policy, planning and program design, research on renewable and efficiency technologies, electricity transmission systems, integrated resource planning and savings verification. As a Managing Consultant, Mr. Loiter manages projects, oversees staff development, and contributes to firm management in the areas of hiring and business development.

PROFESSIONAL EXPERIENCE

Optimal Energy, Inc. Hinesburg, VT

Managing Consultant, 2006-present

- Leads Optimal's energy efficiency consulting services to the Connecticut Municipal Electric Energy Cooperative (CMEEC). These services include program planning, program savings analysis and reporting, developing incentive and delivery strategies, and managing CMEEC's participation in the ISO-NE Forward Capacity Market. The latter has included drafting M&V plans specifying procedures for meeting all ISO-specified M&V rules, including data management calculation of demand reduction values for monthly submission. Mr. Loiter also manages CMEEC's participation in new FCM auctions and arranges for annual certification reviews.

- Submitted expert testimony on behalf of environmental interveners or state agencies in cases related to utility Integrated Resource Plan and Demand Side Management Plan filings. Cases typically involve filing review, developing alternative analyses, drafting pre-filed testimony, and appearing before public service commissions for cross-examination. Cases have included utility filings in Virginia, Ohio, Arkansas, Pennsylvania, Maryland, and Missouri.

- Supporting program implementation and on-going program design and development for Orange and Rockland Utilities. Previously managed the preparation of a DSM plan and Commission filings for this client. The project included on-site customer audits and residential surveys, efficiency program designs, and an efficiency potential study.

- Led Optimal's participation in preparing a Technical Resource Manual for the Mid-Atlantic States (Maryland, Delaware, District of Columbia), for the Northeast Energy Efficiency Partnerships' Regional EM&V Forum.

- Managed Optimal's participation in a team developing a Five-Year Energy Efficiency and Demand Response Plan for the Tennessee Valley Authority. Optimal's role focused on programs for the commercial sector in TVA's service territory, encompassing efforts to reach a variety of markets and end-uses, including specific offerings for both very large and small commercial entities.

- Supporting Efficiency Vermont with technical analysis, market research, and program design consultation. Recent projects include market characterization studies of refrigeration, lodging establishments, and food service entities; and developing several Technical Resource Manual entries.

- Prepared two documents for inclusion with EPA's National Action Plan for Energy Efficiency: a guidebook on conducting efficiency potential studies and a handbook describing the funding and administration of clean energy funds.

- Led or contributed to several studies of efficiency potential, ranging from meta-analyses to detailed sector-specific assessments. Assessments have included both the residential sector and the commercial/industrial sectors, in locations including New York, Vermont, New England, Texas, and a Canadian Atlantic province.

Independent Consultant **Cambridge, MA**

2005-2006

- For the Massachusetts Renewable Energy Trust SEED Initiative, evaluated renewable energy technology companies' applications for early-stage funding. Responsibilities included leading due diligence efforts on three applications and contributing to several others. Awards recommended for approval totaled $1.4 million.

- Led an effort to draft a whitepaper on policies to encourage investment in electricity transmission facilities.

- Prepared two articles describing the potential impact of proposed federal legislation to increase domestic oil refining capacity, published in Petroleum Technology Quarterly (1Q 2006) and BCC Research/Energy Magazine (2006).

Industrial Economics, Incorporated **Cambridge, MA**

Associate, 1997-2000; Senior Associate, 2001-2004

Managed multi-disciplinary qualitative and quantitative assessments of natural resource damages and environmental policy for clients such as NOAA, USFWS, USEPA, USDOJ, the National Park Service, the State of Indiana, and the United Nations.

URS Consultants, Incorporated **New Orleans & Boston**

1991-1995

Prepared water, air, and solid and hazardous waste permit applications for state and federal agencies on behalf of industry clients.

EDUCATION

M.S., Technology & Policy, Massachusetts Institute of Technology, Cambridge, MA, 1997

B.S. with distinction, Civil and Environmental Engineering, Cornell University, Ithaca, NY, 1991

PUBLICATIONS & PRESENTATIONS

"Collaboration that Counts: The Role of State Energy Efficiency Stakeholder Councils," (with D. Sosland, M. Guerard, and J. Schlegel), *2012 ACEEE Summer Study on Energy Efficiency in Buildings,* Pacific Grove, CA, August 2012.

"Persistence and Cost of Behavioral Programs," presented at National Association of State Utility Consumer Advocates Mid-Year Meeting, Charleston, SC, June 2012.

"Impending EISA Lighting Standards: Impacts on Consumers and Energy Efficiency Lighting Programs," presented at National Association of Regulatory Utility Commissioners Annual Meeting (with M. DiMascio), Atlanta, GA, November 2010.

"From Resource Acquisition to Relationships: How Energy Efficiency Initiatives Can Work Effectively with Large Commercial & Industrial Customers," (with E. Belliveau, J. Kleinman, D. Gaherty, and G. Eaton), *2008 ACEEE Summer Study on Energy Efficiency in Buildings,* Pacific Grove, CA, August 2008.

National Action Plan for Energy Efficiency (2007). *Guide for Conducting Energy Efficiency Potential Studies.* Prepared by Philip Mosenthal and Jeff Loiter, Optimal Energy, Inc. December.

Loiter J.M and V. Norberg-Bohm (1999), "Technology policy and renewable energy: public roles in the development of new technologies," *Energy Policy* Vol.27 no.85-97

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Technical Assistance Program
Energy Efficiency Cost-Effective Resource Assessment for Kentucky
March 8, 2012

OAK RIDGE NATIONAL LABORATORY
Managed by UT-Battelle for the Department of Energy

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Contact Information:

Max Neubauer, American Council for an Energy-Efficient Economy
Primary Author
mailto:mneubauer@aceee.org
(202) 507.4005

R. Neal Elliott, American Council for an Energy-Efficient Economy
Secondary Author
rnelliott@aceee.org
(202) 507.4009

ACEEE

EXECUTIVE SUMMARY

As the Commonwealth of Kentucky moves forward to fully integrate energy efficiency into its future resource planning, it is critical to first quantify the volume of potential energy and economic savings available from energy efficiency. Conducting this assessment allows policymakers and stakeholders to understand the degree to which demand-side resources can meet increasing consumption and load requirements. Energy efficiency can also help reduce the strain on the Commonwealth's current system and delay, or even negate, the need for future investments in supply-side resources, such as generation facilities and transmission infrastructure. Quantifying the potential energy savings available also highlights the role energy efficiency plays in lowering customers' utility bills, creating jobs, and stimulating economic activity for Kentucky's businesses. Ultimately, the goal of this process is to provide tangible evidence to stakeholders that energy efficiency is the least-cost energy resource available to spur economic development and guarantee environmental health.

This assessment is the first of three (3) documents that comprise ACEEE's energy efficiency potential study for the Commonwealth. This report presents the results from our analysis of the cost-effective energy efficiency resources available in residential, commercial, and industrial buildings and facilities in Kentucky. We examine the potential energy savings and costs generated by specific efficient technology measures, such as high-efficiency windows, water heaters, and central air conditioning units.

Results

Table ES-1 presents a summary of the cost-effective energy efficiency potential by sector in 2030. In total, we estimate that over 21,000 gigawatt-hours (GWh) and 52,200 billion British thermal units (BBtu), or 19% of projected electricity and 24.5% of natural gas consumption in 2030, can be saved through the implementation of cost-effective energy efficiency resources. Readers should note that this assessment includes mostly existing technologies and practices, though we anticipate that new and emerging technologies and market learning will increase the availability of cost-effective energy resources by 2030. Table ES-2 presents the energy bill savings that would result if all of the available cost-effective energy efficiency potential were captured, which amounts to over $2.1 billion by 2030.

Table ES-1. Summary of Cost-Effective Energy Efficiency Potential by Sector, by 2030

Sector	Electricity			Natural Gas		
	GWh	%*	% of Sector**	BBtu	%*	% of Sector**
Residential	7,787	7.1%	21%	12,356	5.8%	30%
Commercial	6,900	6.2%	28%	16,263	7.6%	45%
Industrial	6,411	5.8%	13%	23,629	11.1%	17%
Total	**21,098**	**19.1%**		**52,248**	**24.5%**	

*Savings are represented as a percent of the total projected energy consumption in 2030.
**Savings are represented as a percent of the projected energy consumption in that sector in 2030. Projected residential energy consumption includes sales to multifamily homes. We did not have the capacity in our modeling to include multifamily energy efficiency measures, which would increase the overall savings in this sector and in total.

Table ES-2. Energy Bill Savings by Sector, by 2030

Sector	Electricity			Natural Gas		
	GWh	$/kWh*	Million$	BBtu	$/MMBtu*	Million$
Residential	7,787	$0.086	$669.7	12,356	$12.53	$154.8
Commercial	6,900	$0.078	$538.2	16,263	$11.38	$185.1
Industrial	6,411	$0.061	$391.1	23,629	$9.71	$229.4
Total	**21,098**		**$1,599.0**	**52,248**		**$569.3**

*Retail energy prices from DEDI 2011

Next Steps

The next phase of the project will be to vet a list of energy efficiency policies and programs with stakeholders that can be implemented by the Commonwealth and Kentucky utilities in order to capture the available resources identified through this assessment. It is important to understand that many market barriers exist that prevent all of the cost-effective resource potential savings from being captured by energy efficiency policies and programs. Policymakers and utilities must design policies and programs carefully to overcome those barriers, ensuring that they are properly marketed and that Kentuckians are well-educated in the potential benefits of energy efficiency.

Once stakeholders agree on a set of policies and programs to be evaluated, ACEEE will conduct its maximum achievable potential analysis, also known as the policy and program analysis, which will estimate the level of potential that can be realistically achieved through this set of policies and programs. The results from this analysis will provide a roadmap that the Commonwealth can follow to ramp-up energy savings from efficiency. The results from the policy analysis will then feed into ACEEE's macroeconomic model to estimate the overall economic benefits, including energy bill savings and jobs, that can be achieved through investments in energy efficiency.

Introduction

As the Commonwealth of Kentucky moves forward to fully integrate energy efficiency into its future resource planning, it is critical to first quantify the volume of potential energy and economic savings available from energy efficiency. Conducting this assessment allows policymakers and stakeholders to understand the degree to which demand-side resources can meet increasing consumption and load requirements. Energy efficiency can also reduce the strain on the Commonwealth's current system and delay, or even negate, the need for future investments in supply-side resources, such as generation facilities and transmission infrastructure. Quantifying the potential energy savings available also highlights the role energy efficiency plays in lowering customers' utility bills, creating jobs, and stimulating economic activity for Kentucky's businesses. Ultimately, the goal of this process is to provide tangible evidence to stakeholders that energy efficiency is the least-cost energy resource available to spur economic development and guarantee environmental health.

This assessment is the first of three (3) documents that comprise ACEEE's energy efficiency potential study for the Commonwealth. This report presents the results from our analysis of the cost-effective energy efficiency resources available in residential, commercial, and industrial buildings and facilities in Kentucky.

Methodology

This assessment is a bottom-up, measure-by-measure analysis of energy efficiency resources, meaning that we quantify the potential energy savings and costs through 2030 generated by specific efficient technology measures over their lifetime, such as windows, water heaters, and central air conditioning units. These values are then used to determine each measure's overall cost-effectiveness, taking into account the current market share/penetration. The measures included in this analysis are limited to those that are currently commercially available and currently cost-effective. New efficiency measures will become available or become cost-effective in the future, however, and therefore there will be new opportunities for cost-effective energy efficiency that are not captured in this analysis. For all measures that are deemed cost-effective, we aggregate the potential savings, grouped by end-use, to provide an estimate of the volume of statewide energy savings potential available in each sector.

The volume of savings quantified in this assessment shows the maximum cost-effective energy savings potential available for utility- and state-funded energy efficiency policies and programs to capture. It is important to understand that many market barriers exist that prevent all of the cost-effective resource potential savings identified from being captured by energy efficiency programs. The maximum *achievable* potential analysis, also known as the policy/program analysis, follows this cost-effective resource assessment and provides an estimate of the percent of the cost-effective resource potential that can be captured through energy efficiency policies and programs.[1]

The results of the policy analysis — specifically total program costs, energy and dollar savings, and investments (customer costs and incentives) — are then fed into ACEEE's *Dynamic Energy Efficiency Policy Evaluation Routine* (DEEPER) model, a macroeconomic model that is used to determine the impact of the energy efficiency policies and programs on a number of economic indicators, such as job creation and gross state product.

Individual measure assumptions, methodologies, and detailed results of the measure-by-measure analyses can be found in the appendices of this document.

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[1] A list of suggested energy efficiency policies and programs will be compiled by ACEEE and shared with stakeholders to give them an opportunity to weigh in on the relative political palatability and economic feasibility of each suggested policy or program. Once a list has been vetted and finalized, it will serve as the basis for the policy analysis.

Results

The cost-effectiveness of more efficient technologies, compared to a standard baseline technology, is determined from the customer's perspective — in other words, a measure is deemed cost-effective if its levelized[2] cost of saved energy (CSE) is less than the average retail energy price for a given customer class. Average CSEs for each sector are given in the following sections. Table 1 presents a summary of energy efficiency potential by sector in 2030. In total, we estimate that over 21,000 gigawatt-hours (GWh) and 52,200 billion British thermal units (BBtu), or 19% and 24.5% of projected electricity and natural gas consumption in 2030, can be saved through the implementation of cost-effective energy efficiency resources. Readers should note that this assessment includes mostly existing technologies and practices, though we anticipate that new and emerging technologies and market learning will increase the availability of cost-effective energy resources by 2030.

Table 1. Summary of Cost-Effective Energy Efficiency Potential by Sector, by 2030

Sector	Electricity			Natural Gas		
	GWh	%*	% of Sector**	BBtu	%*	% of Sector**
Residential	7,787	7.1%	21%	12,356	5.8%	30%
Commercial	6,900	6.2%	28%	16,263	7.6%	45%
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Total	**21,098**	**19.1%**		**52,248**	**24.5%**	

*Savings are represented as a percent of the total projected energy consumption in 2030.
**Savings are represented as a percent of the projected energy consumption in that sector in 2030. Projected residential energy consumption includes sales to multifamily homes. We did not have the capacity in our modeling to include multifamily energy efficiency measures, which would increase the overall savings in this sector and in total.

Using retail electricity and natural gas price data from projections estimated by the Kentucky Department of Energy Development and Independence (DEDI 2011), we can determine the magnitude of the energy bill savings arising from capturing 100% of the cost-effective energy efficiency potential. If all of the cost-effective energy efficiency potential were able to be captured, Kentucky would save over $2.1 billion on its energy bills by 2030 (see Table 2).[3]

Table 2. Energy Bill Savings by Sector, by 2030

Sector	Electricity			Natural Gas		
	GWh	$/kWh*	Million$	BBtu	$/MMBtu*	Million$
Residential	7,787	$0.086	$669.7	12,356	$12.53	$154.8
Commercial	6,900	$0.078	$538.2	16,263	$11.38	$185.1
Industrial	6,411	$0.061	$391.1	23,629	$9.71	$229.4
Total	**21,098**		**$1,599.0**	**52,248**		**$569.3**

*Retail energy prices from DEDI 2011

Residential

For our analysis of energy efficiency potential for Kentucky's residential sector, we used a residential building energy modeling software package, the Targeted Retrofit Energy Analysis Tool (TREAT), to compute the average baseline Kentucky single-family home, and the potential energy savings available (PSD 2011). The baseline home was computed using a variety of housing characteristics gathered from a local utility as well as national datasets. First, we input these housing characteristics into TREAT to model a typical home. Table 3 shows the baseline energy use for a typical Kentucky home.

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[2] Levelized cost is the amount of payment necessary each year to recover the total investment over the life of the energy efficiency measure.

[3] This is a high-level estimate made from a number of simplifying assumptions. It is based on current fuel costs, which are highly variable over time.

Table 3. Baseline Single-Family Home Annual Energy Use in Kentucky[4]

End-Use	Average Electricity Use (kWh)	Average Gas Use (MMBtu)
Heating	2,190	61.2
Cooling	2,450	—
Hot water	3,610	10.6
Lighting	1,490	—
Appliances & electronics	8,140	—
Total	**17,880**	**71.7**

We evaluated 18 efficiency measures that can be adopted in existing single-family residential homes based on the overall cost-effectiveness of the combined measures. An upgrade to a new measure is considered cost-effective if its levelized cost of conserved energy is less than 8.6 cents per kilowatt-hour (kWh), or $12.53/MMBtu for gas, the regional residential prices for energy (DEDI 2011); in other words, if it is cheaper to pay to save a unit of energy than to pay to use that energy. For the measures we analyzed, the average levelized cost per measure was $4.61/MMBtu for natural gas and $0.04 for electricity. Tables 4 and 5 outline the end-uses analyzed and their savings potential. The savings potential is based on the amount of energy that can be saved compared to the total single-family energy use in Kentucky. Because that information was not directly available for Kentucky, we estimated it by applying the ratio of single-family use to average residential use,[5] to Kentucky's residential energy use. This calculation results in approximately 27,000 GWh for single-family homes out of 36,000 GWh for all residential; and 30,000 BBtu natural gas for single-family homes out of 41,000 BBtu for all residential.

Table 4. Single-Family Residential Energy Efficiency Potential and Costs in 2030 — Electricity

End-Use	Savings (GWh)	Savings %[6]	% End-use savings[6]	% of Efficiency Potential	Levelized cost of saved energy ($/kWh saved)
HVAC	2,965	11%	42%	38%	$ 0.04
Water Heating	1,166	4%	20%	15%	$ 0.03
Lighting	707	3%	20%	9%	$ 0.04
Appliances	2,180	8%	18%	28%	$ 0.02
Whole house	510	2%	2%	7%	$ 0.09
Existing homes	7,528	28%	28%	97%	$ 0.04
New construction	258	1%	1%	3%	$ 0.03
TOTAL	**7,787**	**29%**	**29%**	**100%**	**$ 0.04**

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[4] The analysis only considers single-family homes due to a lack of state-specific data on end-use consumption by housing type. As a result, these values are slightly higher than they would be if consumption patterns from other housing types (multifamily and manufactured housing) were included. These values are not used as an input in the TREAT model, however, and so do not influence the results in Tables 3 & 4. Rather, we apply the percent savings by measure from TREAT to the overall Residential Energy Consumption Survey (RECS) baseline to estimate measure and end-use savings.

[5] We derived this ratio using housing stock data from Kentucky for single-family homes, multi-family homes, and manufactured housing (Economy.com 2011a); multiplied by average energy usage from RECS (for the East South Central region that includes Kentucky) (EIA 2005).

[6] Savings are relative to the 27,000 GWh baseline electricity use for single family homes.

Table 5. Single-Family Residential Energy Efficiency Potential and Costs in 2030 — Natural Gas

End-Use	Savings (BBtu)	Savings %[7]	% End-use savings[7]	% of Efficiency Potential	Levelized cost of saved energy ($/MMBtu)
HVAC	9,019	30%	35%	73%	$ 4.98
Water Heating	1,292	4%	29%	10%	$ 4.49
Lighting	-	0%	0%	0%	$ -
Appliances	-	0%	0%	0%	$ -
Existing buildings	10,311	34%	34%	83%	$ 4.92
New construction	2,045	7%	7%	17%	$ 3.08
TOTAL	**12,356**	**40%**	**40%**	**100%**	**$ 4.61**

For electricity in single-family houses, we estimated a statewide economic potential for efficiency resources of 7,790 GWh annually by 2030, a potential savings of 29% of baseline electricity use for single family homes (see Table 4). For natural gas in single-family houses, we estimated a statewide economic potential of 12,360 BBtu annually by 2030, a potential savings of 40% of baseline natural gas use for single family homes (see Table 5).

In the residential sector, a large percentage of savings potential can be realized through improved housing shell[8] performance (e.g., insulation measures, duct sealing, reduced air infiltration, and ENERGY STAR® windows) and heating, ventilating, and air conditioning (HVAC) equipment and systems. These categories account for more approximately half of the potential savings.

Water heating, refrigeration, and other appliances can also contribute substantial savings potential. Measures to reduce hot water load, (such as low-flow showerheads) and more efficient water heaters (including heat pump electric water heaters and condensing gas water heaters) can substantially contribute to energy savings. Additional savings are garnered through more efficient water-using appliances, such as dishwashers and clothes washers. See Appendix A for a detailed methodology and specific efficiency opportunities and cost-effectiveness for residential buildings (see Table A-4).

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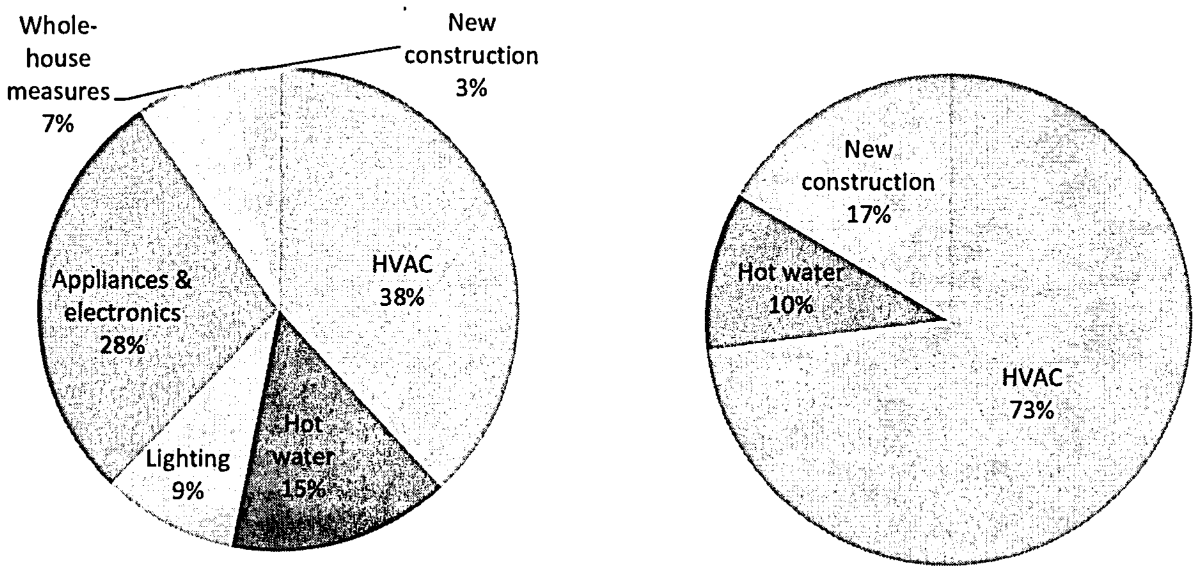
[7] Savings are relative to the 30,000 Btu baseline natural gas use for single family homes.

[8] Housing shell measures are those that address a home's foundation, walls, floors, and roofs.

Figure 1. Single-Family Energy Efficiency Potential in 2030 by End-Use and Fuel

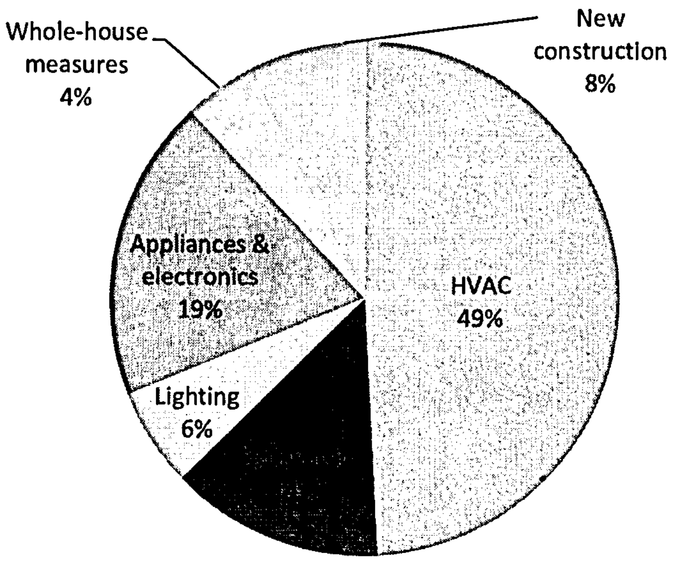


Electricity
Total: 7,790 GWh
29% of Projected Electricity Consumption

Natural gas
Total: 12,360 BBtu
40% of Projected Gas Consumption

Figure 2. Single-Family Energy Efficiency Potential in 2030 — Electricity and Natural Gas

Total: 38,930 BBtu
32% of Projected Energy Consumption in 2030



Commercial

Our analysis of energy efficiency potential in the commercial buildings sector is based on a proprietary Microsoft Excel spreadsheet model. This ACEEE buildings model evaluates sector-wide savings relative to the basecase energy forecast and estimated commercial floor space in Kentucky. We use two separate models to evaluate electric and natural gas savings, accounting for the fact that the electric and natural gas measures are applicable to different percentages of commercial floorspace in the state.

Electricity

The potential for electricity savings through energy efficiency for the commercial sector in Kentucky is examined through a scenario of 41 cost-effective measures for electricity savings that would be adopted during the 21-year period from 2010 to 2030. An upgrade to a new measure is considered cost-effective if its levelized cost of conserved energy is less than 7.8 cents/kWh saved, which is the average retail electricity price for the commercial sector in Kentucky over the study time period (DEDI 2011). For the sum of all measures, the estimated levelized cost is 1.7 cents/kWh saved (see Table 6). See Appendix A for a detailed methodology and specific efficiency opportunities and cost-effectiveness for commercial buildings (see Table A-7).

Table 6. Commercial Electricity Potential and Costs by End-Use in 2030

End-Use	Savings (GWh)	Savings over Reference Case (%)*	% of Efficiency Potential	Weighted Levelized Cost of Saved Energy ($/kWh)
HVAC and building shell	1,700	30%	25%	$ 0.030
Water heating	40	8%	1%	$ 0.032
Refrigeration	420	20%	6%	$ 0.017
Lighting	2,750	48%	40%	$ 0.015
Office equipment	640	45%	9%	$ 0.003
Appliances and other	10	0%	0%	$ 0.021
Existing buildings	5,560	34%	80%	$ 0.020
New buildings	1,350	17%	20%	$ 0.006
Total electricity	**6,900**	**28%**	**100%**	**$ 0.017**

*Percent savings are relative to forecasted consumption for the commercial sector in 2030.

Commercial buildings can reduce electricity consumption by 28% through the adoption of a variety of efficiency measures. The economic potential for efficiency resources in the commercial sector will reduce electricity use by 6,900 GWh through the period 2010–2030.

In the commercial sector, electricity savings from efficiency resources are realized through improved HVAC equipment, controls, and building shell measures (e.g., roof insulation and new windows); improved water heating (e.g., heat pump water heaters); more efficient refrigeration systems (e.g., ENERGY STAR vending machines and coolers); and efficient lighting, office equipment, and miscellaneous appliances. The greatest portion of the savings, at 40%, is from improvements to lighting systems, which include savings from more efficient light bulbs such as fluorescent and HID, improved lighting controls such as daylight dimming systems and occupancy sensors, and certain LED applications such as task lighting. Our analysis raises the baseline from which we project lighting savings at 2013 and 2020, accounting for the upcoming lighting standards.

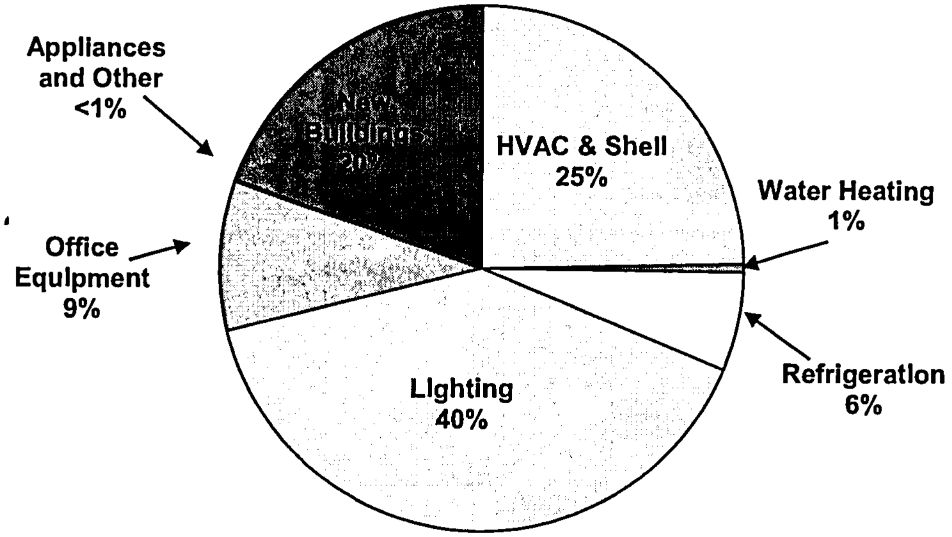
Improvements to HVAC systems and building shells account for the second greatest portion of the savings, at 25%. Shell measures include roof insulation and improved windows. HVAC measures include better heating and cooling systems (e.g., high efficiency chillers and heat pumps) and better controls (e.g., dual enthalpy controls and energy management system installations).

Office equipment measures can provide another 9% of the total savings with measures including more efficient computers, printers, and copiers, etc., as well as turning off this equipment after hours. Office measures have the lowest weighted levelized cost of saved energy among the sectors we examined, accounting for only three-tenths of one cent of the total levelized cost. These measures are extraordinarily cost effective.

Water heating measures include heat pump water heaters, and efficient clothes washers that reduce hot water demand. Refrigeration measures include improved commercial refrigeration systems (e.g., walk-in coolers, ice makers, and vending machines). And, as with lighting measures, we raise the baseline from which we project savings for commercial clothes washers and room air conditioners to account to upcoming standards that take effect in 2013 and 2014, respectively.

New construction measures contribute a significant portion of the overall savings potential for the commercial sector, reaching 20% of total electric savings. We estimate that up to 50% savings can be reached cost-effectively for commercial new construction (NREL 2008).

Figure 1. Commercial Electric Efficiency Potential in 2030 by End-Use
Total: 6,900 GWh
28% of Projected Electricity Use in 2030



Natural Gas

The potential for natural gas savings through energy efficiency in Kentucky's commercial building sector is examined through a scenario of 23 cost-effective measures for gas savings that would be adopted during the 21-year period from 2010 to 2030. An upgrade to a new measure is considered cost-effective if its levelized cost of conserved energy is less than $11.38/MMBtu, which is the average retail natural gas price for the commercial sector in Kentucky over the study time period (DEDI 2011). For the sum of all measures, the estimated levelized cost is $3.94/MMBtu saved (see Table 7). See Appendix A for a detailed methodology and specific efficiency opportunities and cost-effectiveness for commercial buildings (see Table A-10).

Table 7. Commercial Natural Gas Efficiency Potential and Costs by End-Use in 2030

End-Use	Savings (BBtu)	Savings over Reference Case (%)*	% of Efficiency Potential	Weighted Levelized Cost of Saved Energy ($/MMBtu)
HVAC equipment & controls	8,870	40%	55%	$ 1.62
Building shell	715	10%	4%	$ 0.30
Water heating	1,210	16%	7%	$ 4.29
Cooking	701	32%	4%	$ 6.38
Other	1,838	30%	11%	$ 6.48
Existing buildings	*13,333*	*58%*	*82%*	*$ 4.53*
New buildings	*2,930*	*22%*	*18%*	*$ 1.71*
Total gas	**16,263**	**45%**	**100%**	**$ 3.94**

*Percent savings are relative to forecasted consumption for the commercial sector in 2030.

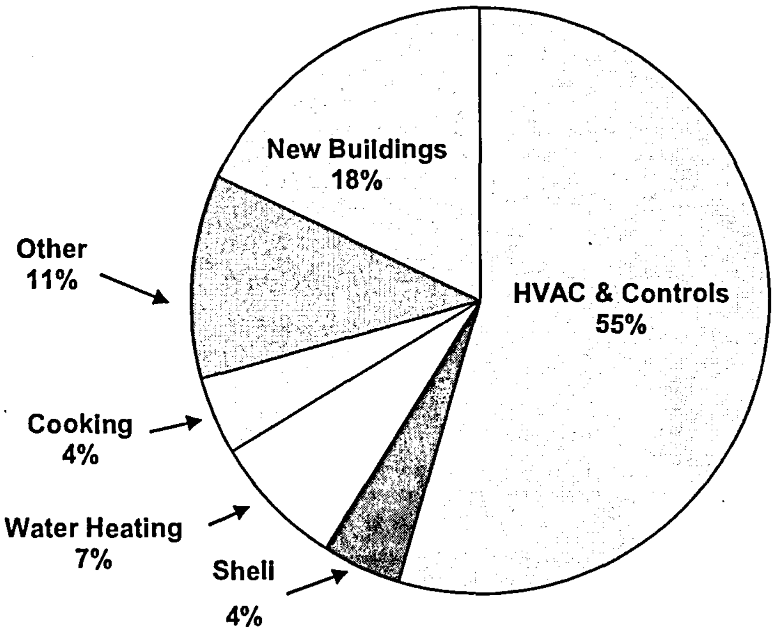
Commercial buildings can reduce natural gas consumption by 45% through the adoption of a variety of efficiency measures. The economic potential for efficiency resources in the commercial sector will reduce natural gas use by over 16 trillion Btu through the period 2010–2030.

In the commercial sector, gas savings from efficiency resources are realized through improved HVAC equipment, controls, and building shell measures (e.g., duct sealing and pipe insulation); improved water heating (e.g., instantaneous water heaters); and more efficient cooking equipment (e.g., ENERGY STAR fryers). The majority of the savings is provided by improved HVAC measures, including heating system measures, and improved controls, which provide 55% of the total gas savings potential. Our calculations for improved heating equipment take into account the different types of equipment that are appropriate for different size buildings, and include furnaces, rooftop heating units, and boilers. Improved controls include programmable thermostat and energy management systems. Building shell measures include roof insulation and low-e windows.

Improved water heating also provides substantial savings, with 7% of the total gas savings potential. Gas condensing water heaters contribute the vast majority of water heating savings with over 1,000 BBtu savings potential. Building shell and cooking measures each provide another 4% of the savings potential. For cooking measures, high efficiency convection range/ovens and ENERGY STAR fryers provide the largest portion of the savings, while roof insulation and low-e windows comprise the shell measures.

New construction measures contribute a sizeable portion of the overall savings potential for the commercial sector as well, totaling 18% of natural gas savings. We estimate that up to 50% savings can be reached cost-effectively for commercial new construction (NREL 2008).

Figure 4. Commercial Natural Gas Efficiency Potential in 2030 by End-Use
Total: 16,200 BBtu
45% of Projected Natural Gas use in 2030

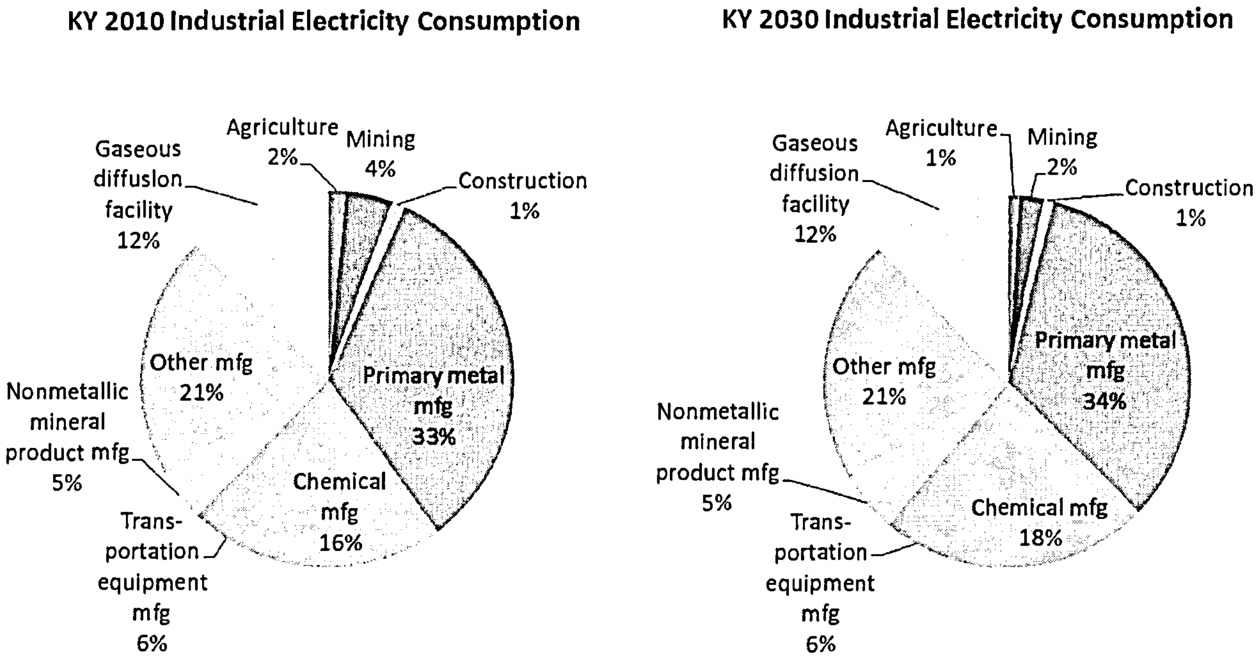


Industrial

The industrial sector is the most diverse economic sector, encompassing agriculture, mining, construction and manufacturing. Because energy use and efficiency opportunities vary by individual industry (if not individual facility), it is important to develop a disaggregated forecast of industrial electricity and natural gas consumption. Unfortunately, this energy use data is not available at the state level, so ACEEE has developed a method using state-level economic data to estimate disaggregated electricity and natural gas use. This study drew upon national industry data to develop a disaggregated forecast of economic activity for the sector. We then applied energy intensities derived from industry group electricity consumption data and data on the value of shipments to characterize each sub-sector's share of the industrial sector electricity consumption and projected the energy use through 2030. One issue unique to Kentucky is the Paducah Gaseous Diffusion Plant, which is run by the U.S. Department of Energy: it consumes about 12% of industrial electricity. Please see Appendix A for more details.

Figure 5 shows the largest electricity consuming industries in Kentucky in 2010 and their share of electricity use changes by 2030.

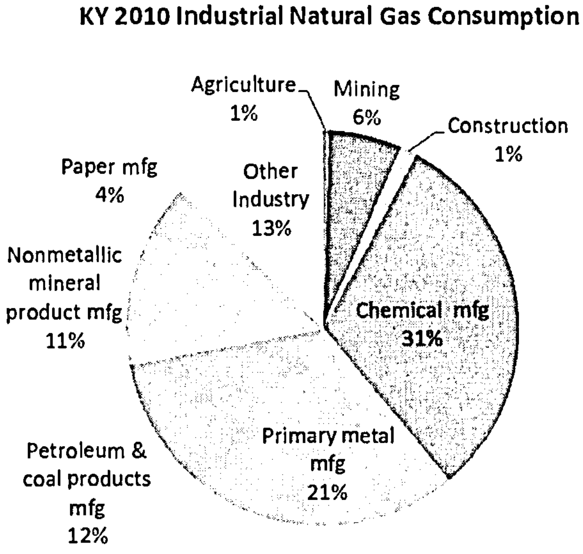
Figure 5. Estimated Electricity Consumption for the Largest Consuming Industries in Kentucky in 2010 and 2030

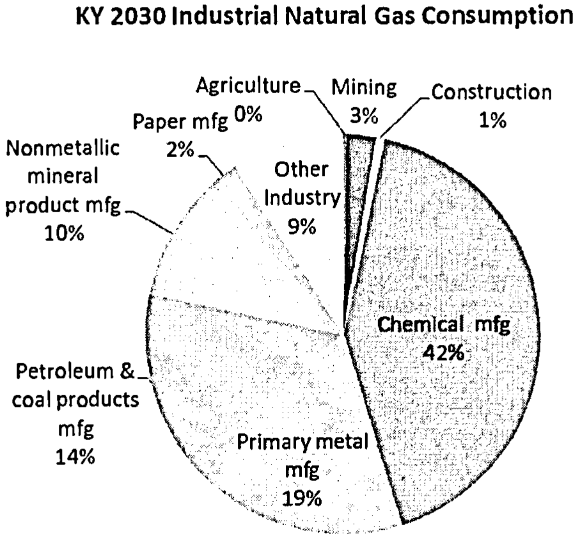


Due to changes in economic activity and energy intensity as discussed in Appendix A, we see some minor intra-sectoral shifts in electricity consumption (see Figure 5). Despite modest economic growth in the agriculture and mining sectors, their share of electricity use will fall by 2030. In most manufacturing sectors, growth is offset by projected increases in energy efficiency. Where most manufacturing sees only minor growth and thus decreasing energy use, chemical manufacturing will experience much greater increases in economic activity and energy use. These intra-sectoral shifts are important because they identify where new investments are being made and where energy efficiency opportunities are concentrated.

Figure 6 shows the largest natural gas consuming industries in Kentucky in 2010 and their share of electricity use changes by 2030.

Figure 6. Estimated Natural Gas Consumption for the Largest Consuming Industries in Kentucky in 2010 and 2030





Similar changes in economic activity and energy intensity cause significant intra-sectoral shifts in natural gas consumption. The chemical manufacturing will see substantial growth in natural gas use, due largely to a projected *increase* in energy intensity. Combined with modest economic growth, the chemical industry will increase from consuming 31% of industry sector natural gas in 2010 to 42% in 2030. A similar (but more modest) increase in natural gas intensity will lead to an increase in natural gas consumption in the petroleum and coal products sector. These intra-sectoral shifts are important because they identify where new investments are being made and where energy efficiency opportunities are concentrated.

Electricity

We examined 18 electricity saving measures, nine of which were cost effective considering Kentucky's average industrial electric rate[9] of $0.061/kWh (DEDI 2011). These measures were applied to an industry specific end-use electricity breakdown.

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[9] Average electricity rate taken from actual and projected rates from 2009–2030.

Table 8 shows results for industrial energy efficiency potential by 2030.

Table 8. Industrial Electric Efficiency Potential and Costs by End-Use in 2030

Measures	Savings Potential in 2030 (GWh)	Savings Potential in 2030 (%)*	% of Efficiency Potential	Levelized Cost of Saved Energy ($/kWh)
Sensors & controls	168	0.3%	3%	$0.014
Duct/Pipe insulation	1,409	2.9%	22%	$0.052
Electric supply	1,291	2.6%	20%	$0.010
Lighting	422	0.9%	7%	$0.020
Motors	1,460	3.0%	23%	$0.027
Compressed air	601	1.2%	9%	$0.000
Pumps	833	1.7%	13%	$0.008
Fans	155	0.3%	2%	$0.024
Refrigeration	72	0.1%	1%	$0.003
Total	**6,411**	**13%**	**100%**	**$0.023**

*Percent savings are relative to forecasted consumption for the industrial sector in 2030.

This analysis found economic savings from these cross-cutting measures of 6,411 million kWh or 13% of industrial electricity use in 2030 at a levelized cost of about $0.023/kWh saved. This analysis did not consider process-specific efficiency measures that would be applied at the individual site level because available time, funding, and data did not allow this level of analysis. The analysis also did not count any savings for the Gaseous Diffusion Plant. However, based on experience from site assessments by the U.S. Department of Energy (IAC 2012) and other entities, we would anticipate an additional economic savings of 5–10%, primarily at large energy-intensive manufacturing facilities. The overall economic industrial efficiency resource opportunity is on the order of 20–25%. Therefore, the total economic potential for electricity savings in the industrial sector in 2030 would be about 10,000 GWh.

Natural Gas

We examined 36 natural gas saving measures, 35 of which were cost effective considering Kentucky's average industrial natural gas rate of $9.71/MMBtu (DEDI 2011). These measures were applied to an industry specific end-use natural gas breakdown.

Table 9 shows summarized results for industrial natural gas efficiency potential by 2030. A full measure list can be found in Appendix A.

Table 9. Industrial Natural Gas Efficiency Potential and Costs by End-Use In 2030

Measures	Savings Potential In 2030 (BBtu)	Savings Potential In 2030 (%)*	% of Efficiency Potential	Levelized Cost of Saved Energy ($/MMBtu)
Improved boiler insulation	2,974	2.3%	13%	$0.63
Steam trap maintenance	2,323	1.8%	10%	$0.45
Boiler load control	1,487	1.1%	6%	$0.13
Other boiler measures	3,711	2.8%	16%	$0.20
HVAC measures	445	0.3%	2%	$4.47
Efficient process heat burners	3,370	2.6%	14%	$1.85
Process controls & management	2,848	2.2%	12%	$0.51
Other process heat	6,471	4.9%	27%	$5.31
Total	**23,629**	**18.0%**	**100%**	**$2.03**

*Percent savings are relative to forecasted consumption for the industrial sector in 2030.

This analysis found economic savings from these cross-cutting measures of 23,629 billion Btu, or 18% of industrial natural gas use in 2030 at a levelized cost of about $2.03/MMBtu saved. Once again, this analysis did not consider process-specific efficiency measures that would be applied at the individual site level. As with electricity, we would anticipate an additional economic savings of 5–10%, primarily at large energy-intensive manufacturing facilities. The overall economic industrial efficiency resource opportunity is on the order of 23–28%. Therefore, the total economic potential for natural gas savings in the industrial sector in 2030 would be about 33,500 Btu.

Conclusion

The goal of this energy efficiency cost-effective resource assessment is to provide Kentucky stakeholders with a picture of the maximum economic potential for energy efficiency resources in the Commonwealth. This report is the first step in estimating the overall economic benefits that energy efficiency can create for the state, such as lowering customer utility bills, creating jobs, and stimulating economic growth. These results will help Kentucky stakeholders determine the degree to which they should focus their policy and program efforts across the various sectors. The savings generated by these policies and programs will create the economic benefits described above.

In total, we estimate that around 19,000 GWh and 49,500 BBtu, or 17% and 23% of projected electricity and natural gas consumption, respectively, in 2030, can be saved through investments in cost-effective energy efficiency resources, such as efficient HVAC systems in residential and commercial buildings, and efficient motors used in industrial manufacturing processes. If all of the cost-effective energy efficiency potential were able to be captured, Kentucky would save almost $2 billion on its energy bills by 2030 (see Tables 10 and 11 below). Individual measure assumptions, methodologies, and detailed results of the analyses can be found in the appendices of this document.

Table 10. Summary of Cost-Effective Energy Efficiency Potential by Sector, by 2030

Sector	Electricity			Natural Gas		
	GWh	%*	% of Sector**	BBtu	%*	% of Sector**
Residential	7,787	7.1%	21%	12,365	5.8%	30%
Commercial	6,900	6.2%	28%	16,263	7.6%	45%
Industrial	6,411	5.8%	13%	23,629	11.1%	17%
Total	**21,098**	**19.1%**		**52,248**	**24.5%**	

*Savings are represented as a percent of the total projected energy consumption in 2030.
**Savings are represented as a percent of the projected energy consumption in that sector in 2030.

Table 11. Energy Bill Savings by Sector, by 2030

Sector	Electricity			Natural Gas		
	GWh	$/kWh*	Million$	BBtu	$/MMBtu*	Million$
Residential	7,787	$0.086	$669.7	12,356	$12.53	$154.8
Commercial	6,900	$0.078	$538.2	16,263	$11.38	$185.1
Industrial	6,411	$0.061	$391.1	23,629	$9.71	$229.4
Total	**21,098**		**$1,599.0**	**52,248**		**$569.3**

*Retail energy prices from DEDI 2011

The next phase of the project will be to vet a list of energy efficiency policies and programs with stakeholders that can be implemented by the Commonwealth and Kentucky utilities in order to capture the available resources identified through this assessment. It is important to understand that many market barriers exist that prevent all of the cost-effective resource potential savings from being captured by energy efficiency policies and programs. Policymakers and utilities must design policies and programs carefully to overcome those barriers, ensuring that they are properly marketed and that Kentuckians are well-educated in the potential benefits of energy efficiency.

Once stakeholders agree on a set of policies and programs to be evaluated, ACEEE will conduct its maximum achievable potential analysis, also known as the policy and program analysis, which will estimate the level of potential that can be realistically achieved through this set of policies and programs. The results from this analysis will provide a roadmap that the Commonwealth can follow to ramp-up energy savings from efficiency. The results from the policy analysis will then feed into ACEEE's macroeconomic model to estimate the overall economic benefits, including energy bill savings and jobs, that can be achieved through investments in energy efficiency.

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APPENDIX A – ENERGY EFFICIENCY RESOURCE ASSESSMENT

A.1. Residential Buildings Sector

A.1.1. Overview of Approach

Our analysis of energy efficiency potential for Kentucky's residential electricity and natural gas sectors considered a scenario with widespread adoption of cost-effective energy efficiency measures during the 20-year period from 2010–2030. We analyzed 18 single-family measures for existing single-family homes in Kentucky. These measures are grouped by end-use (heating and cooling loads, water heating, appliances, etc.). For each measure, we estimated average measure lifetime, energy savings, and costs per home upon replacement of the product or retrofitting of the measure. For a replacement-on-burnout measure, the cost is the incremental cost of the efficient technology compared to the baseline technology. For retrofit measures, where exiting equipment is not being replaced, such as improved insulation and infiltration reduction, the cost is the full installation cost of the measure.

A measure is determined to be cost-effective if its levelized cost of saved energy (CSE), which discounts the incremental cost of a measure over its lifetime, is less than $0.086/kWh for electricity, or $12.53/MMBtu for natural gas, the current average residential costs in Kentucky (DEDI 2011). Estimated levelized costs for each efficiency measure, which assumes a discount rate of 5%,[10] are shown in Table A-4. Equation 1 shows the calculation for cost of conserved energy.

Equation 1. CSE = PMT ((Discount Rate), (Measure Lifetime), (Measure Cost)) / (Annual Savings per Measure)

Existing Buildings

Existing buildings were analyzed using building modeling software. The software package, TREAT[11], was chosen for its reputation as one of the better residential modeling packages available. It uses a variety of inputs, including house characteristics, appliances, weather data, and occupancy patterns to model the expected energy use of a particular home. It also includes a library of efficiency measures that can be used to model potential efficiency improvements. TREAT was used to establish a baseline as well as model the effects of efficiency improvement measures on the average Kentucky single-family home.

Establishing a Baseline

TREAT uses multiple house characteristics and measures to determine annual energy use. We used approximately 100 inputs to model the baseline average Kentucky home. First, we gathered Kentucky-specific data for each of the inputs, using detailed housing characteristic information provided by a local utility. Where there was no data we used RECS data, Building America averages, or TREAT defaults to fill in the gaps. In several cases further calculations were needed to determine the inputs. For instance, in the case of furnace and water heater efficiency levels, where only the average age of existing equipment were known, an assumption was made that the minimum federal efficiency would account for the majority of installations. We assume that the federal efficiency level for the years most furnaces and water heaters were installed would be used. Table A-1 gives the data collected for the various TREAT inputs (with multiple values for different percentages of the population, in some cases). For inputs without values, either the default TREAT value was used, or a value had to be derived (see Table A-2).

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[10] The 5% discount rate is a real discount rate, which excludes the effects of inflation. A 5% real discount rate is equivalent to an 8-9% nominal discount rate as typically used by utilities in their analyses of cost-effectiveness. Nominal discount rates are typically based on utility cost of capital and include allowance for inflation. Our assumption of a 5% real discount rate applies to our commercial and industrial analyses as well. We use real rates since all of our calculations are in terms of 2007$.

[11] http://www.psdconsulting.com/software/treat

Table A-1. Data Collected for TREAT Inputs

Treat Input Categories	Treat Inputs	Kentucky		
		Value	% of homes	Data source
General	City	Louisville		U.S. Census — highest population city in KY
	Stories	1 story 2 stories	71% 21%	RECS 2005
	# Bedrooms	3		RECS 2005
	# Occupants	2.47		U.S. Census
	Wall color			Default
	Roof color			Default
	Foundation type	Basement Crawlspace Concrete slab	24% 42% 34%	RECS 2005
	If basement, is it heated?	No	66%	
	Attic			Default
	Air leakage			Default
	Shielding			Default
Surface Construction	Walls	R value: 4.7 - 6.9		Duke and Building America
	Ceiling	R value: 8.5		Duke and Building America
	Ground			Default
	Foundation - Basement wall			Default
	Foundation - Crawl space			Default
Windows	Glazing	Single pane Double pane	45% 49%	RECS 2005
	Frame type			Default
	Size			Default
Layout	Ceiling height			Default
	Shape of the house			Default
	Dimensions (s.f.)	1876		Duke
	Quantity of windows on each wall	13 total per house		RECS 2005
	Direction house points			Default
	Space type			Default
	Is the space cooled?	Yes	97%	Duke
	Programmable thermostat?			Default
	Hours per day occupied	16.5		Building America
Exterior doors	Quantity of doors on each wall	2		Assumption
	Door type			Default
	Size			Default
	U-Value	0.2		Building America
Heating	Heating type	Furnace Heat pump	80% 20%	Average of Duke and RECS 2005
	Heating fuel	Gas Electric	80% 20%	Duke (rounded)

	Capacity			Determine using TREAT
	Efficiency	78%		Duke - average age combined with min fed efficiency in that year
	Location			Default
	Year of heating equipment	2000		Duke
	Supply temperature			Default
Air conditioning	Capacity			Determine using TREAT
	SEER	10 SEER 6.8 HSPF		Duke — average age combined with min fed efficiency in that year
	Supply temperature			Default
	Year of cooling equipment	2001		Duke
	Number of units			Default
	Type of unit	Central AC Heat pump Room AC	68% 20% 12%	Duke & RECS 2005
Fans	Ventilated area	2.4 fans/home		Default
	Ventilation rate			Default
	Heat recovery effectiveness			Default
	Hours/day used			Default
Hot Water	Type of unit	Storage unit		Assumption
	Hot water fuel	Electric Gas	64% 36%	Duke and RECS 2005
	Tank volume	43 gallons		RECS 2005
	Input			Default
	Supply temperature			Default
	Additional insulation R-Value			Default
	Number of units			Default
	Solar fraction of water heating			Default
	Year	2003		Duke
	Thermal efficiency	0.54 0.89	Gas Electric	Duke — average age combined with min fed efficiency in that year
Hot Water Piping	Insulation R-Value			Default
	Total area of piping			Default
	Recirculating system			Default
	% Piping running through each space			Default
Hot Water Demand	Usage adjustment multiplier			Default
	Are dishes handwashed			Default
Lighting	Watts per fixture	67 38	Incandescent Fluorescent	Navigant Lighting Characterization
	Hours/day used	1.9 2.2	Incandescent Fluorescent	Navigant Lighting Characterization
	# of fixtures	37 6	Incandescent Fluorescent	Navigant Lighting Characterization
Appliances	Refrigerator	1		Duke
	Clothes Dryer	1		Duke
	Clothes Washer	1		Duke

	TVs	3		Duke
	Freezer	0		Duke
	Dishwasher	1		Duke
	Microwave	1		Duke
	Computer	1		Duke
	Oven/range	1		Duke
	DVD/Blu Ray	1		Duke
	DVR	1		Duke
	MP3/CD player	1		Duke
	Gaming system	0		Duke

After gathering and/or calculating the data, we determined which values to use in TREAT. Because TREAT models a single home, for inputs that had multiple values (e.g., 71% of homes are one story and 21% are two stories) a determination was made which value to use. Wherever possible an average was used. However, for discrete data points (e.g., gas vs. electric), the majority won. This method was used for all inputs except for five. Five inputs that were deemed most critical to baseline energy use, including foundation type, heating equipment, square footage, air conditioner type, and water heater fuel, were selected to have variable inputs. We ran the model 36 times to account for every possible combination of these five inputs, and used a weighted average of the results to calculate the average baseline home. Table A-2 lists the inputs chosen or calculated for the TREAT baseline model.

Table A-2. TREAT Inputs

Treat Input Categories	Treat Inputs	
General	City	Louisville
	Stories	1 story
	# Bedrooms	3
	# Occupants	2
	Wall color	
	Roof color	
	Foundation type	VARIABLE
	If basement, is it heated?	No
	Attic	Default
	Air leakage	
	Shielding	Default
Surface Construction	Walls	R value: 4.7 - 6.9
	Ceiling	R value: 8.5
	Ground	Default
	Foundation - Basement wall	Default
	Foundation - Crawl space	Default
Windows	Glazing	Double pane
	Frame type	Default
	Size	Default

Layout	Ceiling height	Default
	Shape of the house	Default
	Dimensions	1049 1986 3278
	Quantity of windows on each wall	9 for small houses 13 for medium houses 16 for large houses
	Direction house points	Default
	Space type	Default
	Is the space cooled?	Yes
	Programmable thermostat?	Default
	Hours per day occupied	16.5
Exterior doors	Quantity of doors on each wall	2
	Door type	Default
	Size	Default
	U-Value	0.2
Heating	Heating type	VARIABLE
	Heating fuel	Gas for furnace Electric for heat pump
	Capacity	Determine using TREAT
	Efficiency	78% for furnaces
	Location	Default
	Year of heating equipment	2000
	Supply temperature	Default
Air conditioning	Capacity	Determine using TREAT
	SEER	10 SEER 6.8 HSPF
	Supply temperature	Default
	Year of cooling equipment	2001
	Number of units	1
	Type of unit	VARIABLE
Fans	Ventilated area	2.4 fans/home
	Ventilation rate	Default
	Heat recovery effectiveness	Default
	Hours/day used	Default
Hot Water	Type of unit	Storage
	Hot water fuel	VARIABLE
	Tank volume	38 gallons for small houses 43 gallons for medium houses 47 gallons for large houses
	Input	Default
	Supply temperature	Default
	Additional insulation R-Value	Default
	Number of units	1

	Solar fraction of water heating	Default
	Year	2003
	Thermal efficiency	0.54 - Gas 0.89 - Electric
Hot Water Piping	Insulation R-Value	Default
	Total area of piping	Default
	Recirculating system	Default
	% Piping running through each space	Default
Hot Water Demand	Usage adjustment multiplier	Default
	Are dishes handwashed	Default
Lighting	Watts per fixture	67 W incandescent 38 W fluorescent
	Hours/day used	1.9 for incandescent 2.2 for fluorescent
	# of fixtures	37 incandescents 6 fluorescents
Appliances	Refrigerator	1
	Clothes Dryer	1
	Clothes Washer	1
	TVs	3
	Freezer	0
	Dishwasher	1
	Microwave	1
	Computer	1
	Oven/range	1
	DVD/Blu Ray	1
	DVR	1
	MP3/CD player	1
	Gaming system	0

TREAT takes these inputs and gives total home energy use as well as electricity and natural gas consumption by end-use category. All of these outputs were collected for all 36 scenarios, and weighted averages were calculated. Table A-3 gives the average energy use of a Kentucky single-family home, per TREAT.

Table A-3. Average Energy Use of a Single-Family Kentucky Home

End-Use	Average Electricity Use (kWh)	Average Gas Use (MMBtu)
Heating	2,190	61.2
Cooling	2,450	—
Hot water	3,610	10.6
Lighting	1,490	—
Appliances & electronics	8,140	—
Total	17,880	71.7

New Construction

We estimate savings from new construction by looking at three levels of efficiency in new homes: 15%, 30%, and 50% better than current energy code. In estimating new home energy savings, we use a similar approach as building codes, which address HVAC and water heating consumption only. We estimated *% Applicable* by allocating each home into one of the three bins, with 15% predominating the early years and 50% the later years. See Equation 2 for a summary of how we calculate savings in new construction.

Equation 2. Efficiency Resource Potential in 2030 (GWh/MMBtu) = (% savings per home) x (Percent Applicable) x (Baseline energy use per single family home) x (Projected number of new homes)

Efficiency Potential Analysis

For the analysis of energy efficiency improvement measures, we used TREAT to calculate the savings against the established baseline. Measures were chosen that were applicable to the baseline (e.g., efficient pool pumps were not chosen since pool pumps were not included in the baseline), and were available in the TREAT library of efficiency improvement measures. Cost assumptions and lifetime estimates for each of the measures came from multiple sources.

One of the advantages of using modeling software is that the interaction factors between various measures are automatically calculated. For instance, when lighting is switched from incandescents to CFLs, the cooling load decreases and the heating load increases. These interactions are difficult to account for without the assistance of modeling software. Because TREAT displays both the savings from individual measures and the overall savings of all the measures as a package, this phenomenon can be quantified: in many of the scenarios, the sum of the individual measure savings was roughly double the actual savings of the measures as a package.

We ran these efficiency improvement models on all of the variable scenarios. The weighted average individual measure savings were used to compute the residential efficiency potential in Kentucky.

The next step was to adjust the measure savings by the current market share of products that already meet the efficiency criteria. We also adjusted the incremental cost so that the cost would be split between gas and electric savings. The electric incremental cost for a measure was determined by the percentage of savings attributed to electricity (versus gas); and vice versa for determining gas incremental cost. These assumptions are made explicit in Tables A-4 and A-5.

We then adjusted replacement measures with lifetimes more than 20 years to only account for the percent turning over in 20 years, which represents the time period of the analysis.

Equation 3 shows our calculation for efficiency resource potential, incorporating the 2 factors discussed above.

Equation 3. Efficiency Resource Potential = $\sum$ (Annual Savings per Measure) x (Percent Turnover) x (Adjustment Factor)

To calculate the efficiency resource potential savings by end-use in 2030, we present savings as a percent of end-use energy consumption (assuming current energy consumption by end-use from the baseline TREAT modeling). We then multiply the "% savings" by projected residential energy consumption for that end-use in 2030 to estimate the total savings potential in that year (see Equation 3).

Table A-4. Residential Single-Family Energy Efficiency Measure Characterizations - Electricity

Measures	End-use category	Adjusted savings per home	Cost of saved energy	% Turnover	% End-use savings	Total savings in 2030
		kWh	$/kWh			GWh
Attic insulation	HVAC	761.7	$ 0.01	95%	16%	1,100
Infiltration reduction	HVAC	75.3	$ 0.02	100%	2%	110
SEER 16 AC	HVAC	574.6	$ 0.08	100%	12%	870
Efficient heat pump	HVAC	250.9	$ 0.05	100%	5%	380
Triple-paned windows	HVAC	209.5	$ 0.04	95%	4%	300
HVAC tune-up	HVAC	129.8	$ 0.03	100%	3%	200
HVAC measures					*42%*	*2,960*
CFLs	Lighting	165.2	$ (0.01)	100%	11%	250
Advanced lighting (LEDs)	Lighting	300.3	$ 0.06	100%	20%	460
Lighting Measures					*31%*	*710*
1 W Standby	Appliances	164.3	$ -	100%	2%	250
Energy Star refrigerator	Appliances	394.9	$ 0.01	100%	5%	600
Energy Star clothes washer	Appliances	266.3	$ 0.02	100%	3%	400
Energy Star dishwasher	Appliances	252.9	$ 0.01	100%	3%	380
Energy Star TV	Appliances	34.9	$ 0.64	100%	0%	50
Second refrigerator removal	Appliances	323.0	$ -	100%	4%	490
Appliance Measures					*18%*	*2,170*
Low Flow Showerheads	Water heating	306.2	$ 0.00	100%	8%	460
Heat pump water heater	Water heating	412.2	$ 0.06	100%	11%	630
Water Heating Measures					*20%*	*1,090*
Whole-house information feedback system	ALL	336.3	$ 0.09	100%	2%	510
Whole House Measures					*2%*	*510*
New home 15% better than code (Energy Star home)	New Construction	122.7	$ 0.03	63%	0%	20
New home 30% better than code (Proposed Building Code)	New Construction	486.9	$ 0.03	63%	2%	80
New home 50% better than code (Tax-credit-eligible)	New Construction	1043.4	$ 0.04	63%	4%	160
New Construction					*6%*	*260*
TOTAL						**7,700**

Table A-5. Residential Single-Family Energy Efficiency Measure Characterizations – Natural Gas

Measures	End-use category	Adjusted savings per home	Cost of saved energy	% Turnover	% End-use savings	Total savings in 2030
		MMBtu	$/MMBtu			Bbtu
Attic insulation	HVAC	10.4	$ 3.71	95%	16%	4,200
Infiltration reduction	HVAC	1.9	$ 4.43	100%	3%	820
Condensing furnace	HVAC	7.5	$ 5.95	95%	12%	3,020
Triple-paned windows	HVAC	1.2	$ 12.09	95%	2%	500
HVAC tune-up	HVAC	1.7	$ 2.36	100%	3%	730
Energy Star refrigerator	HVAC	-0.6	$ -	100%	-1%	(250)
HVAC measures					*35%*	*9,020*
Energy Star clothes washer	Water heating	0.7	$ 6.75	100%	7%	290
Energy Star dishwasher	Water heating	0.3	$ 2.32	100%	3%	130
Efficient water heater - gas	Water heating	1.2	$ 6.35	100%	11%	500
Low Flow Showerheads	Water heating	0.9	$ 0.94	100%	8%	370
Water Heating Measures					*29%*	*1,290*
New home 15% better than code (Energy Star home)	New Construction	1.6	$ 3.08	63%	1%	150
New home 30% better than code (Proposed Building Code)	New Construction	6.4	$ 2.84	63%	6%	600
New home 50% better than code (Tax-credit-eligible)	New Construction	13.8	$ 3.19	63%	12%	1,290
New Construction					*19%*	*2,040*
TOTAL						**12,350**

A.1.4 Residential Sector Measure Descriptions

Infiltration Reduction

Measure Description: Application of foam and/or caulk around leakage areas applied and tested by a professional using a blower-door.

Data Explanation: Cost ($100) from MT 2004. Useful life of 15 years from SWEEP (2002).

Attic Insulation

Measure Description: Add insulation in attic floor to R-38.

Data Explanation: Incremental cost of $0.32/sq ft from DEER database (CEC 2005). Useful measure life of 20 years from NYSERDA (2003).

Efficient Windows

Measure Description: Window replacements that are triple-paned, argon-filled, and e=0.1 on surface 2 or 3.

Data Explanation: Incremental cost of $1.50/sq ft. Number of windows determined by regional RECS data, and size of windows set as TREAT default, resulting in an average of 195 sq ft of fenestration.

Efficient Central AC

Measure Description: 16 SEER Central AC

Data Explanation: Incremental cost of $556 from ENERGY STAR calculator (EPA 2008).

Efficient Gas Furnace

Measure Description: AFUE 94%

Data Explanation: Incremental cost ($320) from ENERGY STAR calculator (EPA 2008). Market share (32%) and measure life (18 years) from Sanchez et al. (2007).

Efficient Heat Pump

Measure Description: HSPF 9.

Data Explanation: Incremental cost ($1000) from ENERGY STAR calculator. Measure life (18 years) from Sanchez et al. (2007).

HVAC Tune-up

Measure Description: Tune-up of heating and cooling eq uipment.

Data Explanation: Incremental cost ($125) from Kema (2011). Measure life (5 years) from Cadmus (2011).

Low-Flow Showerhead

Measure Description: 2.0 gallons per minute (gpm) showerhead.

Data Explanation: Cost estimate ($23) for a low-cost, basic model from the DEER database (CEC 2005). Measure life (10 years) from ACEEE (1994).

Condensing Gas Water Heater

Measure Description: 54 gallon natural gas storage water heater, 0.86 EF.

Data Explanation: Incremental cost ($750) and measure life (13 years) from Amann et al. (2007).

Efficient Electric Water Heater

Measure Description: 54 gallon electric storage water heater, 0.93 EF.

Data Explanation: Incremental cost ($90) from Amann et al. (2007). Measure life (14 years) from NYSERDA (2003). Market share (36%) estimated based on percent of products on the market meeting EF 0.93 in the GAMA product database (GAMA 2007).

Heat Pump Water Heater

Measure Description: 40-55 gallon heat pump water heater, 2.0 EF.

Data Explanation: Incremental cost ($814), measure life (13 years), and market share (5%) from Lowenberger et al (2012).

Compact Fluorescent Lighting

Measure Description: 22W CFL's replacing 70% of baseline lighting that isn't already CFL.

Data Explanation: Lamp installed base, wattage, and proportion of CFL's from Navigant study (2008) and ACEEE estimates of market changes since the release of the Navigant report. Negative incremental cost is due to the higher initial costs for CFLs being canceled out by the longer lifetime of CFLs.

LED Lighting

Measure Description: LED lighting replacing 30% of baseline lighting that isn't already CFL.

Data Explanation: Savings and market share from SWEEP (2012). The incremental cost was determined from ACEEE's analysis of market prices from common home improvement stores.

Efficient Refrigerator

Measure Description: ENERGY STAR 20-CF top-freezer refrigerator.

Data Explanation: Incremental cost ($34) and measure life (19 years) from ACEEE analysis for PG&E/CA Title 24 (PG&E 2007). Market share (28%) from Sanchez et al. (2007) appliance sales data.

Removal of Second Refrigerator

Measure Description: Removal service for homes with a second refrigerator.

Data Explanation: Average savings determined through TREAT. The incremental cost is assumed to be zero, because utilities typically offer an incentive to for refrigerator removal. Market share is zero, as there are no known programs currently being run in Kentucky.

Efficient Clothes Washer

Measure Description: ENERGY STAR clothes washer

Data Explanation: Incremental cost ($167) from Sanchez et al. (2007). Current market share (36%) from EPA (2007).

Efficient Dishwasher

Measure Description: ENERGY STAR dishwasher

Data Explanation: Incremental cost ($30) from DOE (2007). Market share (15%) from Sanchez et al. (2007).

Efficient Televisions

Measure Descriptions: ENERGY STAR televisions.

Data Explanation: Incremental cost ($50) from the incremental cost of 3 televisions ($25 each); ACEEE estimate. Current market share (25%) from ENERGY STAR 2006 appliance sales data.

One-Watt Standby for All Household Electronics

Measure Description: All new electronics devices required to have maximum "off" mode power level of 1 watt.

Data Explanation: New measure consumption (440 kWh) and baseline energy consumption (175 kWh) from Sachs et al. (2004). Current market share (34%) assumed by averaging market shares of all ENERGY STAR home electronics equipment.

Enhanced Billing and Home Energy Reports

Measure Description: Improved information on how energy is being used in the home included on the utility bills, along with customized home energy reports.

Data Explanation: Savings (1.9% of electricity use) from SWEEP (2012). Current market share (1%), measure life (11 years), and incremental cost ($250) from Eldridge et al (2009).

A.2. Commercial Buildings Sector

A.2.1. Electric Analysis

To estimate the resource potential for efficiency in commercial buildings in Kentucky, we first developed a disaggregate characterization of baseline electricity consumption in the state for current electricity use and a reference load forecast (see Table A-6 below). Highly disaggregated commercial electricity consumption data is unfortunately not available at the state level. To estimate these data, we started with current electricity consumption for the Kentucky commercial sector (EIA 2011) and a forecast out to 2030 based on DEDI projections, and we disaggregated by end-use using average regional data from CBECS 2003 (EIA 2006) and AEO 2011 (EIA 2011).

Table A-6. Baseline Commercial Electricity Consumption by End-Use (GWh)

End-Use	2010	%	2020	%	2030	%
Heating	798	4%	899	4%	880	4%
Cooling	2,539	13%	2,861	13%	2,879	12%
Ventilation	2,272	12%	2,559	12%	2,912	12%
HVAC subtotal	*5,609*	*29%*	*6,319*	*29%*	*6,671*	*27%*
Water Heating	429	2%	483	2%	509	2%
Refrigeration	2,079	11%	2,342	11%	2,353	10%
Lighting	5,740	30%	6,467	30%	7,015	29%
Office Equipment	1,409	7%	1,588	7%	1,863	8%
Other	4,102	21%	4,622	21%	6,203	25%
Total	**19,389**	**100%**	**21,846**	**100%**	**24,613**	**100%**

Next, we estimated commercial square footage in Kentucky using commercial square footage data for the East South Central census region from EIA 2011. We apportion this square footage to Kentucky based on employment data from Moody's Economy.com (Economy.com 2011a). We assume that the percentage of employment in the East South Central census region attributable to Kentucky is roughly equal to the percentage of commercial square floorspace attributable to the state. By multiplying this percentage to the total commercial square footage in the East South Central census region we calculated 1.02 billion square feet of commercial floorspace in the state.

A.2.1.1 Measure Cost-Effectiveness

We then analyzed thirty-eight efficiency measures for existing commercial buildings and three new construction whole-building measures to examine the cost-effective energy efficiency resource potential. For each efficiency measure, we estimated electricity savings (Annual Savings per Measure) and incremental cost (Measure Cost) in a "replacement on burnout scenario," which assumes that the product is replaced or the measure is installed at the end of the measure's useful life. Savings and costs are incremental to an assumed Baseline Measure. We estimated savings (kWh) and costs ($) on a per-unit and/or a per-square foot commercial floorspace basis. For each measure we also assumed a Measure Lifetime, or the estimated useful life of the product.

A measure is determined to be cost-effective if its levelized cost of saved energy, or cost of conserved energy (CCE), is less than 7.8 cents/kWh, the estimated current average commercial cost of electricity in Kentucky (DEDI 2011). The estimated CCE for each efficiency measure, which assumes a discount rate of 5%, are shown in the measure descriptions below. Equation 1 shows the calculation for cost of conserved energy.

Our assumed Baseline Measure, Annual Savings per Measure, Measure Cost, Measure Lifetime, and CCE are reported for each of the efficiency measures in the list of measure descriptions below. We group the thirty-eight efficiency measures for existing commercial buildings by end-use and list the three new building measures last.

Equation 1. CCE = PMT ((Discount Rate), (Measure Lifetime), (Measure Cost)) / (Annual Savings per Measure (kWh))

A.2.1.2. Total Statewide Resource Potential

For each measure, we derived Annual Savings per Measure on a per square foot basis (kWh per square foot) for the applicable end-use. For measures that we only have savings on a per-unit or per-building basis, we first derive the percent savings and multiply by the Baseline Electricity Intensity for that end-use. The assumed baseline intensities for each end use are shown in Table A-7. As an example, for a specific lighting measure we multiply its percent savings by the baseline electricity intensity (kWh per square foot) for the lighting end-use.

Table A-7. Commercial End-Use Baseline Electricity Intensities (kWh per s.f.)

End Use	2010 kWh/s.f.
Heating	0.67
Cooling	2.1
Ventilation	1.90
Water Heating	0.4
Cooking	0.1
Lighting	4.8
Refrigeration	1.74
Office Equipment	1.2
Other	3.3
HVAC Subtotal	4.7
Total	16.2

To estimate the total efficiency resource potential in existing commercial buildings in Kentucky by 2030, we first adjusted the individual measure savings by an Adjustment Factor (see Equation 2). This factor accounts for two adjustments: the technical feasibility of efficiency measures, called the Percent Applicable (the percent of Kentucky floorspace that satisfies the basecase conditions and other technical prerequisites such as heating fuel type and cooling equipment, etc.); and the Current Market Share, or the percent of products that already meet the efficiency criteria. These assumptions are outlined in each of the efficiency measure descriptions below.

Equation 2. Adjustment Factor = Percent Applicable x (1-Current Market Share)

We then adjusted total savings for interactions among individual measures. For example, we adjusted HVAC equipment savings downward to account for savings already realized through improved building envelope measures (insulation and windows), which reduce heating and cooling loads. Similarly, we adjusted water heating equipment savings to account for reduced water heating loads from the use of more efficient clothes washers. The multiplier for these adjustments is called the Interaction Factor.

Finally, we adjusted replacement measures with lifetimes more than 11 and 21 years to only account for the percent turning over in 11 and 21 years, which represents the benchmark years of 2020 and 2030, respectively. Note that the multiplier, Percent Turnover, is only applicable to products being replaced upon burnout and not retrofit measures such as insulation. These retrofit measures therefore have 100% of measures "turning over."

We then calculated the resource potential for each measure in the state using Equation 3, which takes into account all of the adjustments described above. The sum of the resource potential from all measures is the overall energy efficiency resource potential in the state's commercial buildings sector.

Equation 3. Efficiency Resource Potential in 2020 and 2030 (GWh) = (Annual Savings per Measure (kWh per square foot)) x (Commercial floor space in Kentucky in millions of square feet) x (Percent Applicable) x (Interaction Factor) x (Percent Turnover)

A.2.1.3 Efficiency Measures

Below we present the forty-one efficiency measures examined for this analysis, grouped by end-use costs, savings (kWh) per product or square foot, *Percent Applicable, Interaction Factor, Percent Turnover,* and total savings potential (GWh) in 2030. Detailed descriptions of each measure are given below, grouped by end-use.

Building Shell Improvements

Cool Roof

Measure Description: This measure involves installing a sun-reflective coating on the roof of a building with a flat top. This reduces air conditioning energy loads by reducing the solar energy absorbed by the roof.

Basecase: The baseline electricity intensity for HVAC end uses in Kentucky (4.7 kWh/ft^2/year) is used as the basecase.

Data Explanation: We assume 4% HVAC load savings (ACEEE 1997) off the baseline electricity intensity for HVAC end-uses in Kentucky (EIA 2006), an incremental cost of \$0.25/ft^2 (SWEEP 2002), and a 20-year average lifetime (SWEEP 2002). Percent applicable (80%) is an ACEEE estimate. Savings and cost per unit are based on a 15,000 ft^2 building (ACEEE 1997). The levelized cost is calculated to be 5.5 cents/kWh.

Roof Insulation

Measure Description: Fiberglass or cellulose insulation material in roof cavities will reduce heat transfer, though the type of building construction limits insulation possibilities. R-values describe the performance factor for insulation levels.

Basecase: The basecase electricity intensity for this measure was disaggregated from the post-savings electricity intensity and the percentage of savings.

Data Explanation: We assume 3% savings and a post-savings electricity intensity of 0.28 kWh/ft^2/year, based on an average of four building types (ACEEE 1997). An average lifetime of 25 years (CL&P 2007) and an incremental cost of 11 cents/s.f. were also assumed. The measure is shared with gas savings as well, so the portion of the incremental cost attributed to electric savings is 6 cents/s.f. The levelized cost is 1.7 cents/kWh.

Double Pane Low-Emissivity Windows

Measure Description: Double-pane windows have insulating air- or gas-filled spaces between each pane, which resist heat flow. Low-emissivity (low-e) glass has a special surface coating to reduce heat transfer back through the window, and a window's R-value represents the amount of heat transfer back through a window. Low-e windows are particularly useful in climates with heavy cooling loads, because they can reflect anywhere from 40% to 70% of the heat that is normally transmitted through clear glass. The Solar Heat Gain Coefficient (SHGC) represents the fraction of solar energy transferred through a window. For example, a low-e window with a 0.4 SHGC keeps out 60% of the sun's heat.

Basecase: The basecase electricity intensity for this measure was disaggregated from the post-savings electricity intensity and the percent savings.

Data Explanation: Percent savings of 3% apply to whole-building electricity consumption (ACEEE 1997). Incremental costs assume \$2 per square foot of window (SWEEP 2002). This measure is shared with gas savings as well. A measure life of 25 years is from SWEEP (2002). Percent applicable is an ACEEE estimate. The levelized cost is calculated to be 1.1 cents/kWh.

Heating and Cooling Measures: Equipment and Controls

Duct Testing and Sealing

Measure Description: Testing and sealing air distribution ducts saves energy. This measure assumes supply and return ducts will be fully sealed.

Basecase: The basecase assumes air loss of 29% of fan flow, and leakage of 15% of the system flow.

Data Explanation: Percent savings of 6% apply to whole-building electricity consumption (SWEEP 2002). An incremental cost of $3,375, which assumes $300 per ton, a 10 year lifetime, and 25% applicability are ACEEE estimates. The levelized cost is calculated to be 1.1 cents/kWh.

Primary Air-Handler Fans with Variable-Frequency Drive

Measure Description: Variable Frequency Drive (VFD) controls the speed of a motor by adjusting the frequency of incoming power. By controlling the speed of a motor, the output of the system can be matched to the requirements of the process, thereby improving efficiency.

Basecase: The basecase unit is a 50 hp fan with 60% load factor, 93% efficiency (ODP, EPAct levels) and 3653 operating hours/year (21-50 hp category from ACEEE standards savings analysis).

Data Explanation: We assume 25% savings applies to ventilation only (ACEEE 1997), which is a conservative estimate. We estimate a $6,650 incremental cost, which assumes $125/hp for VFD and $8/hp for a better fan, and a 10-year measure life (SWEEP 2002). ACEEE estimates that this measure can apply to 40% of systems. The levelized cost is calculated to be 3.9 cents/kWh.

High-Efficiency Unitary AC/HP

65,000 Btu – 135 Btu
135,000 Btu – 240,000 Btu

Measure Description: Unitary packaged air conditioners and heat pumps represent the heating, ventilating, and air conditioning (HVAC) equipment class with the greatest energy use in the commercial sector in the United States, and are used in approximately 48 percent of the cooled floor space in the commercial sector (DOE 2004). High efficiency units have a greater energy efficiency ratio (EER).

Basecase: The assumed basecase unit meets the 2010 federal efficiency standard. Baseline electricity intensity for this end-use, 4.9 kWh/ft^2, is the estimated HVAC consumption in commercial buildings in Kentucky. This is data from the West South Central census division from EIA's commercial buildings survey (EIA 2006).

Data Explanation: This measure includes two size ranges; the first is 65,000 Btu to 135,000 Btu, and the second is 135,000 Btu to 240,000 Btu. The measure assumes a 12 EER unit relative to the 2010 federal standard, which ranges from about 10.4 EER to 11.2 EER, depending on the unit type and size. The energy savings average 1,070 kWh (7.2%) for the smaller unit and 3,371 kWh (10.8%) for the larger unit. We assume a measure lifetime of 15 years (LBNL 2003). Incremental costs (average $629 for 65 kBtu to135 kBtu and $1,415 for 135 kBtu to 240 kBtu) are derived from DOE's Technical Support Document (DOE 2004). Percent applicable (33% for 65 kBtu to 135 kBtu and 15% for 135 kBtu to 240 kBtu), and the percent of floorspace with cooling from unitary equipment are also from DOE's Technical Support Document (DOE 2004). The levelized cost is calculated to be 4–5.7 cents/kWh, depending on unit type and size.

High-Efficiency Packaged Terminal AC/HP

Measure Description: PTACs and PTHPs are self-contained heating and air-conditioning units encased inside a sleeve specifically designed to go through the exterior building wall. The basic design of a PTAC is comprised of a compressor, an evaporator, a condenser, a fan, and an enclosure. They are primarily used to provide space conditioning for commercial facilities such as hotels, hospitals, apartments, dormitories, schools, and offices. High-efficiency units have a higher energy efficiency ratio (EER) for cooling units and coefficient of performance (COP) for heat pumps.

Basecase: Consistent with all HVAC-related measures, the baseline electricity intensity is 4.7 kWh/ft^2, which is the estimated HVAC consumption in commercial buildings in Kentucky. This is based on the East South Central region from EIA's commercial buildings survey (EIA 2006).

Data Explanation: We assume that high efficiency units save an average of 7.8%, or 226 kWh per unit, relative to a basecase, which is based on an ACEEE submission to ASHRAE using web data. The measure life is 15 years (ANSI/ASHRAE 1999). Percent applicable is 5%, which is the percent of cooling floorspace from packaged terminal units (ADL 2001). The levelized cost is calculated to be 3.8 cents/kWh.

Efficient Room Air Conditioner

Measure Description: An ENERGY STAR room AC must be at least a 10% improvement over the 2000 federal standard (an average 8000 Btu unit must have a 10.8 EER).

Basecase: The assumed basecase unit is a room AC that meets 2000 federal energy standards (an average 8000 Btu unit has a 9.8 EER) and uses an average of 677 kWh per unit. Baseline electricity intensity for this end-use, 2.1 kWh/ft^2, is the estimated cooling consumption in commercial buildings in Kentucky. This is based on the East South Central census division from EIA's commercial buildings survey (EIA 2006).

Data Explanation: We assume an ENERGY STAR room AC uses 590 kWh per year, saves 13% of basecase energy, and has an incremental cost of $35 (ENERGY STAR calculator). We assume a measure life of 13 years (ENERGY STAR calculator), a current market share of 52% (EPA 2007), and percent applicable assumes 8% percent of cooling floorspace uses room AC units (ADL 2001). The levelized cost is calculated to be 4.3 cents/kWh. This measure is applicable only from 2010 through the end of 2013.

2014 Efficient Room Air Conditioner

Measure Description: A room AC with higher efficiency than the 2014 federal standard (an 8000 Btu unit must have a 10.9 CEER).

Basecase: The assumed basecase unit is a room A/C that meets 2014 federal energy standards (an 8000 Btu unit must meet 10.9 CEER) and uses an average of 969 kWh per unit in commercial applications. Baseline electricity intensity for this end-use, 2.1 kWh/ft^2, is the estimated cooling consumption in commercial buildings in Kentucky. This is based on the East South Central census division from EIA's commercial buildings survey (EIA 2006).

Data Explanation: We assume a moderate increase in efficiency to 11.5 CEER, which saves 51 kWh/year, or 5% of annual energy consumption. This efficiency level carries an incremental cost of $28 (DOE 2011). We assume a measure life of 13 years (ENERGY STAR calculator), a current market share of 52% (EPA 2007), and percent applicable assumes 8% percent of cooling floorspace uses room AC units (ADL 2001). The levelized cost is calculated to be 5.8 cents/kWh. This measure is applicable only from 2014 through 2030.

High-Efficiency Chiller

Measure Description: "Chillers" are the hearts of very large air-conditioning systems for buildings and campuses with central chilled water systems. A centrifugal chiller utilizes the vapor compression cycle to chill water and reject the heat collected from the chilled water plus the heat from the compressor to a second water loop controlled by a cooling tower.

Basecase: The basecase unit assumes 0.634 kW/ton T24 from DEER for an average 150 ton system and 1,593 national average full-load operating hours from the ASHRAE 90.1-1999 analysis. Baseline electricity intensity for this end-use, 4.7 kWh/ft^2, is the estimated HVAC consumption in commercial buildings in Kentucky. This is based on the East South Central census division from EIA's commercial buildings survey (EIA 2006).

Data Explanation: We assume the new measure has 20% savings, which is derived from estimates provided in SWEEP (2002) and ACEEE (1997). The lifetime estimate of 23 years is from the ASHRAE Handbook (ASHRAE 2007). Incremental costs are $9,900 and assume a 150 ton average unit (CEC 2005). Percent applicable (33%) assumes percentage of cooling floorspace using chillers (ADL 2001). The levelized cost is calculated to be 2.4 cents/kWh.

Dual-Enthalpy Economizer

Measure Description: Economizers modulate the amount of outside air introduced into the ventilation system based on the relative temperature and humidity of the outside and return air. If the enthalpy, or the latent and sensible heat, of the outside air is less than that of the return air when space cooling is required, then the outside air is allowed to reduce or eliminate the cooling requirement of the AC equipment.

Basecase: Baseline electricity intensity, 2.1 kWh/ft^2, is the estimated cooling intensity in commercial buildings in Kentucky. This is based on the East South Central census division from EIA's commercial buildings survey (EIA 2006).

Data Explanation: Savings per unit assume 276 kWh (20% savings) per ton for an average 11-ton unit (CL&P 2007). Average measure life is 10 years (CL&P 2007). Incremental costs per unit are from NYSERDA (2003). Percent applicable is the portion of cooling square footage represented by packaged AC and HP units, and assumes that 90% of these unitary systems could benefit from economizers (ACEEE estimate). It also assumes a 5% current market share (ACEEE estimate). The levelized cost is calculated to be 3.8 cents/kWh.

Demand-Controlled Ventilation

Measure Description: Often, HVAC systems are designed to supply ventilated air based on assumed occupancy levels, resulting in over-ventilation. Demand-controlled ventilation monitors CO_2 levels in different zones and delivers the required ventilation only when and where it is needed.

Basecase: The basecase is standard ventilation electricity consumption for a 50,000 ft^2 office building, or about 40,000 kWh/year (Sachs et al. 2004). Baseline electricity intensity for this end-use, 1.9 kWh/ft^2, is the estimated ventilation consumption in commercial buildings in Kentucky. This is based on the East South Central census division from EIA's commercial buildings survey (EIA 2006).

Data Explanation: We assume 20% savings for this measure (Sachs et al. 2004). Energy use per unit is 32,000 kWh/year, assuming a 50,000 ft^2 building (Sachs et al. 2004). The lifetime estimate is 15 years, and incremental costs are $3,450 (Sachs et al. 2004). The measure is applicable to 90% of larger (60%) cooling units (Sachs et al. 2004). The levelized cost is calculated to be 4.2 cents/kWh.

HVAC Tune-Up

Measure Description: Most HVAC technicians lack interest, training, equipment and methods to perform quality refrigerant charge and airflow (RCA) tune-ups. Because many new and existing air conditioners have improper RCA, which reduces efficiency, there is significant potential for energy savings by diagnosing and correcting RCA.

Basecase: The assumed basecase unit is a 4.5 ton commercial unitary AC/HP per California program experience (CPUC 2006), estimated to use 8,396 annual kWh per the unitary AC/HP measure. The base electricity intensity for the HVAC end-use is 4.1 kWh/ ft^2, the average for small buildings less than 25,000 ft^2, for which this measure is applicable.

Data Explanation: We assume 11% percent savings from this measure according to California's DEER database (CEC 2005) and the California Refrigerant and Air Charge (RCA) program report (CPUC 2006). We assume that 60% of units have improper RCA (CPUC 2006), and therefore this measure is applicable to 60% of unitary HVAC units in buildings less than or equal to 25,000 ft^2 (EIA 2006; average of south and mid-Atlantic regions). We estimate an average measure life of 3 years, as units need to be periodically re-tuned. We assume a cost of $158 for this measure, based on a $35/ton labor cost (CEC 2005) and an assumed 4.5-ton unit. The levelized cost is calculated to be 6.3 cents/kWh.

Retrocommissioning

Measure Description: Commercial building performance tends to degrade over time, and many new buildings do not perform as designed, requiring periodic upgrades to restore system functions to optimal performance. Retrocommissioning (RCx) is a systematic process to optimize building performance through O&M tune-up activities and diagnostic testing to identify problems in mechanical systems, controls, and lighting. The best candidates for RCx are buildings over 50,000 or 100,000 ft^2.

Basecase: The baseline is electricity intensity for HVAC and lighting end-uses in buildings greater than 50,000 ft^2 (10 kWh/ ft^2), which is based on data from CBECS (EIA 2006). We take the average of the East South Central census division to estimate electricity intensity in Kentucky buildings.

Data Explanation: We assume 10% savings for HVAC and lighting end-uses (Sachs et al. 2004) in all commercial floorspace for buildings greater than 100,000 ft^2, and 50% of floorspace in buildings 50,000 ft^2 or greater based on data from CBECS (EIA 2006). Xcel Energy's RCx program results estimate an average RCx useful life of 7 years (Xcel Energy 2006). We assume a $0.14 cost per ft^2 (Sachs et al. 2004). The cost is shared with gas savings from the same measure, so the actual cost for electric savings is $0.13/s.f. The levelized cost is calculated to be 2.2 cents/kWh.

Water Heating Measures

Heat Pump Water Heater

Measure Description: A heat pump water heater uses electricity to move heat from one place to another, rather than a less efficient electric resistance water heater which uses electricity to generate the heat directly. The heat source is the outside air or air in the basement where the unit is located.

Basecase: The basecase is standard electric water heating, with electricity consumption of 28,310 kWh/year (derived from energy savings and percent savings). Baseline electricity intensity for this end-use, 0.36 kWh/ft^2, is the estimated water heating intensity in commercial buildings in Kentucky. This is based on the East South Central region from EIA's commercial buildings survey.

Data Explanation: We assumed a 50% savings, based on a simple coefficient of performance ratio. The assumed 14,155 kWh savings, $4,067 incremental cost, and 12 year lifetime estimates are from NYSERDA (2003). Percent applicable is based on engineering estimates for NYSERDA (2003), which assumes the measure is applicable to 70% of food service floorspace and 30% of lodging, education, and health care floorspace. Percent applicable is then multiplied by 2, since these building types are more energy and hot-water intensive than the average commercial building. The levelized cost is calculated to be 3.2 cents/kWh.

Efficient Commercial Clothes Washer (Water Heating Portion)

Measure Description: A high-efficiency commercial clothes washer saves both energy and water, and as a result reduces water heating loads. For a high-efficiency clothes washer, we assume a unit with an MEF of 2.0, which represents about 80% of products on ENERGY STAR's product lists.

Basecase: The basecase unit is a clothes washer that meets DOE's federal efficiency standard of 1.26 MEF. An average unit consumes 1,136 kWh annually for water heating, which is derived from DOE (2007). Baseline electricity intensity for this end-use is 0.36 kWh/ft^2/year (water heating portion only).

Data Explanation: Savings on electric water heating from this measure assume a 2.0 MEF clothes washer uses an average 431 kWh annually, for a 62% savings, which is derived from DOE's TSD (DOE 2007). We assume the measure is applicable to the 17% of units that have electric water heating, and assume a 20% market share of efficient products. The overall stock estimate is based on national stock data (DOE 2007) and prorated to Kentucky based on commercial building floorspace. We assume an incremental cost for an efficient unit is $316 and an 11-year measure life (DOE 2007). The levelized cost is calculated to be 3.2 cents/kWh. This measure is applicable from 2010 through the end of 2012.

2013 Efficient Commercial Clothes Washer (Water Heating Portion)

Measure Description: A commercial clothes washer that achieves higher efficiency than the 2013 federal standard, with a weighted average MEF of 2.2.

Basecase: The basecase unit is a clothes washer that meets DOE's 2014 federal efficiency standard of 1.74 MEF (weighted average of top- and front-loading models). An average unit consumes 600 kWh annually for water heating, which is derived from DOE (2009). Baseline electricity intensity for this end-use is 0.36 kWh/ft^2/year (water heating portion only).

Data Explanation: Savings on electric water heating from this measure assume a 2.2 MEF clothes washer uses an average 360 kWh annually, for a 40% savings, which is derived from DOE's TSD (DOE 2009). We assume the measure is applicable to the 17% of units that have electric water heating, and assume a 20% market share of efficient products. The overall stock estimate is based on national stock data (DOE 2007) and prorated to Kentucky based on commercial building floorspace. We assume an incremental cost for an efficient unit is $63 and an 11-year measure life (DOE 2007). The levelized cost is calculated to be 0.7 cents/kWh. This measure is applicable only from 2013 through 2030.

Refrigeration Measures

Efficient Walk-In Refrigerators & Freezers

Measure Description: Walk-in refrigerators and freezers (walk-ins) are medium and low-temperature refrigerated spaces that can be walked into, and that are used to maintain the temperature of pre-cooled materials (not to rapidly cool down materials from warmer temperatures). A high-efficiency walk-in is defined as meeting the 2004 CEC standard for walk-ins. This includes prescriptive requirements such as higher levels of insulation, motor types, and the use of automatic door-closers (Nadel et al. 2006).

Basecase: The baseline energy use for an average walk-in is 18,859 kWh/year (Nadel et al. 2006). Baseline electricity intensity for this end-use, 1.74 kWh/ft^2, is the estimated refrigeration energy intensity in commercial buildings in Kentucky. This is based on the East South Central division from EIA's commercial buildings survey.

Data Explanation: For a high-efficiency walk-in unit, we assume 44% savings over a baseline unit, or 8220 kWh/year, $957 incremental cost, and a 12 year measure lifetime (Nadel et al. 2006), which are based on PG&E (2008). We estimate percent applicable as the 18% of refrigeration energy use attributed to walk-ins (ADL 1996) and estimate a 50% current market share of high-efficiency products (ACEEE estimate). The levelized cost is calculated to be 1.3 cents/kWh.

Efficient Reach-In Coolers & Freezers

Measure Description: This measure includes high-efficiency packaged commercial reach-in refrigerators and freezers with solid doors, and refrigerators with transparent doors such as beverage merchandisers. High-efficiency units are those that meet the CEE Tier 2 performance standard, as estimated in PG&E (2005).

Basecase: We assume a baseline unit that meets the 2010 federal standard and uses 4,027 kWh per year. This is weighted by sales of unit type per PG&E (2004b). Baseline electricity intensity for this end-use, 1.74 kWh/ft^2, is the estimated refrigeration energy intensity in commercial buildings in Kentucky. This is based on the East South Central division from EIA's commercial buildings survey.

Data Explanation: The savings estimate for a high-efficiency unit, 31% savings or 1,268 kWh per year, is a weighted average of different types of reach-ins that meet CEE's Tier 2 performance standard (PG&E 2004a). We estimate an average lifetime of 9 years and an incremental cost of $177, both per PG&E (2004a). We estimate percent applicable as the percent of refrigeration energy use attributed to reach-ins and beverage merchandisers, or 17% (ADL 1996), and assume a 10% current market share of high-efficiency products per PG&E (2004a). The levelized cost is calculated to be 2.0 cents/kWh.

Efficient Ice-Maker

Measure Description: Commercial ice makers, which are used in hospitals, hotels, and food service and preservation, have energy savings potential largely in their refrigeration systems. We assume an efficient icemaker meets CEC's Tier 2 level of energy savings, which incorporate improved compressors, heat exchangers, and controls, as well as better insulation and gaskets.

Basecase: The baseline energy use, 3,338 kWh per year, is a weighted average of different types of ice-makers that meet the 2010 federal standard. Baseline electricity intensity for this end-use, 1.74 kWh/ft^2, is the estimated refrigeration energy intensity in commercial buildings in Kentucky. This is based on the East South Central region from EIA's commercial buildings survey.

Data Explanation: The 16% savings estimate for a high-efficiency unit, or 542 kWh per year, is a weighted average of different types of ice-makers that meet CEC's tier 2 energy savings (PG&E 2004a. We estimate an average lifetime of 10 years and an incremental cost of $100, both per PG&E (2005). We estimate percent applicable as the percent of refrigeration energy use attributed to ice-makers, or 10% (ACEEE estimate), and assume a 10% current market share of high-efficiency products per PG&E (2004a) and ACEEE judgment. The levelized cost is calculated to be 2.4 cents/kWh.

Efficient Built-Up Refrigeration System

Measure Description: Built-up or supermarket refrigeration systems are primarily made up of refrigerated display cases for holding food for self-service shopping, as well as machine room cooling technologies. More efficient built-up systems include improved machine room technologies (evaporative condensers, mechanical sub-cooling, and heat reclaim), high-efficiency evaporative fan motors, hot gas defrost, liquid-suction heat exchangers, antisweat control, and defrost control.

Basecase: The measure baseline is 1,600,000 kWh for a 45,000 ft^2 supermarket with a built-up refrigeration system. Baseline electricity intensity for this end-use, 1.74 kWh/ft^2, is the estimated refrigeration energy intensity in commercial buildings in Kentucky. This is based on the East South Central division from EIA's commercial buildings survey.

Data Explanation: Per-unit savings of 336,000 kWh (21%) are from ADL 1996 and assume an average new 45,000 ft^2 supermarket with a 5-year payback. We estimate percent applicable as the percent of refrigeration energy use attributed to built-up refrigeration, or 33% (ADL 1996). Incremental cost ($37,000) and lifetime (10 years) are from ADL 1996. The levelized cost is calculated to be 1.4 cents/kWh.

Efficient Vending Machine

Measure Description: ENERGY STAR vending machines must consume 50% less energy than standard machines. Under the Tier II ENERGY STAR level, this translates to a maximum energy consumption of 2309 kWh/year for a 600-can machine.

Basecase: A Tier I ENERGY STAR level vending machine is assumed to be the basecase. On average, it uses 2,816 kWh per year (ENERGY STAR calculator for a 600 can machine). Baseline electricity intensity for this end-use, 1.74 kWh/ft^2, is the estimated refrigeration energy consumption in commercial buildings in Kentucky. This is based on the East South Central division from EIA's commercial buildings survey.

Data Explanation: Per unit savings of 18% (507 kWh/year) are estimated from ASAP (2007) based on ENERGY STAR calculator estimates. Likewise, an incremental cost of $30, and a lifetime estimate of 10 years are from ASAP (2007). We estimate percent applicable as the percent of refrigeration energy use attributed to built-up refrigeration, or 13% (NYSERDA 2003). The levelized cost is calculated to be 0.8 cents/kWh.

Vending Miser

Measure Description: A Vending Miser is an energy control device for refrigerated vending machines. Using an occupancy sensor, the control turns off the machine's lights and duty cycles the compressor based on ambient air temperature.

Basecase: The basecase unit is an efficient vending machine that meets the ENERGY STAR tier II level and uses 2,309 kWh per year (ENERGY STAR calculator for a 600 can machine). Baseline electricity intensity is for the refrigeration end-use (1.74 kWh/ ft^2).

Data Explanation: We assume 35% savings for this measure based on manufacturer data (USA Technologies 2008), an incremental cost of $167 (NYSERDA 2003), and a measure life of 10 years (NYSERDA 2003). The levelized cost is calculated to be 2.7 cents/kWh.

Appliances

Efficient Hot Food Holding Cabinets

Measure Description: Commercial hot food holding cabinets are used in the commercial kitchen industry primarily for keeping food at safe serving temperature, without drying it out or further cooking it. These cabinets can also be used to keep plates warm and to transport food for catering events. High efficiency models differ mainly in that they are better insulated.

Basecase: The basecase unit is an uninsulated cabinet that consumes 5,190 kWh per year. This was calculated from PG&E (2004b) using a simple average of three sizes of cabinets, and then weighting the average using CASE figures for insulated cabinets.

Data Explanation: The energy savings from an insulated holding cabinet are 1,815 kWh per year (35% savings), with an incremental cost of $453, and an estimated 15 year lifetime (Neubauer et al. 2009). Percent applicable refers to the 25% of holding cabinets that are currently uninsulated (Neubauer et al. 2009). The levelized cost is calculated to be 2.4 cents/kWh.

Efficient Commercial Clothes Washer (excluding hot water energy)

Measure Description: A high-efficiency commercial clothes washer saves both energy and water. For a high-efficiency clothes washer, we assume a unit with an MEF of 2.0, which represent about 80% of products on ENERGY STAR's product lists.

Basecase: The basecase unit is a clothes washer that meets DOE's federal efficiency standard of 1.26 MEF. An average unit consumes 1,530 kWh annually for non-water heating uses, which is derived from DOE 2007.

Data Explanation: Electric savings from this measure assume a 2.0 MEF clothes washer uses an average 1,186 kWh annually, for a 22% savings, which is derived from DOE's TSD (DOE 2007). We assume the measure is applicable to the 37% of units that have electric dryer heating (removal of moisture from clothes), and assume a 20% market share of efficient products. The overall stock estimate is based on national stock data (DOE 2007) and prorated to Kentucky based on commercial building floorspace. We assume an incremental cost for an efficient unit is $316 and an 11-year measure life (DOE 2007). The levelized cost is calculated to be 3.2 cents/kWh. This measure is applicable from 2010 through the end of 2012.

2013 Efficient Commercial Clothes Washer (excluding hot water energy)

Measure Description: A commercial clothes washer that achieves higher efficiency than the 2013 federal standard, with a weighted average MEF of 2.2.

Basecase: The basecase unit is a clothes washer that meets DOE's 2013 federal efficiency standard of 1.74 MEF (weighted average of top- and front-loading models). An average unit consumes 1,294 kWh annually for non-water heating uses, which is derived from DOE 2009.

Data Explanation: Electric savings from this measure assume a 2.0 MEF clothes washer uses an average 1,107 kWh annually, for a 14% savings, which is derived from DOE's TSD (DOE 2009). We assume the measure is applicable to the 37% of units that have electric dryer heating (removal of moisture from clothes), and assume a 20% market share of efficient products. The overall stock estimate is based on national stock data (DOE 2007) and prorated to Kentucky based on commercial building floorspace. We assume an incremental cost for an efficient unit is $63 and an 11-year measure life (DOE 2007). The levelized cost is calculated to be 0.6 cents/kWh. This measure is applicable only from 2013 through 2030.

Lighting Measures

Fluorescent Lighting Improvements

Measure Description: The new measure assumes extra-efficient ballasts and high-lumen lamps are installed with the ballast factor of new ballasts chosen to provide the right amount of light for an application.

Basecase: Basecase watts per square foot reflects current installed fixtures. This includes 84,000 kWh used annually for fluorescent lighting per average 14,000 ft^2 commercial building (Navigant 2002). On average, fluorescent lights are operated 9.7 hours/day. We assume 2-lamp standard T8 fixtures and electronic ballasts as the baseline, plus a small number of existing 3-lamp T12 fixtures with magnetic ballasts that are not likely to be replaced in the absence of programs over the time horizon.

Data Explanation: We assume a percent savings of 27%. The incremental costs are $2 extra per ballast, and $1 extra for each of 2 lamps. The percent applicable (56%) is the fluorescent percent of total commercial lighting kWh (Navigant 2002). The levelized cost is calculated to be 0.7 cents/kWh.

HID Lighting Improvements

Measure Description: Metal halide lamps produce light by passing an electric arc through a mixture of gases. Efficiency improvements in metal halide lamps include pulse start lamp technology, electronic ballasts, and improved fixtures.

Basecase: Same basecase as fluorescent lighting improvements.

Data Explanation: The new measure savings and costs are from a PG&E CASE study on Metal Halide Lamps & Fixtures (PG&E 2004c). Energy savings were 447 kWh per year (26%), and incremental costs were $60. Percent applicable (12%) is the percentage of commercial electricity use for lighting that comes from HIDs (Navigant 2002). The levelized cost is calculated to be 6.3 cents/kWh.

Replace Incandescent Lamps with CFLs

Measure Description: We assume that 32% of lighting in the commercial sector is incandescent (Navigant 2002). The new measure assumes that 70% of current incandescents are replaced with CFLs.

Basecase: The basecase is an electric load of 2.0 kWh/s.f. This represents the amount of energy used for incandescent lighting in the average commercial building, and is derived from the average number of lamps, the average lamp wattage, and the average annual operating time (Navigant 2002).

Data Explanation: Energy savings are 1.5 kWh/s.f. annually, or 72%. This equates to annual per unit savings of 223 kWh. Incremental costs include $10 in the cost of a CFL, but save $8 in labor for replacing every 4 bulbs. ACEEE estimates that 70% of sockets are applicable for the new measure. The levelized cost is calculated to be 0.2 cent/kWh. This measure is applicable from 2010 through the end of 2012.

2013 Replace Incandescent Lamps with CFLs

Measure Description: We assume that 32% of lighting in the commercial sector is incandescent (Navigant 2002). The new measure assumes that 70% of current incandescents are replaced with CFLs.

Basecase: As federal standards phase in, the basecase load for incandescent lighting falls to 1.4 kWh/s.f. This represents the amount of energy used for incandescent lighting in the average commercial building, and is based on an interpolation of data from Navigant (2002).

Data Explanation: Energy savings are 0.9 kWh/s.f. annually, or 61%. This equates to annual per unit savings of 136 kWh. Incremental costs include $10 in the cost of a CFL, but save $8 in labor for replacing every 4 bulbs. ACEEE estimates that 70% of sockets are applicable for the new measure. The levelized cost is calculated to be 0.3 cent/kWh. This measure is applicable from 2013 through the end of 2019.

2020 Replace Incandescent Lamps with CFLs

Measure Description: We assume that 32% of lighting in the commercial sector is incandescent (Navigant 2002). The new measure assumes that 70% of current incandescents are replaced with CFLs.

Basecase: Based on expected 2020 lighting standards, the basecase load for incandescent lighting is further reduced to 1.1 kWh/s.f. This represents the amount of energy used for incandescent lighting in the average commercial building, and is based on an interpolation of data from Navigant (2002).

Data Explanation: Energy savings are 0.5 kWh/s.f. annually, or 72%. This equates to annual per unit savings of 82 kWh. Incremental costs include $10 in the cost of a CFL, but save $8 in labor for replacing every 4 bulbs. ACEEE estimates that 70% of sockets are applicable for the new measure. The levelized cost is calculated to be 0.5 cent/kWh. This measure is applicable from 2020 through 2030.

Replace Incandescent Lamps with LEDs

Measure Description: The new measure assumes that 20% of current incandescents (10% low-wattage and 10% miscellaneous) are used for display lighting, and can be replaced with LED lights.

Basecase: The basecase is 0.23 kWh/s.f. annually. This is derived from the average wattage of quartz halogen, low-wattage, and average incandescents; the average number of each type of bulb in a commercial building; and the average annual operating time (Navigant 2002).

Data Explanation: Energy savings are 0.2 kWh/s.f. annually, or 88%, assuming LED replacement wattages as indicated by Navigant (2008). Incremental costs include $0.05/s.f., a weighted average of the costs of each bulb, and including a $32 labor savings for replacing each bulb. The LED prices were calculated using average efficacy and $/klm projections for 2010 (Navigant 2008). Percent applicable assumes that 100% of these specific bulbs are replaceable (Navigant 2008). Between this measure and the previous measure (replacing incandescents with CFLs), 90% of incandescents are assumed to be replaceable, allowing 10% of incandescents (for specialty applications) to remain. The levelized cost is calculated to be 3.7 cents/kWh.

Occupancy Sensor for Lighting

Measure Description: Installation of occupancy sensors can greatly reduce lighting energy demands in commercial spaces, by automatically turning off lights in unoccupied spaces.

Basecase: Same basecase as fluorescent lighting improvements.

Data Explanation: Energy savings of 361 kWh per year (NYSERDA 2003) assumes 30% energy reduction in individual offices and rooms and 7.5% reduction in open spaces (ACEEE estimate). Incremental cost ($48) and lifetime (10 years) estimates are from NYSERDA (2003). Percent applicable (38%) is from Sachs et al. (2004). The levelized cost is calculated to be 1.7 cents/kWh.

Daylight Dimming System

Measure Description: A daylight dimming system automatically dims electric lights to take advantage (or "harvest") natural daylight.

Basecase: Same basecase as fluorescent lighting improvements

Data Explanation: Energy savings are estimated to be 143 kWh per year, or 35% (NYSERDA 2003). Savings apply for lamps on the perimeters of buildings (25% applicable—PIER 2003). Incremental cost ($68) and lifetime (20 years) estimates are from NYSERDA (2003). The levelized cost is calculated to be 3.8 cents/kWh.

Outdoor Lighting—Controls

Measure Description: This measure includes a variety of lighting control technologies for exterior lights.

Basecase: No basecase data was available for this measure.

Data Explanation: We assume a savings of 174 kWh, or 20%, from lighting controls. Incremental costs of $43 are from DEER 2001 and assume each control on average controls three fixtures. Percent applicable of 30% is an ACEEE estimate. Number of installed units is based on national stock for parking and roadway from Navigant (2002), apportioned to Kentucky based on commercial floorspace. The levelized cost is calculated to be 2.5 cents/kWh.

Miscellaneous

Office Equipment

Measure Description: This measure assumes a high-efficiency fax, printer, computer display, internal power supply, and a low mass copier.

Basecase: Baseline electricity use is 2886 kWh per year (NYSERDA 2003). Baseline electricity intensity for this end-use, 1.2 kWh/ft^2, is the estimated office equipment energy intensity in commercial buildings in Kentucky. This is based on the East South Central Division from EIA's commercial buildings survey.

Data Explanation: Energy savings were 1410 kWh per year (49%), lifetime was 5 years, and incremental costs were $20. Percent applicable is estimated to be (50%) (NYSERDA 2003). The levelized cost is calculated to be 0.3 cents/kWh.

Turn Off Office Equipment after Hours

Measure Description: This measure involves turning off, or putting into a low-power state: vending machines, computers, monitors, printers and copiers.

Basecase: Baseline electricity use is 1.2 kWh/ft^2, based on data from CBECS, LBNL, and ENERGY STAR.

Data Explanation: Energy savings were 6763 kWh per year (40%), lifetime was 20 years, and incremental costs were $0. Percent applicable is 100%, as data for the savings already took into account the number of buildings that already shut down equipment after hours. The levelized cost is $0/kWh

New Buildings

Efficient New Building (15% Savings)

Measure Description: Incorporating energy efficiency into building design is best achieved at the time of construction. New buildings can achieve major energy savings in heating and cooling, as well as energy-saving appliances.

Basecase: Basecase of 15.1 kWh/ft^2 is an estimate of HVAC, water heating, and lighting end-use electricity intensity for new buildings in Kentucky, derived from data for buildings built from 2000–2003 (EIA 2006).

Data Explanation: Incremental cost of $0.35 per ft^2 and measure life of 17 years are from NGRID (2007). The cost is shared with gas savings from the same measure, so the actual cost for electric savings is $0.18. Percent applicable of 18% for this new buildings measure assume that 30% and 50% new buildings savings are phased in one to two years prior to enactment of codes in the policy scenarios (30% in 2012 and 50% in 2020). The levelized cost is calculated to be 0.7 cents/kWh.

Efficient New Building (30% Savings)

Measure Description: Incorporating energy efficiency into building design is best achieved at the time of construction. New buildings can achieve major energy savings in heating and cooling, as well as energy-saving appliances.

Basecase: Basecase of 15.1 kWh/ft^2 is an estimate of HVAC, water heating, and lighting end-use electricity intensity for new Kentucky buildings, derived from data for buildings built from 2000–2003 (EIA 2006).

Data Explanation: In New York, estimates show that commercial buildings can reach 30% beyond code at an investment of $0.70/kWh. To be conservative, we estimate $0.70/kWh by doubling the costs of a 15%-beyond-code building. The cost is shared with gas savings from the same measure, so the actual cost for electric savings is $0.36. Measure life of 17 years is from NGRID (2007). Percent applicable of 35% for 30% savings new buildings assume that 30% and 50% new buildings savings are phased in one to two years prior to enactment of codes in the policy scenarios (30% in 2012 and 50% in 2020). The levelized cost is calculated to be 0.7 cents/kWh.

Tax-Credit Eligible Building (50% Savings)

Measure Description: A federal tax incentive is available for new buildings that are constructed to save at least 50% of the heating, cooling, ventilation, water heating, and interior lighting cost of a building that meets ASHRAE standard 90.1-2001.

Basecase: Basecase of 15.1 kWh/ft^2 is an estimate of HVAC, water heating, and lighting end-use electricity intensity for new buildings in Kentucky, derived from data for buildings built from 2000–2003 (EIA 2006).

Data Explanation: Incremental costs of $0.66 per ft^2 are derived from NREL (2008) studies on energy savings for medium box retail stores and supermarkets. This cost is shared with gas savings from the same measure, so the actual cost for electric savings is $0.34. Percent applicable is 18%, accounting only for the share of buildings that call into the two types of buildings covered in the NREL studies. Measure life of 17 years is from NGRID (2007). The levelized cost is calculated to be 0.4 cents/kWh.

Table A-8. Commercial Building Electricity Measure Characterizations

Measures	Measure Life (Years)	Annual kWh svgs per unit	2007 Kentucky Stock	kWh svgs per sf	Incremental cost per unit	Incremental cost per sf	Cost of Conserved Energy (2010$/kWh saved)	Adjustment Factor	% Turnover	Interaction Factor	Savings in 2030 (GWh)
Existing Buildings											
Building Shell											
Cool roof	20	5,500	NA	0.17	$ 3,750	$ 0.25	$ 0.05	80%	100%	100%	142
Roof insulation	25	NA	NA	0.28	NA	$ 0.06	$ 0.02	35%	100%	100%	99
Low-e windows	25	NA	NA	0.26	NA	$ 0.04	$ 0.01	75%	84%	100%	171
											412
HVAC											
Duct testing and sealing	10	24,800	NA	0.53	$ 3,380	NA	$ 0.02	25%	100%	100%	136
Efficient ventilation fans & motors w VFD	10	22,000	NA	0.47	$ 6,650	NA	$ 0.04	40%	100%	91%	176
HVAC Load-Reducing Measures Subtotal											**312**
High-effic. unitary AC & HP (65-135 kBtu)	15	1,100	NA	0.34	$ 630	NA	$ 0.06	33%	100%	91%	103
High-effic. unitary AC & HP (135-240 kBtu)	15	3,400	NA	0.51	$ 1,420	NA	$ 0.04	15%	100%	91%	70
Packaged Terminal HP and AC	15	230	NA	0.37	$ 90	NA	$ 0.04	5%	100%	91%	17
Efficient room air conditioner	13	90	NA	0.27	$ 40	NA	$ 0.04	4%	38%	91%	4
2014 Efficient room air conditioner	13	50	NA	0.11	$ 30	NA	$ 0.06	4%	62%	91%	3
High-efficiency chiller system	23	30,300	NA	0.94	$ 9,900	NA	$ 0.02	33%	91%	91%	263
HVAC Equipment Measures Subtotal											**459**
Dual Enthalpy Control	10	3,000	NA	0.43	$ 890	NA	$ 0.04	46%	100%	80%	162
Demand-Controlled Ventilation	15	8,000	NA	0.38	$ 3,450	NA	$ 0.04	54%	100%	80%	169
HVAC tuneup (smaller buildings)	3	920	NA	0.45	$ 160	NA	$ 0.06	29%	100%	80%	110
Retrocommissioning	7	NA	NA	0.98	NA	$ 0.13	$ 0.02	10%	100%	80%	81
HVAC Control Measures Subtotal											**522**
HVAC Subtotal											**1,294**
Water Heating											
Commercial clothes washers	11	700	31,300	0.00	$ 320	NA	$ 0.03	14%	37%	100%	1
2013 High efficiency commercial clothes washer	11	240	31,300	0.00	$ 60	NA	$ 0.01	14%	63%	100%	1
Heat pump water heater	12	14,200	NA	0.18	$ 4,070	NA	$ 0.03	19%	100%	99%	34
											36
Refrigeration											
Walk-in coolers & freezers	12	8,200		0.76	$ 960	NA	$ 0.01	9%	100%	100%	70
Reach-in coolers & freezers	9	1,300		0.55	$ 180	NA	$ 0.02	15%	100%	100%	87
Ice-makers	10	540		0.28	$ 100	NA	$ 0.02	9%	100%	100%	27

Supermarket (built-up) refrigeration system	10	336,000		0.36	$ 37,000	NA	$ 0.01	33%	100%	100%	122
Vending machines (to tier 2 ENERGY STAR level)	10	500		0.31	$ 30	NA	$ 0.01	13%	100%	100%	43
Vending miser	10	800		0.50	$ 170	NA	$ 0.03	13%	100%	100%	69
											418
Lighting											
Fluorescent lighting improvements	13	60	-	1.31	$ 5	NA	$ 0.01	56%	100%	100%	750
HID lighting improvements	2	450	-	1.25	$ 60	NA	$ 0.06	12%	100%	100%	153
Replace incandescent lamps with CFLs	13	220	-	1.45	$ NA	$ 0.03	$ 0.00	70%	31%	100%	639
Replace 2013 incandescent lamps with CFLs	13	140	-	0.88	$ NA	$ 0.03	$ 0.00	70%	54%	100%	340
Replace 2020 incandescent lamps with CFLs	13	80	-	0.53	$ NA	$ 0.03	$ 0.01	70%	15%	100%	59
Replace incandescent lamps with LEDs	9	160	-	0.21	$ 760	$ 0.05	$ 0.04	100%	100%	100%	210
Occupancy sensor for lighting	10	360	-	0.90	$ 50	NA	$ 0.02	38%	100%	59%	207
Daylight dimming system	20	140	-	1.68	$ 70	NA	$ 0.04	25%	100%	54%	233
Outdoor Lighting Controls	14	170	860,000	NA	$ 40	NA	$ 0.03	30%	100%	100%	45
											2,752
Office Equipment											
Office equipment	5	1,400	-	0.58	$ 0.01	$ 20	$ 0.003	50%	100%	100%	294
Turn off office equipment after-hours	5	4,500	NA	0.44	$ -	$ -	$ -	100%	100%	76%	344
											638
Appliances/Other											
Hot Food Holding Cabinets	15	1,800	8,500	NA	$ 450	NA	$ 0.02	25%	100%	100%	4
Commercial clothes washers	11	340	31,300	NA	$ 320	NA	$ 0.03	29%	37%	100%	1
2013 High efficiency commercial clothes washers	11	190	31,300	NA	60	NA	$ 0.01	29%	63%	100%	1
											6
Existing Buildings Subtotal											**5,143**
New Buildings											
Efficient new building (15% savings)	17	NA	-	2.27	NA	$ 0.18	$ 0.01	18%	100%	100%	160
Efficient new building (30% savings)	17	NA	-	4.53	NA	$ 0.36	$ 0.01	35%	100%	100%	642
Tax credit eligible building (50% svgs)	17	NA	-	7.56	NA	$ 0.34	$ 0.00	18%	100%	100%	546
											1,348
										TOTAL	**6,491**

A.2.2. Natural Gas Analysis

To estimate the resource potential for efficiency in commercial buildings in Kentucky, we first develop a disaggregate characterization of baseline natural gas consumption in the state for current gas use and a reference load forecast (see Table A-9 below). Highly disaggregated commercial gas consumption data is unfortunately not available at the state level. To estimate these data, we start with current natural gas consumption for the Kentucky commercial sector (EIA 2008) and a forecast out to 2030 based on SERC forecasts, and we disaggregate by end-use using average regional data from CBECS 2003 (EIA 2006) and AEO 2011 (EIA 2011).

Table A-9. Baseline Commercial Natural Gas Consumption by End-Use (BBtu)

End-Use	2010	%	2020	%	2030	%
Heating	22,104	58%	21,565	58%	20,292	56%
Cooling	240	0.6%	234	0.6%	192	1%
HVAC subtotal	*22,344*	*59%*	*21,798*	*59%*	*20,483*	*56%*
Water Heating	7,443	20%	7,261	20%	7,435	21%
Cooking	2,186	6%	2,133	6%	2,158	6%
Other	6,123	16%	5,974	16%	6,183	17%
Total	**38,096**	**100%**	**37,166**	**100%**	**36,259**	**100%**

Next, we estimated commercial square footage in Kentucky using commercial square footage data for the East South Central census region from EIA 2011. We apportion this square footage to Kentucky based on employment data from Moody's Economy.com (Economy.com 2011a). We assume that the percentage of employment in the East South Central census region attributable to Kentucky is roughly equal to the percentage of commercial square floorspace attributable to the state. By multiplying this percentage to the total commercial square footage in the East South Central census region we calculated 1.02 billion square feet of commercial floorspace in the state.

A.2.2.1 Measure Cost-Effectiveness

We then analyzed twenty efficiency measures for existing commercial buildings and 3 new construction whole-building measures to examine the cost-effective energy efficiency resource potential. For each efficiency measure, we estimated natural gas savings (Annual Savings per Measure) and incremental cost (Measure Cost) in a "replacement on burnout scenario," which assumes that the product is replaced or the measure is installed at the end of the measure's useful life. Savings and costs are incremental to an assumed Baseline Measure. We estimate savings (MMBtu) and costs ($) on a per-unit and/or a per-square foot commercial floorspace basis. For each measure we also assume a Measure Lifetime, or the estimated useful life of the product.

A measure is determined to be cost-effective if its levelized cost of saved energy, or cost of conserved energy (CCE), is less than $11.38/MMBtu, the estimated current average commercial cost of natural gas in Kentucky (DEDI 2011). Commercial natural gas prices in Kentucky dipped precipitously for the year 2010, but are projected to rise over the period of this study. For this reason, we averaged gas prices from DEDI 2011 for the years 2009 and 2011 to use as a baseline for cost-effectiveness. The estimated CCE for each efficiency measure, which assumes a discount rate of 5%, are shown in the measure descriptions below. Equation 1 shows the calculation for cost of conserved energy.

Our assumed Baseline Measure, Annual Savings per Measure, Measure Cost, Measure Lifetime, and CCE are reported for each of the efficiency measures in the list of measure descriptions below. We group the 20 efficiency measures for existing commercial buildings by end-use and list the 3 new building measures last.

Equation 1. CCE = PMT ((Discount Rate), (Measure Lifetime), (Measure Cost)) / (Annual Savings per Measure (kWh))

A.2.2.2. Total Statewide Resource Potential

For each measure, we derived Annual Savings per Measure on a per square foot basis (MMBtu per square foot) for the applicable end-use. For measures that we only have savings on a per-unit or per-building basis, we first derive the percent savings and multiply by the Baseline Natural Gas Intensity for that end-use. The assumed baseline intensities for each end use are shown in Table A-10. As an example, for a specific HVAC measure we multiply its percent savings by the baseline gas intensity (MBtu per square foot) for the HVAC end-use.

Table A-10. Commercial End-Use Baseline Natural Gas Intensities (MMBtu per sf.)

End Use	2010 MMBtu/s.f.
Heating	24.7
Cooling	0.3
Ventilation	0.0
Water Heating	8.3
Cooking	2.4
Other	6.8
HVAC Subtotal	25.0
Total	**42.6**

To estimate the total efficiency resource potential in existing commercial buildings in Kentucky by 2030, we first adjusted the individual measure savings by an Adjustment Factor (See Equation 2). This factor accounts for two adjustments: the technical feasibility of efficiency measures, called the Percent Applicable (the percent of Kentucky floorspace that satisfy the basecase conditions and other technical prerequisites such as heating fuel type and cooling equipment, etc); and the Current Market Share, or the percent of products that already meet the efficiency criteria. These assumptions are outlined in each of the efficiency measure descriptions below.

Equation 2. Adjustment Factor = Percent Applicable x (1-Current Market Share)

We then adjusted total savings for interactions among individual measures. For example, we must adjust HVAC equipment savings downward to account for savings already realized through improved building envelope measures (insulation and windows), which reduce heating and cooling loads. Similarly, we adjust water heating equipment savings to account for reduced water heating loads from the use of more efficient clothes washers. The multiplier for these adjustments is called the Interaction Factor.

Finally, we adjust replacement measures with lifetimes more than 11 and 21 years to only account for the percent turning over in 11 and 21 years, which represents the benchmark years of 2020 and 2030, respectively. Note that the multiplier, Percent Turnover, is only applicable to products being replaced upon burnout and not retrofit measures such as insulation. These retrofit measures therefore have 100% of measures "turning over."

We then calculate the resource potential for each measure in the state using Equation 3, which takes into account all of the adjustments described above. The sum of the resource potential from all measures is the overall energy efficiency resource potential in the state's commercial buildings sector.

A.2.3. Efficiency Measures

Table A-10 shows the twenty-three efficiency measures examined for this analysis, grouped by end-use costs, savings (MBtu) per product or square foot, *Percent Applicable, Interaction Factor, Percent Turnover,* and total savings potential (MMBtu) in 2030. Detailed descriptions of each measure are given below, grouped by end-use.

Building Shell Improvements

Roof Insulation

Measure Description: Fiberglass or cellulose insulation material in roof cavities will reduce heat transfer, though the type of building construction limits insulation possibilities. R-values describe the performance factor for insulation levels.

Basecase: The basecase electricity intensity for this measure was disaggregated from the post-savings electricity intensity and the percentage of savings.

Data Explanation: We assume 3% savings and a post-savings gas intensity 24.2 Mbtu/ft^2/year, based on HVAC natural gas intensity per EIA commercial building survey for East South Central region. An average lifetime of 25 years (CL&P 2007) and an incremental cost of 11 cents/ft^2 were also assumed. The measure is shared with gas savings as well, so the portion of the incremental cost attributed to gas savings is 5 cents/s.f. The levelized cost is $4.86/MMBtu.

Double Pane Low-Emissivity Windows

Measure Description: Double-pane windows have insulating air- or gas-filled spaces between each pane, which resist heat flow. Low-emissivity (low-e) glass has a special surface coating to reduce heat transfer back through the window, and a window's R-value represents the amount of heat transfer back through a window. Low-e windows are particularly useful in climates with heavy cooling loads, because they can reflect anywhere from 40% to 70% of the heat that is normally transmitted through clear glass. The Solar Heat Gain Coefficient (SHGC) represents the fraction of solar energy transferred through a window. For example, a low-e window with a 0.4 SHGC keeps out 60% of the sun's heat.

Basecase: The basecase electricity intensity for this measure was disaggregated from the post-savings electricity intensity and the percent savings.

Data Explanation: Percent savings of 3% apply to whole-building electricity consumption (ACEEE 1997). Incremental costs assume $2 per window (SWEEP 2002). As with roof insulation, this measure is shared with gas savings. A measure life of 25 years is from SWEEP (2002). Percent applicable is an ACEEE estimate. The levelized cost is calculated to be $3.22/MMBtu.

Heating and Cooling: Equipment and Controls

Boiler Tune-Up

Measure Description: A boiler tune-up should be done regularly to keep the boiler system running at optimal efficiency.

Basecase: Same basecase as for high-efficiency main/front-end boilers is assumed.

Data Explanation: A boiler tune-up saves 2% of the energy of a baseline unit annually, or 30 MMBtu, and has an incremental cost of $250 per boiler (GDS 2005). Percent applicable of 7% was calculated using CBECS data of percentage of buildings with boilers that don't perform regular maintenance (CBECS 2003). We assume a measure life of 2 years (GDS 2005). The levelized cost is $9.04/MMBtu.

Duct Sealing

Measure Description: Duct sealing involves sealing gaps in ductwork that allow conditioned air to escape.

Basecase: The basecase is heating and cooling energy intensity, 25.0 MBtu/ft^2. This is the average of data for the East South Central census division (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 18% (48 MMBtu) of heating and cooling energy annually, and has an incremental cost of $7,000 (Sachs et al 2004). Percent applicable is 49% based on the number of buildings under 25,000 s.f., and the measure life is 25 years (Sachs et al 2004). The levelized cost is $10.43/MMBtu.

Pipe Insulation

Measure Description: This measure includes insulating accessible steam or hot water supply pipes in the boiler room.

Basecase: The basecase is standard heating energy intensity, 24.7 MBtu/ft^2. This is the average of data for the East South Central census division (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 2% (5 MMBtu) of heating energy annually (NYSERDA 2006), and has an incremental cost of $450, based on an ACEEE estimate of 75 feet of pipe to insulate at $6 per linear foot of pipe (RSMeans). Percent applicable is 48%, current market share is 75%, and the measure life is 15 years (NYSERDA 2006). The levelized cost is $8.49/MMBtu.

High-Efficiency Rooftop Furnace Unit

Measure Description: This measure involves technologies such as condensing units to capture latent heat from water vapor in the flue, and modulating units which have a variable firing rate to match the output to heat load.

Basecase: The basecase is a 10 ton gas-fired condensing rooftop packaged unit with 80% steady state efficiency. The average annual gas use is 179 MMBtu (Sachs et al. 2004).

Data Explanation: A high efficiency rooftop unit uses 150 MMBtu/year, saves 16% of basecase energy, and has an incremental cost of $1,000 (Sachs et al. 2004). Percent applicable is 35% based on the percent of buildings less than 100,000 square feet multiplied by the assumption that the following percentages of size buildings use rooftop units: 40% of buildings 1,000-5,000 s.f., 80% of buildings 5,000-25,000 s.f., and 66% of buildings 25,000-100,000 s.f. This assumption is based on CBECS data as well as ACEEE estimates. We assume a measure life of 15 years and 0% current market share (Sachs et al. 2004). The levelized cost is shown to be $3.42/MMBtu.

High-Efficiency Standalone Furnace

Measure Description: This measure replaces minimum-efficiency gas furnaces with condensing furnaces and/or modulating capacity (variable firing rate that matches the output to heat load).

Basecase: The basecase is a 80 AFUE residential furnace. The average annual gas use is 142 MMBtu (ENERGY STAR figure modified by a factor of 1.45 to represent the slightly larger average size of a small commercial building than a residential building).

Data Explanation: A high efficiency furnace with 90 AFUE (ENERGY STAR minimum) uses 126 MMBtu/year, saves 11% of basecase energy, and has an incremental cost of $464 (ENERGY STAR; cost and savings modified as per basecase). Percent applicable is 2% based on the percent of buildings less than 5,000 square feet multiplied by the assumption that 40% of smaller buildings use furnaces. This assumption is based on CBECS data as well as ACEEE estimates. We assume a measure life of 18 years and 35% current market share (ENERGY STAR). The levelized cost is shown to be $2.51/MMBtu.

High-Efficiency Boiler

Measure Description: Substitution of condensing boilers with outdoor reset or equivalent controls (including circulation pump time clocks) for basecase non-condensing boilers without adaptive controls (just thermostats and equivalent).

Basecase: A case study of boilers with 68% efficiency was assumed. The average annual gas use is 1,106 MMBtu, which was modified from the original statistic (26,267 MMBtu) to account for the difference in the case study building size and the average commercial building size in Kentucky(Sachs et al. 2004).

Data Explanation: Boilers with 90% efficiency use 832 MMBtu/year in an average commercial building, save 50% of basecase energy (Durkin), and have an incremental cost of $3,024 (Sachs et al. 2004). The cost reflects the incremental cost of a high-efficiency boiler as well as the cost of an outdoor temperature reset system. Percent applicable is 41% based on assumptions of percentage of buildings in each size class that use boilers and an assumption of 90% that can be easily replaced, per CBECS and ACEEE estimates. We assume a measure life of 24 years (Sachs et al. 2004). The levelized cost is shown to be $0.88/MMBtu.

Programmable Thermostat

Measure Description: This measure involves replacing conventional thermostats with programmable thermostats. This measure is only appropriate to smaller buildings.

Basecase: The basecase of 29.1 MBtu/ft^2 is the standard heating and cooling intensity modified by the overall intensity ratio of small buildings to the average (EIA 2006, 2011).

Data Explanation: This measure saves 5% (3 MMBtu) of heating energy annually (RLW 2007). The measure has an incremental cost of $101 (CEC 2005) and a percent applicable of 7%. The percent applicable derives from the percentage of East South Central commercial buildings under 2,000 s.f. and the fact that 80% of these buildings do not have an EMS (EIA 2006). The measure life is 12 years (GDS 2005) and the levelized cost is $5.28/MMBtu.

Demand-Controlled Ventilation

Measure Description: Often, HVAC systems are designed to supply ventilated air based on assumed occupancy levels, resulting in over-ventilation. Demand-controlled ventilation monitors CO_2 levels in different zones and delivers the required ventilation only when and where it is needed.

Basecase: The basecase energy use is 215 MMBtu/year, or the portion of commercial gas heating attributable to ventilation (Sachs et al 2004).

Data Explanation: Demand-controlled ventilation saves 20% of the ventilation energy a year (43 MMBtu), and has an incremental cost of $575 per zone (six zones were assumed as an average, for a total cost of $3,450) (Sachs et al 2004). Percent applicable is 54%, and the measure life is 15 years (Sachs et al 2004). The levelized cost is $7.75/MMBtu.

Outdoor Temperature Boiler Reset

Measure Description: Normally, boilers heat water to a fixed temperature. With an outdoor air reset system, the maximum temperature the boiler operates at is variable, depending on the outdoor temperature. The warmer the outdoor temperature, the lower the boiler temperature needs to be, saving energy over the standard fixed (high) temperature operation of a conventional boiler.

Basecase: The basecase is standard heating energy intensity, 24.7 MBtu/ft^2. This is the average of data for the East South Central census division (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 2% (5 MMBtu) of heating energy annually (NYSERDA 2006), and has an incremental cost of $600 (GDS 2005). Percent applicable is 5%, based on the percent of boilers not included in the High Efficiency Boiler measure. The current market share is 60% (NYSERDA 2006), and the measure life is 15 years (ACEEE 2006). The levelized cost is $11.14/MMBtu.

Water Heating

Smart Circulation Pump Controls

Measure Description: This measure involves shutting down the DHW recirculation pump during periods when there is little or no demand for hot water. These periods are determined by the controls from historical use patterns. This leads to savings from heat loss through piping, as well as savings associated with the running of the pump.

Basecase: The basecase is standard water heating energy intensity, 8.3 MBtu/ft^2. This is the average of data for the East South Central census division (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 3% (3 MMBtu) of water heating energy annually, and has an incremental cost of $143 (GDS 2005). Percent applicable is 5% based on the percent of buildings with boilers that are not covered in the high efficiency boiler measure, and the measure life is 15 years (GDS 2005). The levelized cost is $5.34/MMBtu.

Condensing DHW Stand-Alone Tank

Measure Description: This measure involves a new high-efficiency residential-sized tank-type gas water heater, for smaller commercial operations.

Basecase: The basecase is standard water heating energy intensity, 8.3 MBtu/ft^2. This is the average of data for the East South Central census division (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 36% (37 MMBtu) of water heating energy annually (NYSERDA 2006), and has an incremental cost of $1,100 (Sachs et al. 2004). Percent applicable is 35%, current market share is 5%, and the measure life is 15 years (NYSERDA 2006). The levelized cost is $3.43/MMBtu.

Indirect-Fired DHW Off Space Heating Boiler

Measure Description: DHW cylinders are heated indirectly with water from the boiler.

Basecase: The basecase is standard water heating energy intensity, 8.3 MBtu/ft^2. This is the average of data for the East South Central census division (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 30% (30 MMBtu) of water heating energy annually (NYSERDA 2006), and has an incremental cost of $4,000. Percent applicable is 6%, the current market share is close to 0%, and the measure life is 25 years (NYSERDA 2006). The levelized cost is $11.19/MMBtu.

Instantaneous High-Modulating Water Heater

Measure Description: "Instant" or "tankless" water heaters heat water on demand. Advanced units have modulating burners with electronic controls to maintain constant outlet temperature despite variations in inlet temperature and variable demand.

Basecase: The basecase is standard water heating energy intensity, 8.3 MBtu/ft^2. This is the average of data for the West South Central census division (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 21% (21 MMBtu) of water heating energy annually (NYSERDA 2006), and has an incremental cost of $650 (Sachs et al. 2004). Percent applicable is 4%, the current market share is 14%, and the measure life is 15 years (NYSERDA 2006). The levelized cost is $3.55/MMBtu.

Cooking

Direct Fired Convection Range/Oven

Measure Description: Convection ovens use a small fan to circulate hot air within the oven cavity. Circulating air can heat food more efficiently than the still air found in conventional ovens.

Basecase: A conventional range/oven uses approximately 160 MMBtu/year (Food Service Technology Center 2002).

Data Explanation: This measure saves 35% (56 MMBtu) per year per unit (GDS 2005), and has an incremental cost of $2,625 (RSMeans 2008). The measure life is 8 years and the percent applicable is 7%, which accounts for weighted applicability in only the commercial sectors that would have ovens (NYSERDA 2006). The levelized cost is $7.25/MMBtu.

High Efficiency ENERGY STAR Fryer

Measure Description: ENERGY STAR fryers can save 15-25% of the energy used by a conventional model. High-efficiency gas fryers utilize technology such as heat pipes, infrared burners, recirculation tubes, power burners, and pulse combustion.

Basecase: A conventional fryer uses 163 MMBtu per year on average (EPA 2007).

Data Explanation: An ENERGY STAR fryer saves 31% (51 MMBtu) per year per unit, and has an incremental cost of $3,795 (ENERGY STAR). Current market share is 11% (EPA 2007), and the Kentucky stock data (42,000 units) was derived from national annual shipments (EPA 2007), measure life (12 years—ENERGY STAR), and the ratio of commercial buildings that include cooking equipment that use natural gas (CBECS). The levelized cost is $8.48/MMBtu.

High Efficiency ENERGY STAR Steam Cooker

Measure Description: ENERGY STAR steam cookers have better insulation to reduce heat loss, and a more efficient steam delivery system. These steamers can be up to 50% more energy-efficient than conventional steamers.

Basecase: A conventional steamer uses 91 MMBtu per year on average (data derived from ENERGY STAR and Food Service Technology Center data).

Data Explanation: An ENERGY STAR steam cooker saves 50% (45 MMBtu) per year per unit (ENERGY STAR), and incremental cost is a net savings of $1,995 (CEC 2005). Current market share is 8%, and the Kentucky stock data (17,000 units) was derived from national annual shipments (ENERGY STAR) , measure life (10 years—Food Service Technology Center 2002), and the ratio of commercial buildings that include cooking equipment that use natural gas (EIA 2006). The levelized cost is a net savings of $5.63/MMBtu.

High Efficiency Griddle

Measure Description: High efficiency griddles take advantage of technologies such as double sided griddles, chrome finishes, snap-action thermostats, infrared burners, heat pipes, thermal fluid or steam to reduce energy consumption.

Basecase: A conventional griddle uses 112 MMBtu per year on average (Food Service Technology Center 2002).

Data Explanation: A high efficiency griddle saves 14% (15 MMBtu) of energy per year per unit (GDS 2005), and has an incremental cost of $50 (CEC 2005). Percent applicable is 90%. The levelized cost is $0.37/MMBtu.

Miscellaneous

Retrocommissioning

Measure Description: Retrocommissioning results in optimized energy usage of buildings through better operations and maintenance, control calibration, and facilities staff training.

Basecase: The basecase is average heating, cooling, and water heating energy intensity, 33.3 MBtu/ft^2. This is the average of data for the East South Central census division (from the EIA's commercial building survey) and the AEO.

Data Explanation: This measure saves 10% (34 MMBtu) of heating, cooling, and water heating energy (Sachs et al 2004), and has an incremental cost of $0.25 per square foot. This cost is shared with electric savings from the same measure, so the actual cost of gas savings is $0.12. Percent applicable is 54%, and the measure life is 7 years (Sachs et al 2004). The levelized cost is $6.48/MMBtu.

New Buildings

Efficient New Building (15% Savings)

Measure Description: Incorporating energy efficiency into building design is best achieved at the time of construction. New buildings can achieve major energy savings in heating and cooling, as well as energy-saving appliances.

Basecase: The basecase is 48.4 MBtu/ft^2 per year, based on the HVAC and water heating energy intensities for commercial buildings built between 2000 and 2003 (EIA 2006).

Data Explanation: Incremental cost of $0.35 per ft^2 and measure life of 17 years are from NGRID (2007). The cost is shared with electric savings from the same measure, so the actual cost for gas savings is $0.17. Percent applicable of 18% for this new buildings measure assume that 30% and 50% new buildings savings are phased in one to two years prior to enactment of codes in the policy scenarios (30% in 2012 and 50% in 2020). The levelized cost is calculated to be $2.07/MMBtu.

Efficient New Building (30% Savings)

Measure Description: Incorporating energy efficiency into building design is best achieved at the time of construction. New buildings can achieve major energy savings in heating and cooling, as well as energy-saving appliances.

Basecase: The basecase is 48.4 MBtu/ft^2 per year, based on the HVAC and water heating energy intensities for commercial buildings built between 2000 and 2003 (EIA 2006).

Data Explanation: In New York, estimates show that commercial buildings can reach 30% beyond code at an investment of $0.70/kWh. To be conservative, we estimate $0.70/kWh by doubling the costs of a 15%-beyond-code building. The cost is shared with electric savings from the same measure, so the actual cost for gas savings is $0.34. Measure life of 17 years is from NGRID (2007). Percent applicable of 35% for 30% savings new buildings assume that 30% and 50% new buildings savings are phased in one to two years prior to enactment of codes in the policy scenarios (30% in 2012 and 50% in 2020). The levelized cost is calculated to be $2.07/MMBtu.

Tax-Credit Eligible Building (50% Savings)

Measure Description: A federal tax incentive is available for new buildings that are constructed to save at least 50% of the heating, cooling, ventilation, water heating, and interior lighting cost of a building that meets ASHRAE standard 90.1-2001.

Basecase: Basecase of 48.4 MBtu/ft^2 is an estimate of HVAC, water heating, and lighting end-use electricity intensity for new buildings in Kentucky, derived from data for buildings built from 2000–2003 (EIA 2006).

Data Explanation: Incremental costs of $0.66 per ft^2 are derived from NREL (2008) studies on energy savings for medium box retail stores and supermarkets. This cost is shared with electric savings from the same measure, so the actual cost for gas savings is $0.32. Percent applicable is 18%, accounting only for the share of buildings that call into the two types of buildings covered in the NREL studies. Measure life of 17 years is from NGRID (2007). The levelized cost is calculated to be $1.17/MMBtu.

Table A-11. Commercial Natural Gas Measure Characterizations

Measures	Measure Life (Years)	Annual MMBtu svgs per unit	2007 Kentucky Stock	MBtu svgs per s.f.	Incremental cost per unit	Incremental cost per s.f.	Cost of Conserved Energy (2010$/MMBtu saved)	Adjustment Factor	% Turnover	Interaction Factor	Savings in 2030 (BBtu)
Existing Buildings											
Building Shell											
Roof insulation	25	8	NA	0.78	$ -	0.05	4.86	35%	84%	100%	234,929
Low-e windows	25	8	NA	0.75	$ -	0.03	3.22	75%	84%	100%	480,366
											715,295
HVAC											
Boiler tune-up	2	15	NA	1.44	$ 250	$ -	$ 9.04	7%	100%	100%	102,993
Duct sealing	25	48	NA	4.61	$ 7,000	$ 1	$ 10.43	49%	84%	100%	1,944,801
Pipe insulation - heating	15	5	NA	0.49	$ 450	$ -	$ 8.49	12%	100%	100%	60,614
Load-Reducing Measures Subtotal											**2,108,408**
High Efficiency rooftop furnace unit	15	28	NA	2.73	$ 1,000	$ -	$ 3.42	35%	100%	84%	818,763
High efficiency standalone furnace	18	16	NA	1.53	$ 464	$ -	$ 2.51	1%	100%	84%	17,027
High efficiency main/front-end boiler	24	184	NA	17.83	$ 2,229	$ -	$ 0.88	37%	88%	84%	4,981,615
HVAC Equipment Measures Subtotal											**5,817,405**
Programmable thermostat	12	2	NA	1.45	$ 101	$ -	$ 5.28	7%	100%	39%	41,084
Demand-controlled ventilation	15	43	NA	4.15	$ 3,450	$ -	$ 7.75	54%	100%	39%	899,015
Outdoor temperature boiler reset	15	5	NA	0.49	$ 590	$ -	$ 11.14	2%	100%	39%	3,808
HVAC Control Measures Subtotal											**943,907**
HVAC Subtotal											**8,869,720**
Water Heating											
Circulation pump time clock	15	3		0.25	$ 143	$ -	$ 5.34	5%	100%	100%	11,736
Control Measures Subtotal											**11,736**
Condensing DHW stand-alone tank	15	31	NA	2.99	$ 1,100	$ -	$ 3.43	33%	100%	100%	1,007,290
Indirect-fired DHW off space heating boiler	25	25		2.45	$ 4,000	$ -	$ 11.19	6%	84%	100%	130,991
Tankless high-modulating water heater	15	18		1.71	$ 650	$ -	$ 3.55	3%	100%	100%	59,903
Equipment Measures Subtotal											**1,198,185**
Water Heating Subtotal											**1,209,920**
Cooking											
Direct fired convection range/oven	8	56	104,000	0.00	$ 2,625	$ -	$ 7.25	7%	100%	100%	390,725
High efficiency ENERGY STAR fryer	12	51	42,000	0.00	$ 3,795	$ -	$ 8.48	11%	100%	100%	233,178
High efficiency ENERGY STAR steam cooker	10	45	17,000	0.00	$ (1,955)	$ -	$ (5.63)	8%	100%	100%	62,206
High efficiency griddle	12	15	19,000	0.00	$ 50	$ -	$ 0.37	5%	100%	100%	14,493

											700,601
Miscellaneous											
Retrocommissioning	7	34	NA	3.33	$ -	$ 0.12	$ 6.48	54%	100%	100%	1,837,822
											1,837,822
Existing Buildings Subtotal											**13,333,360**
New Buildings											
Efficient new building (15% savings)	17	NA	NA	7.25	NA	$ 0.17	$ 2.07	18%	100%	100%	348,796
Efficient new building (30% savings)	17	NA	NA	14.51	NA	$ 0.34	$ 2.07	35%	100%	100%	1,395,183
Tax credit eligible building (50% svgs)	17	NA	NA	24.18	NA	$ 0.32	$ 1.17	18%	100%	100%	1,185,905
											2,929,884
										TOTAL	**6,263,243**

A.3. Industrial Buildings Sector

A.3.1. Overview of Approach

According to 2006 Manufacturing Energy Consumption Survey (MECS) (EIA 2009[12]), the South region (which includes Kentucky) industrial energy use is broken down as follows: electricity (15%), natural gas (34%), fuel oil (3%), coal & coke (5%), and other (43%). Therefore, this analysis focused on the electricity and natural gas savings potential. It was accomplished in several steps. First, the industrial market in Kentucky was characterized at a disaggregated level and energy consumption for key end-uses was estimated. Then cost effective energy-saving measures were selected based on the projected average retail industrial electricity and natural gas prices. The economic potential savings for these measures was estimated by applying the efficiency measures to end-use energy consumption. The following sections described the process for estimating the savings potential in Kentucky.

A.3.2. Market Characterization and Estimation of Base Year Electricity Consumption

The industrial sector is made up of a diverse group of economic entities spanning agriculture, mining, construction and manufacturing. Significant diversity exists within most of these industry sub-sectors, with the greatest diversity within manufacturing. The various product categories within manufacturing are classified using the North American Industrial Classification System (NAICS) (Census 2007).[13]

Comprehensive, highly-disaggregated electricity or natural gas data for the industrial sector is not available at the state level. To estimate the electricity and natural gas consumption, this study drew upon a number of resources, all using the NAICS system and a consistent sample methodology. Fortunately, a conjunction of the various economic censuses for each state allows us to use a common base-year of 2007.

We then used national industry energy intensities derived from industry group electricity and natural gas consumption data reported in the 2010 Annual Energy Outlook (AEO) (EIA 2010) and value of shipments data reported in the 2007 Annual Survey of Manufacturing (ASM) (Census 2007) to apportion industrial energy consumption. These intensities were then applied to the value of shipments data for the manufacturing energy groups (three-digit NAICS) in Kentucky. These energy consumption estimates were then used to estimate the share of the industrial sector electricity and natural gas consumption for each sub-sector.

Paducah Gaseous Diffusions Plant

The Department of Energy operates a Gaseous Diffusion plant in West Paducah, Kentucky, which enriches uranium for power generation. However, no value of shipments data (or estimates of energy intensity) exists for this one-of-a-kind plant. Based on conversations with staff at the Kentucky Department for Energy Development and Independence, we estimate that this plant consumes a significant portion of the nearby TVA Shawnee power plant (ORISPL 1379),which generated about 8,500 GWh in 2010 (EPA 2011[14]). We assume that about two-thirds of the electricity generated by this plant powers the Gaseous Diffusion plant, accounting for 12% of total industrial electricity consumption. We further assume that the future electricity use will remain at 12%. While the plant is scheduled for shutdown in 2012, there are efforts underway to extend the plant's life. ***If you have any additional information on the energy use and future of the Paducah Gaseous Diffusion plant, please respond with comments.***

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[12] http://205.254.135.24/emeu/mecs/mecs2006/2006tables.html

[13] The industry sector is comprised of four sub-sectors: Manufacturing, Mining, Agriculture, and Construction. Each sub-sector is further broken down into individual industry groups, reflecting the many different definitions for the term 'industrial.'

[14] http://www.epa.gov/airmarkets/images/CoalUnitCharacteristics2010.pdf

Preparation of Baseline Industrial Electricity and Natural Gas Forecast

As is the case for state-level energy consumption data, no state-by-state disaggregated electricity or natural gas consumption forecasts are publicly available. Several alternate data sources were used to calculate estimated energy consumption growth rates for each state and sub-sector. We made the assumption that energy consumption will be a function of gross state value of shipments (VOS). Electricity and natural gas consumption, however, will not grow at the same rate as value of shipments. This is because in general, energy intensity (energy consumed per value of output) decreases with time.

Because state-level disaggregated economic growth projections are not publicly available, data was used from Moody's Economy.com. The average growth rate for specific industrial-subsectors was estimated based on Economy.com's estimates of gross state product (Economy.com 2011c). We used this estimated industrial energy consumption distribution to apportion the EIA estimate (2010) of industrial energy consumption.

The industry sector is comprised of four sub-sectors: Manufacturing, Mining, Agriculture, and Construction. The manufacturing sector is broken down into 21 subsectors, defined by three digit NAICS codes. In order to most closely match available data from the ASM and AEO, three subsectors were further broken down to four digit NAICS codes: chemical manufacturing, nonmetallic mineral product manufacturing, and primary metal manufacturing. Table A-12 below shows the estimated electrical and natural gas consumption for all these subsectors in Kentucky in 2010.

Table A-12. 2010 Electricity & Natural Gas Consumption by Industry in Kentucky

Industry	NAICS Code	Electricity		Natural Gas	
		(GWh)	(%)	(BBtu)	(%)
Agriculture	11	663	1%	**605**	**0%**
Mining	21	1,890	4%	**7,407**	**6%**
Construction	23	482	1%	**1,555**	**1%**
Food mfg	311	1,164	3%	3,991	3%
Beverage & tobacco product mfg	312	460	1%	1,577	1%
Textile mills	313	56	0%	108	0%
Textile product mills	314	56	0%	108	0%
Apparel mfg	315	56	0%	108	0%
Leather & allied product mfg	316	0	0%	0	0%
Wood product mfg	321	479	1%	350	0%
Paper mfg	322	1,633	4%	5,042	4%
Printing & related support activities	323	323	1%	618	1%
Petroleum & coal products mfg	324	1,366	3%	14,293	12%
Chemical mfg	325	7,200	16%	37,771	31%
Pharmaceutical & medicine mfg	*3254*	*128*	*0%*	*672*	*1%*
All other chemical products	*-3253,3255-*	*7,072*	*16%*	*37,099*	*31%*
Plastics & rubber products mfg	326	1,364	3%	1,244	1%
Nonmetallic mineral product mfg	327	2,021	4%	13,264	11%
Glass & glass product mfg	*3272*	*567*	*1%*	*2,949*	*2%*
Cement & concrete product mfg	*3273*	*1,113*	*2%*	*8,542*	*7%*
Other minerals	*3271,3274-*	*341*	*1%*	*1,773*	*1%*
Primary metal mfg	331	15,108	33%	26,046	21%
Iron & steel mills & ferroalloy mfg	*3311*	*4,450*	*10%*	*13,194*	*11%*
Steel product mfg from purchased steel	*3312*	*520*	*1%*	*1,543*	*1%*
Alumina and Aluminum	*3313*	*8,161*	*18%*	*8,338*	*7%*
Nonferrous Metals, except Aluminum	*3314*	*1,485*	*3%*	*1,517*	*1%*
Foundries	*3315*	*491*	*1%*	*1,454*	*1%*
Fabricated metal product mfg	332	1,007	2%	1,676	1%
Machinery mfg	333	519	1%	613	1%
Computer & electronic product mfg	334	319	1%	263	0%
Electrical equipment, appliance, & component mfg	335	433	1%	594	0%
Transportation equipment mfg	336	2,849	6%	3,770	3%
Furniture & related product mfg	337	114	0%	218	0%
Miscellaneous mfg	339	181	0%	346	0%
Gaseous Diffusion Plant	x	5,588	12%	x	x
Total Industrial Sector		**45,332**	**100%**	**121,566**	**100%**

A.3.3. Market Characterization Results

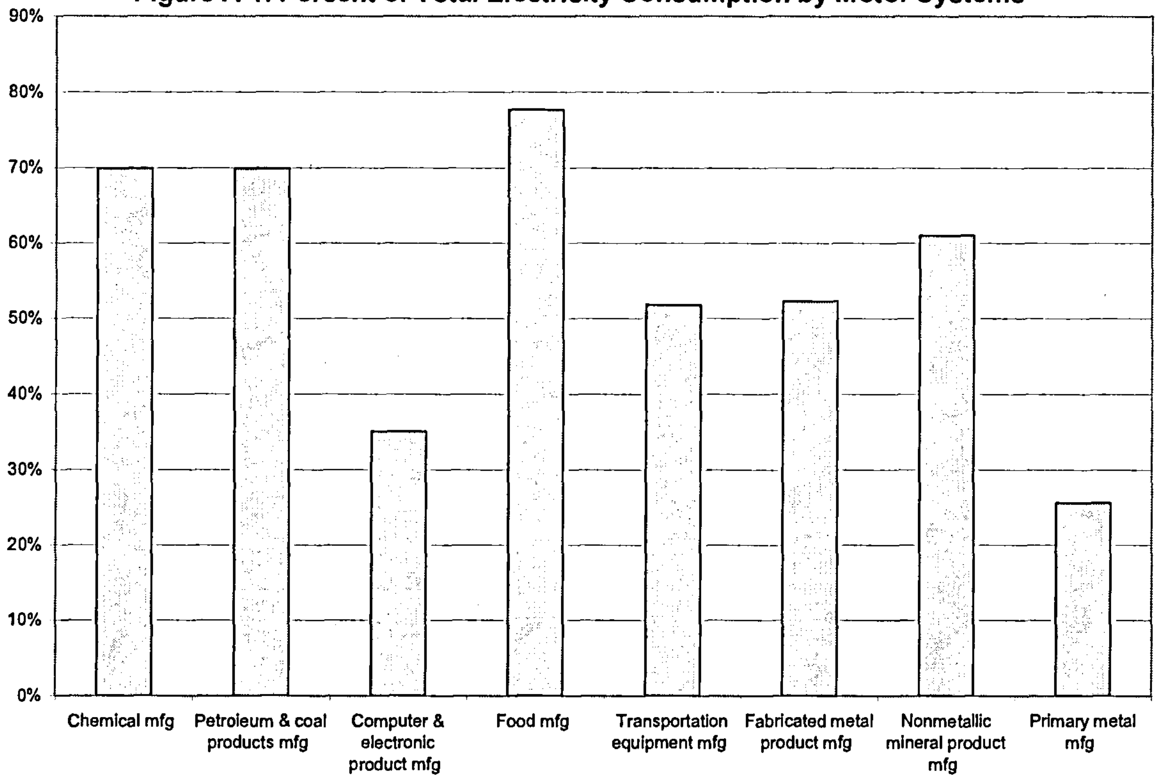
In 2010, Kentucky's industrial sector consumed 45,332 GWh of electricity and 121,566 billion Btus of natural gas. Within the manufacturing sector, the chemical, primary metal, petroleum & coal, and non-metallic mineral products manufacturing industries are the largest consumers of energy, accounting for 65% of electricity consumption and 75% of natural gas.

Industrial Electricity End Uses

In order to determine the electricity savings for any technology, the fraction of the electricity to which the technology is applicable must be determined. Much of the energy consumed by industry is directly involved in processes required to produce various products. Electricity accounts for about a third of the primary energy used by industries (EIA 2010). Electricity is used for many purposes, the most important being to run motors, provide lighting, provide heating, and drive electrochemical processes.

While detailed end-use data is only available for each manufacturing sub-sector and group through the MECS survey (EIA 2009), motor systems are estimated to consume 60% of the industrial electricity (Xenergy 2002). The fraction of total electricity attributed to motors is presented in Figure A-1.

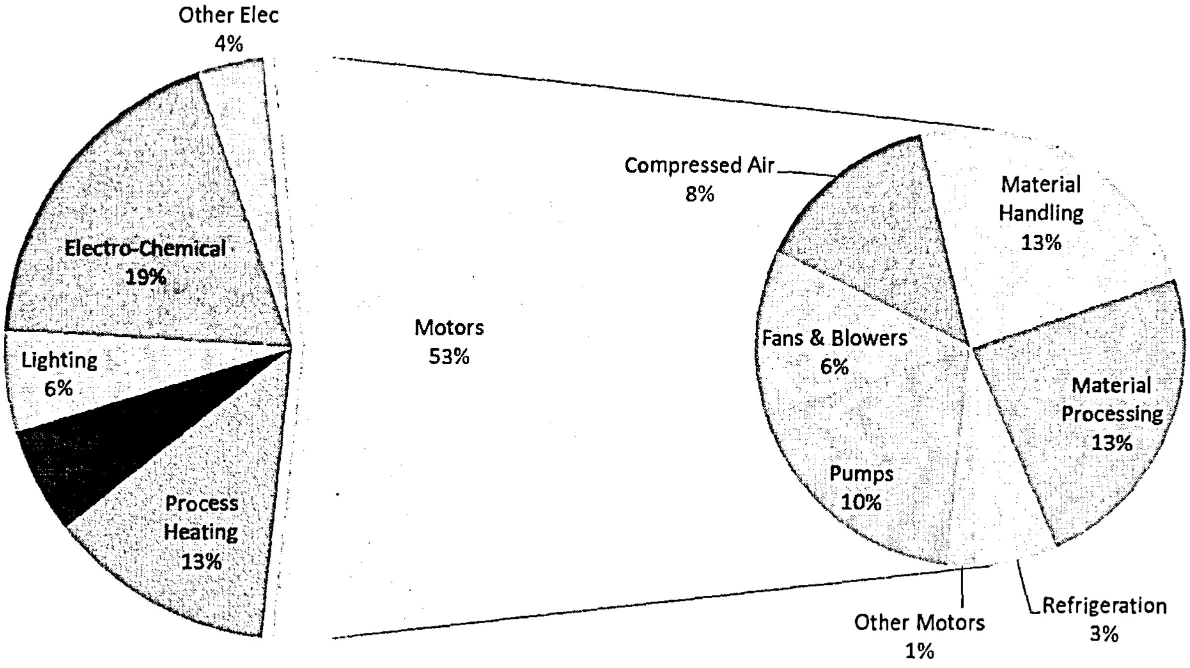
Figure A-1. Percent of Total Electricity Consumption by Motor Systems



Source: XENERGY (2002)

Motors are used for many diverse applications from fluid applications (pumps, fans, and air and refrigeration compressors), to materials handling and processing (conveyors, machine tools and other processing equipment). The distribution of these motor uses varies significantly by industry, with material processing being the largest consumer in the sector. Figure A-2 shows the total weighted average of end-use electricity consumption in Kentucky with a breakdown of motors use in the state.

Figure A-2. Weighted Average of Industrial End-Uses with Breakdown of Industrial Motor System End-Uses

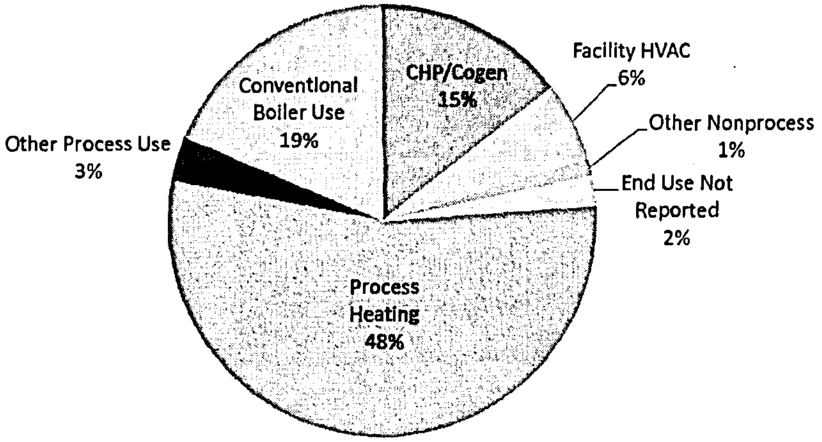


As discussed above, motors make up the majority of industrial electricity use. Electricity use for process heating is also significant, mostly due to the large amount of primary metals manufacturing, particular aluminum. (Note: this excludes end-use consumption at the Gaseous Diffusion Plant.)

Industrial Natural Gas End Uses

A similar methodology was used to determine industrial natural gas end use. The MECS survey (EIA 2010) provided both end use categories and nationwide consumption by industry, which was then applied to the actual industry mix in Kentucky. The results are shown below in Figure A-3.

Figure A-3. Weighted Average of Total Industrial Natural Gas End-Uses In Kentucky



Direct process heating is responsible for nearly half of natural gas use in Kentucky, followed by boilers, which account for close to 50%.

A.3.4. Overview of Efficiency Measures Analyzed

The first step in our technology assessment was to collect limited information on a broad "universe" of potential technologies. Our key sources of information included the DOE, Office of Industrial Technologies; the Center for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET); Lawrence Berkeley National Laboratory (LBNL) and American Council for an Energy-Efficient Economy reports; information from NYSERDA; and Itron. We did not collect any primary data on technology performance.

Oftentimes, no one source provided all of the information we sought for our assessment (energy use, energy savings compared to average current technology, investment cost, operating cost savings, lifetime, etc.). We therefore made our best effort to combine readily available information along with expert judgment where necessary.

We sought to identify technologies that could have a large potential impact in terms of saving energy. These may be technologies that are specific to one process or one industry sector, or so-called "cross-cutting" technologies that are applicable to a variety of sectors. In estimating energy savings, we first identified the specific energy savings of each technology by comparing the energy used by the efficient technology to the energy required by current processes. Our second step was to "scale up" this savings estimate to see how much energy savings—for industry overall—this technology would achieve. For the most part, we derived specific energy savings information from the various technology assessment studies noted above.

In scaling up the technology-specific energy savings, we relied on our general knowledge of the various industrial processes to which this technology could be applied. We also took into account structural limitations to the penetration of the technology. Additionally, we recognized that market penetration, in the absence of significant policy support, can take time given the slowness of stock turnover in many industrial facilities.

Electricity Measures

We identified 13 measures that were cost effective at the average projected industrial electricity rates in Kentucky of $0.061/kWh (see Table B-12). The cost and performance of these measures has been developed over the past decade by ACEEE from research into the individual measures and review of past project performance. The costs of many of these measures has increased in recent years as a result of significant increases in key commodity costs such as copper, steel and aluminum, as well as overall manufacturing costs due to energy prices and market pressures. The estimates presented in Table B-12 represent ACEEE's most current estimates. We present the full normalized installed measure cost (i.e., the full cost required to install a measure per unit of saved energy) as well as the levelized cost (i.e., the annual cost of the measure amortized over the life of the measure).

Table A-13. Cost and Performance of Industrial Electricity Measures

Measure	Measure Life	Cost of Saved Energy		Annual Savings for End-Use
		Installed cost/kWh	Levelized cost/kWh	
Sensors & Controls	15	$0.145	$0.014	3%
Duct/Pipe insulation	20	$0.653	$0.052	20%
Electric supply	15	$0.104	$0.010	3%
Lighting	15	$0.212	$0.020	23%
Advanced efficient motors	25	$0.491	$0.035	6%
Motor management	5	$0.079	$0.018	1%
Lubricants	1	$0.000	$0.000	3%
Motor system optimization	15	$0.097	$0.009	1%
Compressed air manage	1	$0.000	$0.000	17%
Compressed air –advanced	15	$0.001	$0.000	4%
Pumps	15	$0.083	$0.008	20%
Fans	15	$0.249	$0.024	6%
Refrigeration	15	$0.034	$0.003	10%

In addition, we estimated the average normalized cost of industrial energy efficiency investments to be $0.23/kWh saved. This estimate was arrived at by estimating the sum of the annual incremental savings for each measure in each industry based on end-use energy distribution and dividing the corresponding total investment required.

Natural Gas Measures

We identified 35 measures that were cost effective at the average projected industrial natural gas rate in Kentucky of $9.71/MMBtu (see Table B-13). The cost and performance of these measures were taken from a 2006 Itron report. We present the full normalized installed measure cost (i.e., the full cost required to install a measure per unit of saved energy) as well as the levelized cost (i.e., the annual cost of the measure amortized over the life of the measure).

Table A-14. Cost and Performance of Industrial Natural Gas Measures

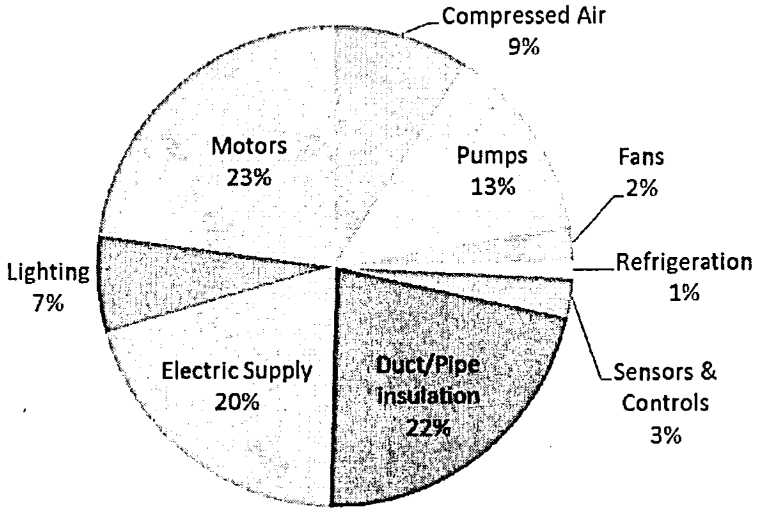
Measure	Measure Life	Installed Cost ($/MMBtu Saved)	Levelized Cost ($/MMBtu Saved)	Annual Savings for End-Use
Boiler Measures				
Improved process control	15	$1.23	$0.12	3%
Maintain boilers	2	$0.02	$0.01	10%
Flue gas heat recovery/economizer	15	$3.48	$0.34	2%
Blowdown steam heat recovery	15	$3.06	$0.29	1%
Upgrade burner efficiency	20	$2.50	$0.20	1%
Water treatment	10	$0.63	$0.08	1%
Load control	15	$1.36	$0.13	4%
Improved insulation	15	$6.55	$0.63	8%
Steam trap maintenance	2	$0.84	$0.45	13%
Automatic steam trap monitoring	15	$3.41	$0.33	5%
Leak repair	2	$0.22	$0.12	4%
Condensate return	15	$9.57	$0.92	10%
HVAC Measures				
Improve ceiling insulation	20	$85.70	$6.88	24%
Install HE(95%) cond. furnace/boiler	20	$37.88	$3.04	18%
Stack heat exchanger	20	$18.41	$1.48	5%
Duct insulation	20	$3.52	$0.28	2%
EMS install	20	$31.79	$2.55	10%
EMS optimization	5	$0.30	$0.07	1%
Process Heat Measures				
Process Controls & Management	8	$3.33	$0.51	5%
Heat Recovery	20	$92.06	$7.39	20%
Efficient burners	10	$14.27	$1.85	18%
Process integration	15	$87.04	$8.39	17%
Efficient drying	20	$61.55	$4.94	17%
Closed hood	15	$34.82	$3.35	5%
Extended nip press	20	$92.59	$7.43	16%
Improved separation processes	20	$26.30	$2.11	10%
Flare gas controls and recovery	15	$87.04	$8.39	50%
Fouling control	5	$1.77	$0.41	7%
Efficient furnaces	20	$13.89	$1.11	6%
Oxyfuel	20	$63.13	$5.07	20%
Batch cullet preheating	15	$27.85	$2.68	16%
Preventative maintenance	5	$0.30	$0.07	2%
Combustion controls	8	$5.32	$0.82	8%
Optimize furnace operations	10	$9.52	$1.23	10%
Insulation/reduce heat losses	15	$29.79	$2.87	5%

We estimated the average normalized cost of industrial energy efficiency investments to be $2.03/MMBtu saved. This estimate was arrived at by estimating the sum of the annual incremental savings for each measure in each industry based on end-use energy distribution and dividing the corresponding total investment required.

A.3.5. Potential for Energy Savings

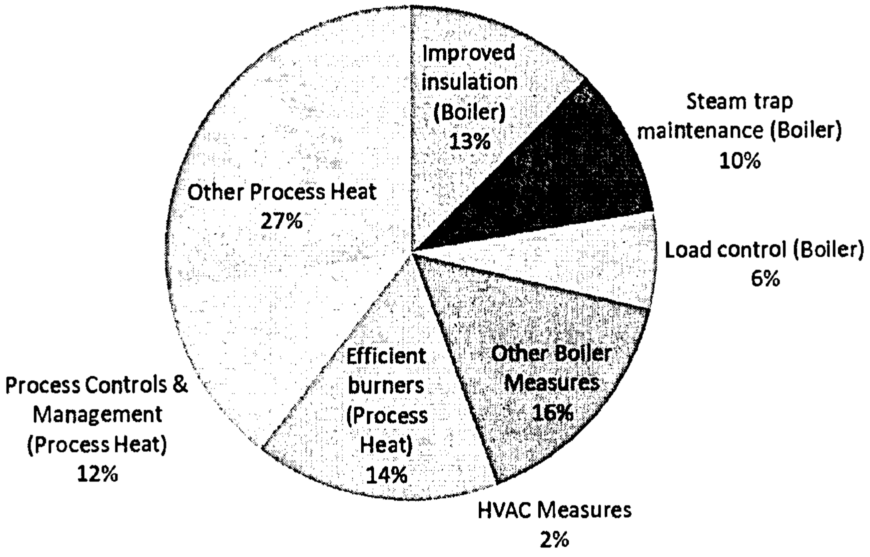
In Kentucky, a diverse set of efficiency measures will provide electricity savings for industry. The application of these measures contributes to total economic electric savings potential of 15%. These savings are distributed as presented in Figure A-4.

Figure A-4. Fraction of Electricity Savings Potential by Measure



The total natural gas savings potential for the Kentucky is about 18%. These savings are distributed as presented in Figure A-5.

Figure A-5. Fraction of Natural Gas Savings Potential by Measure



In addition, this analysis did not consider process-specific efficiency measures that would be applied at the individual site level because available data does not allow this level of analysis. However, based on experience from site assessments by DOE and other entities, we would anticipate an additional economic savings of 5-10%, primarily at large energy intensive manufacturing facilities. Therefore, the overall economic industrial efficiency resource opportunity for electricity and natural gas is on the order of 20-25% and 23%-28%, respectively.