KyPSC-DR-01-006

REQUEST:

Provide copies of any research materials, industry publications, investment banking or rating agency reports, in your possession, that relate to the following issues under review in this investigation:

a. Considerations for utility adoption of cost-effective demand management strategies.

b. Diversification of utility energy portfolios through the use of renewables and distributed generation.

c. Variables and methodologies to consider full-cost accounting of strategies for consideration of alternatives in meeting future energy demand.

d. Rate structure and cost recovery options to mitigate adverse financial impacts of alternative energy option.

e. The need for and type of financial incentives for a utility to provide energy efficiency and lowest alternative generation/DSM options to customers.

RESPONSE:

Objection. Duke Energy Kentucky, Inc. ("DE-Kentucky") generally objects to this data request on the grounds that it is vague and overly broad. Subject to this objection, DE-Kentucky states that, following a reasonable investigation by interviewing the persons most likely to have such information, DE-Kentucky was able to locate the following:

a. Attachment STAFF-DR-01-006(a) provides a draft appendix from a previous weatherization impact evaluation report that addresses this subject.

b. Attachment STAFF-DR-01-006(b)(1) through (4) consists of four studies/reports that may be responsive to this request. Three of the four studies are specific to the Carolinas portion of Duke Energy's service territory and are generally done for the public service commissions, and related to the development of renewable portfolio standards there.

The first three reports, labeled as Attachment STAFF-DR-01-006(b)(1) through (3), are: "A Study of the Feasibility of Energy Efficiency as a Eligible Resource as Part of a Renewable Portfolio Standard for the State of North Carolina," December 2006, GDS Associates, Inc.; "Analysis of a Renewable Portfolio Standard for the State of North Carolina," December 2006, La Capra Associates, Inc., GDS Associates, Inc., Sustainable Energy Advantage, LLC; and "Analysis of Renewable Energy Potential in South Carolina," September 12, 2007, GDS Associates, Inc., La Capra Associates, Inc. While Duke Energy received copes of these studies/reports, Duke Energy does not necessarily agree with or endorse any or all of the findings and/or conclusions contained in the reports/studies.

The fourth report, labeled as Attachment STAFF-DR-01-006(4), is the result of Duke Energy participating in a CERA multi-client study during 2007 entitled "Crossing the Divide – The Future of Clean Energy." The final report became available in November 2007. This document is not produced at this time, but will be provided to any party upon signing a confidentiality agreement and upon Duke Energy receiving notification from CERA that it waives its copyright protection. A brochure describing the study is publicly available on CERA's website at www.cera.com. While Duke Energy was a participant in this multi-client study, Duke Energy does not necessarily agree with or endorse any or all of the findings and/or conclusions contained in the report.

Attachment STAFF-DR-01-006(b)(5) consists of documents from Standard and Poor's and Moody's.

c. No responsive documents were located.

d. See Attachment STAFF-DR-01-006(d).

e. See response to Staff-DR-01-006(d).

WITNESS RESPONSIBLE:

a. Richard G. Stevie

b. John G. Bloemer / Robert D. Moreland / Stephen G. De May

c. Diane L. Jenner

d. Richard G. Stevie

e. Richard G. Stevie

Appendix A. Estimates of the Non-Energy Benefits of Weatherizing Homes

Economic Issues

The economic non-energy benefits of Cinergy's weatherization include increased property values, federal taxes generated from direct employment, income generated from direct employment, job creation, avoided unemployment costs, enhanced national security, reduced reliance on public assistance, reduced occupancy mobility, and reductions in lost rental value and damage from non-occupancy.

Increased Property Value

Weatherization increases home property valuations in proportion to the energy savings. Cinergy's Weatherization Program is responsible for increasing the average value of the home by **$1,905.** This value was determined by multiplying the annual energy savings ($92/home) by $20.70.

The value of $20.70 is based on a study by Nevin-1998 [26 and 57] (See Table 1) which shows that homes increase in valuation by an average $20.70 for every $1 dollar of reduced annual utility bills. The analysis was based on the American Housing Survey and Metropolitan Statistical Area data from 1992 to 1996.[57] Forty-five regression analyses were completed in this study. Eight of these regressions were done specifically on detached homes with a mixture of heating fuel types and were statistically significant above 95 percent and showed a $20.58 increase in home valuation for every dollar of reduction in annual utility bills. Similarly, one regression model (statistically significant at the 95 percent level) of 1994 data on attached homes indicated a home value increase of $35.65 for every dollar of annual utility cost reduced.[57] Also, seven regressions were performed on electrically heated homes at or above the 90 percent confidence interval and an average valuation of $25.71 resulted. Eight regressions (90 percent + confidence) on natural gas heated homes yielded a $25.90 increase. Lastly, two regressions (95+ percent confidence) showed a home valuation increase of $26.18 for every dollar of reduced utility costs.[57]

Table 1
Home valuation in proportion to annual utility costs

Home Type	Regressions	Data Years	Heating Fuel Type	Significance	Home Value Increase / $1 reduction in annual utility bills
Attached	1	1994	Various	95%+	$35.65
Detached	2	1992-1996	Fuel oil	95%+	$26.18
Detached	8	1992-1996	Natural gas	90%+	$25.90
Detached	7	1992-1996	Electric	90%+	$25.71
Detached	8	1992-1996	Various	95%+	$20.58
Overall*	45	1992-1996	Various	Various	$20.70

* Includes regressions below the 90 percent confidence interval. It is believed that low confidence intervals occurred on fuel oil heated homes in 1991 and 1992 due to Gulf War triggered fuel oil price volatility.

After participation in Iowa weatherization, 62 percent of the participants said that their home had improved in value and only three percent said their home was in worse condition.[122]

According to the Oak Ridge National Laboratories (ORNL) study (Brown et al-1993), national weatherization increased the value of participating homes by $126 per home in 1989.[4, 11, 26, 50, and 102] This value is the weighted national average spent on materials for structural repairs and does not include installation costs and is not based on fuel savings.

Skumatz-1997 estimates that home values increased from $0 to $150 dollars per home annually after weatherization due to increased property valuation, neighborhood enhancement and preservation.[44]

Cinergy's weatherization programs involved the replacement of windows and this may have a benefit in preserving the quality and appearance of personal property contained inside low-income homes. Upgrading from single pane to double pane glass, reduces UV induced damage to exposed materials by 16 percent, while going from single to double with low-E reduces damage by 55 percent, and 74 percent when going from single pane to "superwindows." [34]

Federal Taxes Generated from Direct Employment

The 1993 ORNL study estimated that $55.27 in new taxes are generated per weatherized home from weatherization's direct employment impacts. The average amount spent nationally to weatherize a home was $1,550. The amount of federal taxes was determined by taking the average amount spent nationally to weatherize a home times 3.55 percent. This multiplier was obtained by multiplying the average per capita federal income tax paid by households making less than $20,000 per year in 1988 ($1,000), times the estimated job years of increased direct employment and then dividing this product by the number of weatherized homes.[4, 11, 129]

Using this same multiplier and using an average of $2,500 (includes measures, fixed and indirect costs) to weatherize a home for Cinergy, we estimate the value of tax revenues generated to be **$88.75 per unit**.

Community Economic Benefits, Income Generated from Indirect Employment and Personal Discretionary Income Benefits

Weatherization creates three benefits for the local economy, the direct effect of employment, the indirect effect of employment from supportive industries, and the induced economic effect. The latter occurs when wages and avoided energy bills are spent in the local economy. For Cinergy, the first two are allocated using the national weatherization study. The indirect employment impacts of national weatherization in 1989 are estimated to be a multiplier of $0.33 in proportion to weatherization spending. This does not include spending of paychecks among the indirectly employed or program induced energy savings from re-spending.[11] Nationally, this results in $506 of additional income per unit weatherized.[4, 11, 50 and 102] For Cinergy Weatherization, where an average of $2,500 spent per unit, there is a benefit of **$825 per unit.**

Few studies have quantified the "induced" effect of weatherization on local economies. However, one study done by Pigg and Dalhoff-1994 [37] did quantify a value for the benefit that occurs when energy savings and wages are recirculated. This is often called an "economic base multiplier" or the "induced" economic benefit. The Pigg-Dalhoff study looked at the effects of weatherization spending on the Iowa economy and showed that there was $240,000 of "value added" to the Iowa economy for every $1 million spent on weatherization. This equates to a multiplier of 0.24 for the induced economic effect. If the multiplier in Cinergy's Weatherization Program service territory is similar, then the benefit is **$600 per unit**.

The combined multiplier is 0.57, yielding a total community and local economic benefit of **$1,425 per home** ($2,500*0.57).

Several other studies estimated economic benefits in terms of energy savings. Energy savings is reported to have a 7.1 percent to 42.8 percent (midpoint 25 percent) adder effect to avoided electric supply at four cents per kWh. This adder effect is attributable to increased employment of state / regional resources in energy efficient investment plus increased economic activity stimulated by energy cost savings (resulting form cost-effective energy efficient investment).[51, 122]

A 17 percent benefit adder effect (proportional to program spending) was attributed to a 1999 Ohio HWAP [60] for "value added" to the Ohio economy and the author considered this a "conservative" estimate. It was estimated that the energy savings from a shared savings program in Hennipen County, MN would have an economic base multiplier effect of 1.72 during the first three years of that program.[33, 122]

Job Creation

Weatherization also has job creation effects. A 1992 economic sector input-output model showed that for or every 1 million spent on weatherization in Iowa, there is $685,000 worth of additional economic activity in the form of direct and indirect employment, which in turn supports 34 job-years.[4, 5, 37, 38, 50, 122] The indirect economic benefit included induced stimulative effects comprising $240,000 per million spent, resulting in the creation of 5.6 jobs. In this case the induced stimulative effects (via direct employment and indirect employment in secondary and supportive industries) of the program outweighed the depressive effects, such as reduced fuel sales, ratepayer charges to fund the program, and reduced LIHEAP payouts, by $240,000 for every $1 million spent.

Another Iowa study showed that total industry output (similar to Gross Domestic Product) increases by $1.82 million for every $1.00 million spent on weatherization and 43 job-years are created for each million spent.[50, 123]

A 1983 study on national weatherization indicated that for every million dollars spent, there are 36 full time jobs from direct employment and 16 from indirect employment from supportive agencies.[11 and 128] This does not include the induced economic effects when the value of energy savings and wages are recirculated.

A more conservative estimate of job creation was done by Hill-1998 [60] on Ohio's HWAP and found that there are 8.5 job-years for every million dollars spent on weatherization.

For Cinergy, there are an estimated 46 job-years created for every million dollars spent on weatherization from the direct, indirect, and induced economic effects. This is the midpoint value between the 1983 national weatherization study (52 job-years) and a 1992 Iowa study (40 job-years). Cinergy completes on average 1,000 weatherizations per year ands spends an average $2,500 on each home. Thus, there is **$2,500,000** million spent Cinergy on weatherization creating **115** job years of employment each year. In other words, there were **0.115 job-years** for each unit weatherized.

The impact of weatherization spending on job creation can also be viewed in terms of displacing energy supply jobs. A number of authors have done this (See

Table 2). The ratio of DSM jobs created to energy supply jobs created has been computed by a number of studies and shows a positive job creation effect for DSM. The ratio of DSM jobs created to supply jobs created is equal to DSM gross employment + DSM re-spending employment / supply gross employment.[6]

One study quantified several benefit categories together and included the induced effect of increased disposable income. A regional economic sector input-output model was applied to Wisconsin Gas Company's Low Income Weatherization Program. A benefit / cost Ratio of 3.1 was found. The benefit / cost ratio is the first year economic output benefit over the homeowner weatherization program expenditures. The benefits computed were in the form of increased disposable income, reduced arrearages, and increased local spending and jobs.[41, 122] Similarly, the benefit / cost ratio of Wisconsin Natural Gas's "Savings Plus" rental weatherization program was 3.2.

Table 2
DSM/Energy Supply Option Job Ratio

Author/Study	Location	Supply Option	DSM/Supply Job Ratio
Jaccard & Sims-1991	British Columbia	Hydro-electric	4.3
Charles River-1984	Washington	Coal	3.7
Clark et al-1992	Maine	Fluid bed coal	3.7
Charles River-1984	Washington	Nuclear	2.1
Goodman et al-1993	Florida	Fuel mix	1.9
Geller et al-1992	US	Fuel mix	1.7
Goodman et al-1992	Quebec	Hydro-electric	1.5
Average			**2.7**

Avoided Cost of Unemployment

The national weatherization study found a savings of $82.33[1] per weatherized home in avoided unemployment benefits resulting from weatherization spending.[4, 11, 26, 50, 102] Dividing $82.33 by $1,550 results in a multiplier of 0.053. Using this same multiplier for Cinergy's Weatherization Program results in avoided unemployment benefits of **$132.50 per unit** ($2,500*.053).

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1 This assumes that 50% of direct employment and 25% of indirect employment is taken from the ranks of the previously unemployed. These previously unemployed workers would no longer need unemployment.

Skumatz-1998[44] estimates the benefits per person from reduced unemployment for a "generic" weatherization program at $0-$10 per participating household per year.

National Security and Global Economic Effect

A 1994 Pennsylvania Public Utilities Commission (PUC) filing[122] suggested a 10 percent adder effect to avoided electric supply at four cents per kWh for increased independence from reliance on imported oil. This assumes a cost of relying on imported oil of $2.56 per barrel.[2]

For the purpose of this report we will assume that the national security benefit for Cinergy's Weatherization Program is **zero**, because all the savings is for domestic natural gas fuel supplies.

Reduced Reliance on Public Assistance

None of the studies in the literature quantified reductions in participant use of public assistance. Assuming that 25 percent of Cinergy's weatherization participants (N=250/yr) are on some form of public assistance and that 25 percent of those receiving public assistance (N=63/yr) are impacted by weatherization such that their reliance on public assistance is reduced by 25 percent and that the average person on public assistance receive $500 per month or $6,000 per year in public assistance dollars, the reduced need for public assistance is equal to $94,500/yr (0.25*$6,000*63 units). The benefit is equal to $95 annually ($94,500 divided by 1000) per unit. This equates to a NPV of $1,425 per unit ($95*15).[3] Because we do not know how good the assumptions are and because this benefit is not adequately addressed in the literature, we have not included it in the final analysis. However, it is an additional benefit that could be taken into account and suggests our overall estimate is a conservative one.

Reduced Occupancy Mobility Rates

Several studies have demonstrated that high energy bills cause a greater level of housing mobility than would be the case if energy bills were lower. Only Skumatz-1999[26, 44, 45] has estimated the benefit from reduced housing mobility. Skumatz estimated a range of $0-$100 per participant by deriving assumptions from studies that equated lower utility bills among the poor to lower housing mobility, which in turn leads to lower educational achievement, and thus, smaller

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2 There are 42 gallons in a barrel of oil.

3 15 is the Net Present Value (NPV) multiplier for saving natural gas over a 20 year period using US DOE's 1999 gas cost projections and discount rates.

lifetime earnings. We used the midpoint of this range, **$50 per unit annually,** as an estimate of the benefits of reduced mobility.

Pye-1996 [50] reports that low-income homes are abandoned at twice the rate of all homes. In 1974 and 1975 it was found that 2.5 percent of HUD mortgages failed because of high energy prices.[11, 124]

Colton-1995 [52, 54] reported results of a Missouri telephone survey where 42 percent of the "most recent five year frequent movers" said energy bills were "very important" in their move and another 11 percent said that high bills were somewhat important.

Utility service termination is linked to mobility. A study conducted in Philadelphia over a 5-year period found that 32 percent of homes were abandoned in the first year after electric service termination and 22 percent of homes within a year after gas service termination.[11, 50, 54, 100]

Similarly, Colton-1994 [15] reported that 42 percent of homes in Maine were vacated from 1 to 11 months after service termination between 1986 and 1987 (indicating the household had moved subsequent to the shut-off).[4]

A survey of the homeless in Philadelphia by ECA / IPPS cited utility termination as the reason for homelessness in 7.9 percent of the cases.[11, 26, 54, 100]

Brown-1993 [11] estimated the avoided cost from reduced mobility to be less than $1 per weatherized dwelling.[5] This study also found a control adjusted reduction in occupancy turnover rates in weatherized dwellings of 47 percent.[6]

Lost Rental Value or Income and Damage from Non-Occupancy

Lost rental from tenants (because of utility related mobility) was quantified by Skumatz-1997.[44] She estimated an annual lost rental value benefit per participant for a "generic" low-income weatherization program at $0-0.15 per home. For

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4 Estimate based on number of "heat related residential properties" with service termination and no reconnection, filed by Columbia gas to the Maine Public Service Commission.

5 A Philadelphia survey of homeless persons and emergency shelter providers (Robinson - 1993) was used by ORNL to estimate the avoided cost created by WAP's ability to reduce this forced mobility (@ 7.9%). ORNL's methodology not specified.

6 The average number of occupancy changes in weatherized dwelling declined from 11 to 9 per 100 dwellings per year after weatherization. The control group's occupancy rate increased from 12 to 18 per year per 100 dwellings. This was a control adjusted reduction of 8 per 100 or a 47 percent reduction from the post-weatherized control adjusted rate of 18 per 100 dwellings. A 47 percent reduction is therefore attributable to weatherization.

Cinergy's Weatherization Program, we used the midpoint of this range ($0.08) to estimate a benefit of **$1.20 per home** over the 20 year life of the measures.[7]

The cost of damage from non-occupancy to landlords was not quantified in the literature.

Environmental Issues

Environmental benefits of weatherization include reduced air emissions from home heating equipment, water and sewer impacts, and land use impacts.

Air Emissions from Energy Conversion

There are several air emissions that are regulated under the Clean Air Act, Sulfur oxides (SOx), Nitrogen Oxides (NOx), Volatile Organic Compounds (VOC's), Particulate Matter (PM), and Carbon Monoxide (CO).[8] In addition, there are three primary greenhouse gases, Carbon Dioxide (CO_2), Methane (CH_4), and Nitrous Oxide (N_2O). Additionally, there are various heavy metal air emissions that occur from coal and oil fire power plants.

The 1995 Tellus evaluation [6, 122] quantified benefits from reduced air emissions attributable to NEPOOL's 1994 DSM efforts. This study used control costs for Clean Air Act criteria emissions (SOx, NOx, VOC's, PM's, and CO) and the cost of maintaining an emissions target level for greenhouse gases (CO_2, CH_4, and N_2O). The target is consistent with the United Nations Kyoto Protocol, for which signatory nations agreed to reduce greenhouse gas emission levels to 1990 levels by 2010.

A three-step process was used to compute the avoided emissions benefit attributable to Cinergy's weatherization Program from reduced energy consumption:

- ⇐ emissions (in mass units of air pollutant per energy consumption units) was obtained from the literature
- ⇐ an avoided emissions benefit in dollars per mass unit of pollutant also was obtained from the literature
- ⇐ these two values were multiplied to obtain benefit values in dollars per unit of energy savings

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7 $0.08 multiplied by the NPV multiplier of 15 yields $1.20.

8 In addition to being a toxin, CO contributes indirectly to the greenhouse effect, when CO molecules oxidize into CO_2.

A NPV multiplier of 15 is used to compute the benefit value over a 20 year life of weatherization measures. Annual savings are multiplied by this factor to obtain lifetime savings in present dollars. The NPV for avoided air emissions is **$838.19** per home.

Table 3
Summary of Avoided Air Emissions Benefit from Natural Gas Heating Equipment and Electric Savings

	Value/(energy unit)	Cinergy's Annual Fuel Savings (energy units) / home	Cinergy's Avoided Air Emissions Benefit - Annual	Cinergy's – NPV/home*
Natural Gas Savings	$1.7751 mmBTU	15.1 mmBTU	$26.80	$402.06
Electric Savings	$0.1232/kWh	236 kWhs	$29.08	$436.13
Total Savings			**$37.76**	**$838.19**

* Assumes a 20 year life of measures (multiplier of 15).

Below Table 4 details avoided pollution from natural gas heating equipment emissions and Table 5 details avoided electric power plant emissions.

For natural gas savings, data specific to Ohio are used in column two of Table 4 for lbs. / mmBTU of pollutant. Data from SEI & UNEP-1995 [120] are used to estimate the benefit of reduced emissions (in lbs. per mmBTU of fuel input) from natural gas heated homes. This study used ranges for residential space heating equipment based on fuel type. The ranges are attributable to variations in combustion equipment, fuel characteristics, and testing methods. Unless otherwise noted, the midpoint of the range was used for the analysis and displayed in the table below. To convert these SEI & UNEP-1995 emissions into dollars of avoided cost, we used several studies that had data on air emissions in dollars per mmBTU.

Data for column three is taken from the nearest geographic region where estimates have been compiled for the cost of pollutants in dollars per ton. In 1995, the Tellus Institute estimated the value of avoided air emissions (attributable to 1995 Boston Edison DSM programs) and these values are used for column three. This data is selected for Cinergy because it is the closest in geographic proximity.

The first column in Table 4 lists the pollutant. The second column (pounds of pollutant per mmBTU) is multiplied by the third column, dollars per pound, to obtain the benefit in dollars per mmBTU of fuel input which is displayed in column four. For detailed tables containing quantities from a broad range

of studies on each of the 5 criteria, 3 greenhouse gas, and heavy metal air pollutants, see Table 8, Table 10, Table 11,

Table 12, Table 13, Table 14, Table 15, and

Table 16 in Appendix D.

Most of the air emissions cost associated with natural gas consumption is due to CO_2 emissions (84 percent). The total air emissions cost associated with natural gas heating is $1.944 / mmBTU (See Table 4).

Table 4
Natural Gas Emissions

Pollutant	lbs./mmBTU of fuel input [23, 120]	Dollars/lb. Control cost	Dollar benefit/ mmBTU of fuel input
SOx	0.001*	$0.89 [51 and 6]	$0.0009
NOx	0.06	$3.78 [51 and 6]	$0.2268
VOC's	No data		
PM's	0.0115	$2.31 [51 and 6]	$0.0266
CO	0.016	$0.50 [51 and 6]	$0.0080
CO2	121	$0.01 [51 and 6]	$1.5125
CH4	0.0025	$0.13 [51 and 6]	$0.0003
N2O	No data		
Heavy metals	No data		
Total			**$1.7751**

* Low end of estimated range was used

** See Table 16 for detailed breakdown

[51 and 6] Tellus Institute control cost estimate in 1994$

[23, 120] For residential space heating equipment using natural gas

A similar approach is used to compute the avoided power plant air emissions attributable to electric savings. Table 5 details the avoided electric power emissions. The total cost is 12.32 ¢/kWh. CO_2 represents 7.3 ¢/kWh of this cost, followed by NOx at 2.87¢, and SOx at 1.65¢. Particulate matter (PM) is responsible for 0.19 ¢/kWh of this total, heavy metals 0.15¢, Nitrous Oxide (N_2O) 0.08¢, Methane (CH_4) 0.04¢, and Carbon Monoxide (CO) 0.02 ¢/kWh.

Table 5
Electric power emissions

Pollutant	Lbs. / kWh of fuel input	Dollars / lb. Control cost	Dollar benefit / kWh of fuel input
SOx	0.01857 [23, 59, and 119]	$0.89 [51 and 6]	$0.0165
NOx	0.00758 [23, 59, and 119]	$3.78 [51 and 6]	$0.0287
VOC's	No Data		
PM's		$2.31 [51 and 6]	$0.0019 [6 and 122]
CO		$0.50 [51 and 6]	$0.0002 [6 and 122]
CO2	7.32 [23, 59, and 119]	$0.01 [51 and 6]	$0.0732
CH_4		$0.13 [51 and 6]	$0.0004 [6 and 122]
N_2O			$0.0008 [6 and 122]
Heavy metals**			$0.0015 [6]
Total			$0.1232

** See Table 16 for detailed breakdown

[23, 59, and 119] 1994 Ohio HWAP avoided emissions

[51 and 6] Tellus Institute control cost estimate in 1994$

[6 and 122] NEPOOL's estimated value of avoided air emissions due to 1994 DSM program in New England

[6] For toxins with know control costs, the marginal control costs and used. The remaining use relative toxicities.

Several other studies quantify air emissions. The 1999 Galvin meta-study[51] recommended an adder of 15-666 percent to avoided electric supply at four cents per kWh. This includes all criteria emissions (SOx, NOx, VOCs, PM, and CO: 14-57 percent), along with greenhouse gases (CO_2, CH_4, N_2O: 1-115 percent) and heavy metals (arsenic, beryllium, cadmium, chromium, copper, lead, manganese, mercury, nickel, and selenium: 0-247 percent). This study was done for the Massachusetts DTE to support its adoption of a 25 percent adder for DSM non-energy benefits.

A 1995 Tellus [6, 122] study reported that the total federal subsidy associated with coal fuels is 0.4-0.7 cents per kWh in 1994 dollars. Similarly, the total federal subsidy for nuclear fuels is 1.1-1.9 cents per kWh. The Tellus-1995 report [6, 122] estimated the avoided cost of the nuclear fuel cycle (in terms of risk, waste and decommissioning) at 0.00125-228.04 cents per kWh due to DSM in the New

England NEPOOL. The magnitude is due to the possibility that DSM may have no effect on nuclear baseload generators or that DSM may be assumed to displace nuclear directly.

The 1993 ORNL study of the non-energy benefits of the national weatherization program [11, 50, 102] computed a value of $12 per household per year in avoided control cost for SOx and NOx. The Net Present Value (NPV) of the avoided cost of air emissions from the ORNL / DOE study is $172 per home (from reduced SOx and NOx only).

The 1998-99 Ohio HWAP [59, 61, 56] evaluation assigned a NPV benefit of $25-$508 per weatherized home for avoided CO_2, SOx, NOx, CO, CH_4, and PM emissions. In the environmental impact report,[59] an NPV of $264 per home was identified as the value of avoided air emissions. A 1997 study by Blasnik [7] valued avoided emissions attributable to Ohio's Weatherization Assistance Program (such as NOx and CO_2) at $5-$300 per home with a point estimate of $50 per weatherized home.

Skumatz-1997 [44] estimated the total environmental benefits associated with a generic low-income weatherization program such as PG&E's Venture Partners Pilot (VPP) Program to be $3-$20 per participating household per year. Skumatz-1999 [45] estimated an adder to the energy savings associated with a generic low-income program of 15-650 percent.

Water/Aquatic Issues

Galvin-1999 and Tellus-1995 [6, 51] reported an adder effect to avoided electric supply at four cents per kWh of 0.1-0.5 percent for the mitigative costs of preventing fish impingement in power plant cooling loop intake grids. Ottinger-1990 [36] equated this to 0.005-0.02 cents per kWh in mitigative costs per kWh. This assumes a fish impingement rate of 0.00061 fish per kWh. For Cinergy's Weatherization Program, this benefit is assumed to be **zero**, because the savings was for natural gas only.

A 1978 study estimated the benefits of eliminating all impacts of acid rain (caused by SOx emissions) on aquatics, forests, crops and materials in the eastern United States at $5 billion per year. This value assumes that forests are worth the market value for timber. For crop damage, it is assumed that acid damage equals ozone damage. The benefit is $0.25 billion to aquatics, $1 billion to crops, $2 billion to materials, and $1.75 billion to forests.[36, 112] No acid rain benefit is specifically quantified for natural gas home heating.

Skumatz-1997 [44] estimated the total annual water and sewer savings and avoided cost at $10-$155 per participant in a "generic" low-income weatherization program such as PG&E's Venture Pilot Program in California. This includes $2-45 for avoided costs to society for water and wastewater and $8-110 for water and sewer savings to participants. This study was done in California, a water scarce region of the country. The region east of the Mississippi, where Cinergy is located is generally considered a water abundant region. Because of this we used the low end of the range of the Skumatz estimate ($10 per year per home) in water and sewer savings attributable to weatherization measure impacts. The NPV over the average 20-year life of measures is **$150 per home**.

Land Usage

Tellus-1995 [6, 122] provides a value for the amount of land use required for construction and operation of power plants potentially avoided by DSM. The values range from 0.1 square yards per MWh for gas and oil fired plants, 1.2 for conventional coal, 1.5 for nuclear pressurized water reactors, and to 2.7 for nuclear boiling water reactors. This does not include land use required to extract fuels. Since the savings from weatherization is not likely to directly displace the construction of new power plants and there is no value stated for the land, no benefit for Cinergy's Weatherization Program is quantified in this report.

Health and Safety

Health and safety benefits include reduced incidents of fire and carbon monoxide, fewer emergency calls, fewer illnesses, and increased comfort.

Customer Injuries and Loss of Life and Property from Reduced Incidence of Fire

In the Ottinger-1990 "meta-study," the dollar value of human life is quantified from a range of studies. The study recommends using the midpoint of $4 million per life, which falls within the middle of the range of studies ($1 to $10 million). Using a similar methodology, the dollar value of statistical injury or serious illness (morbidity) is $0.4 million per injury.

The 1993 national weatherization report [11] on non-energy benefits methodology estimates the benefit of avoiding fire deaths and property damage at $3.25 in benefit per unit.[9] This methodology did not include injury prevention benefits.

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[9] In 1987, heating systems caused 21 percent of residential fires, 10 percent of fatalities due to fires, and 10 percent of the injuries due to residential fires. There are 5.2 elderly (64 or older) deaths per 100,000 per year and 1.7 non-elderly deaths per 100,000 per year. There were 69,300 elderly and 487,000 non-elderly homes weatherized in 1989. Weatherization is assumed to prevent all furnace-related fires, thus reducing 0.52 elderly deaths per 100,000 per

For Cinergy's Weatherization Program, the methodology of the national weatherization study is used to estimate benefits of avoided fire deaths and property loses with one change to that methodology. A human life is valued at $4 million (as established by the Ottinger study) instead of $250,000 per non-elderly person and $24,000 for elderly lives.[10] The result is a value of $2.15 per unit in annual benefits for reduced property losses and $27.60 per unit per year in prevented deaths. Thus, a value of $29.75 per home per year is appropriate for Cinergy's weatherization with a NPV over the 20 year life of weatherization measures at **$446 per unit.**

Blasnik-1999 [61] estimated the benefits of health and safety equal to the entire amount of money spent on measures having some health and safety benefit (such as furnace replacements). For Ohio's 1994 HWAP, this was $317 per home from a program which had a total program cost of $2381 per home.

Health Benefits from Carbon Monoxide Reduction

Carbon monoxide, a colorless, odorless gas blocks the transport of oxygen to the brain. It has been linked to learning impairment and blurred vision and is a criterion pollutant regulated by the Clean Air Act. CO is indirectly a greenhouse gas because it eventually oxidizes into CO_2 while in the atmosphere. This section deals with CO health effects indoors. See the preceding section for CO emissions impact on the environment.

There are no estimates for how many deaths might be prevented by weatherization in the literature and these are excluded in this report.

Fewer Emergency Calls

According to Magouirk-1995, [30, 43] the first year savings in reduced emergency service calls attributable to the 1993 Colorado Public Service's Energy Savings Partners Program (low-income weatherization) on a per household weatherized basis is $22.57. This value is the sum of $15.58 (for emergency service calls not including calls for flex connectors), $1.98 (for gas flex connectors), and $5.01 (the incremental cost of having the flex connector replaced by emergency services instead of the weatherization agency). This totals to $22.57 per unit for first year

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year and 0.17 non-elderly deaths. Also, there are 610 fires per low-income unit per year, of which 21 percent are due to heating systems and weatherization prevents 25 percent of these at an average cost of $3,530 per home. The value of property and life added together is $3.25 per weatherized home attributable to fire safety.

10 The value of life is based on the average NPV of future lifetime earnings in the national weatherization study

savings.[11] This value is used for Cinergy's Weatherization Program and has an NPV of **$339 per home.**

Another study done by Skumatz-1997 [44] produced similar results. The emergency gas, annual, per participant, benefits to ratepayers and the utility of "Generic" Low-Income Weatherization (such as PG&E's Venture Pilot Program) are $10-20 for fewer emergency gas calls, $0-5 for flex connector replacements (one time), $0-$2 for fewer emergency calls from flex connectors, and $0-0.15 for self insurance savings to utility. This totals to a range of $10.00-$27.15 of savings per home annually for gas emergency items. Skumatz-1997 also attributed $0-0.25 of annual savings due to weatherization enhancing fire safety for a "generic" low-income program.

Fewer Missed Days at Work Due To Illnesses

Skumatz-1997 [44] attributed $0-150 annually to weatherization reducing illnesses for a "generic" low-income program. This assumes that weatherization prevents illness to household breadwinners or children, such that, the key wage earner misses fewer days of work due to illness because of weatherization. Also, it assumes that one bottle of additional cold medicine would not need to be purchased annually. The midpoint of the range ($75 per home per year) and is used for Cinergy's Weatherization Program. The NPV over the 20-year life of measures is **$1,125 per home.**

There were no estimates on the cost of nursing home avoidance in the literature. However, some studies addressed related issues. In the winter of 1990-91, seven percent of North Carolina homes lost their primary heating fuel service and 38 percent of these had no secondary fuel source. Thus, 2.7 percent of all North Carolina Homes went without any form of home heating for some period of time in the winter of 1990-91.[54]

Harrington-1992 [58] found that weatherization and low-income programs reduced customer reported health problems associated with the home being too cold in wintertime. There was a 69 percent reduction from 36 percent of the #1 control group[12] to 11 percent of the #4 full treatment group in the number of persons who

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11 The average cost of sending an emergency gas service crew to a home is $77.91. This was computed by taking the total cost of having staff and equipment for this service spread out on a per call basis. The $15.68 per home weatherized savings is derived from the reduction in emergency service calls after weatherization, not including calls for gas flex connector.

12 Niagara Mohawk 1991 post program telephone survey of four groups: 1) unweatherized control group, 2) weatherized only group, 3) weatherized plus budget counseling, energy usage education, electric DSM measures installed, and affordable bill payment plan group,

perceived having health problems caused by their house being too cold. Specifically, there was a 28 percent relative drop from group 1 (36 percent) to the weatherized group 2 (26 percent). There was a 48 percent relative drop from group 2 (26 percent) to the weatherized and budget counseled and energy educated group 3 (16 percent). Lastly, there was a 31 percent relative drop from group 3 (16 percent) to full treatment group 4 (11 percent) for those who thought they had health problems caused by their house being too cold.

Comfort

Skumatz-1999 [45] used an innovative survey technique to investigate the customer perceived value for non-energy benefits such as improved household comfort. The study asked participants in several DSM and low-income programs how valuable the benefit was in relation to the bill savings. It was found that for "various weatherization measures" (such as insulation, weather-stripping, and caulking) that all the non-energy benefits were 1 to 1.5 times as valuable as the energy savings. Improved comfort was scaled to a point estimate and found to be 12 percent of this perceived benefit. This benefit is not transferable to Cinergy weatherization because the estimate of perceived value included sets of benefits different than those offered within Cinergy's program framework. However, a value of 12 percent of the savings for Cinergy's Weatherization Program equals $6.60 per year or an NPV of $99 over the 20-year life of measures.

A 1990 study by Gladhart [18] suggests that weatherization stabilizes temperatures in the home such that the frequency and magnitude of thermostat adjustments necessary to maintain comfort are reduced.[13] No quantitative value is assigned to this impact.

The reduction of air infiltration is an important method for reducing energy consumption, but it also results in improved comfort levels for home occupants.

Utility Service

Utility services benefits include reduced arrearages and associated carrying costs, reduced accounts and debt write-offs, fewer service terminations, fewer non-emergency service calls, reduced collection costs, avoided rate subsidies, fuel

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and 4) all of the above plus a real-time minute-to-minute feed back on cost and usage of natural gas for water and space heating.

13 The 1990 Gladhart study showed that weatherization improved home occupancy comfort. The percentage of days the thermostat was manipulated at least once went down 13 percent (from 72 percent to 62 percent) after weatherization and the number of times per day the thermostat was manipulated went down 17.6 percent (from 3.4 to 2.8). The average magnitude of temperature changes went down 16.4 percent (from 6.7 degrees to 5.6).

provider insurance savings, and transmission, distribution and fuel delivery savings.

Reduced Arrearages

Weatherization's impacts on arrearages has been analyzed by a number of authors. Table 6 summarizes the arrearage benefits from these studies. There is a wide range ($8-$469) of arrearage reduction per unit attributable to weatherization. See Table 17 for a detailed version of Table 6. The 1993 ORNL evaluation identified a national average benefit of $32 per home per year for reduced arrearages. The NPV of this over a 20-year life measure is **$480 per home**. This national average benefit estimate is used for Cinergy's program.

Table 6
Arrearage beNefits of Low-Income and Weatherization Program Summary*

Location and Year	Benefit Value and Units	Description
National-93	$32 / home	Annual arrearage reduction
Ohio-97	65%	Decline in billing shortfall per annum (PIPP Only)
Ohio-97	63%	Decline in billing shortfall per annum
Ohio-98	$1,200 / home	NPV of ratepayer savings
Detroit Edison-97	0.5%	Increase in bills paid on time
Detroit Edison-94	$150	Reduced account balances
Milwaukee-93	$232 / home	Arrearage reduction
Wisconsin Gas Co / Milwaukee-91	56%	Reduction in un-recovered gas charges
Wisconsin Gas-94	20%	Utility's return on program investment
Wisconsin Gas-94	$353 / home	Arrearage reduction for single family dwelling
Wisconsin Gas-94	$502 / home	Arrearage reduction for two-family dwelling
Missouri Gas Energy-98	-$5.02 / month / home	Change in utility bill balance
Connecticut Light & Power Co.-94	$9.73-18.77 / home	Arrearage reduction
Connecticut Light & Power Co.-94	$40-28 / home	Arrearage reduction (E4 plan)
Niagara Mohawk-92	23%	Increase in dollars paid on utility bill
Niagara Mohawk-92	33%	Increase in dollars paid on utility bill (real-time feedback on usage)
Niagara Mohawk-99	$469 / home	Arrearage reduction
Columbia Gas-93	12%	Arrearage reduction (control group stratified with similar bill pattern)
Columbia Gas-93	15%	Arrearage reduction (regular control group)
Columbia Gas-93	5%	Utility shortfall reduction in monthly bills
Columbia Gas-94	5%	Utility shortfall reduction in monthly bills

Columbia Gas-94	19%	Reduction in billing deficit
PG&E-97	$0.50-7.50 / home	Annual reduction in carrying cost of arrears
PG&E-99	$4-63 / home	Reduced carrying charges on arrears
Washington-93	$84 / home	Arrearage reduction
Washington-91	69%	Reduction of customers in arrears
Washington-92	15%	Reduction of customers classified as problematic (internal control)
Washington-92	9%	Reduction of customers classified as problematic (external control)
Washington-92	61%	Reduction in mean amount of arrears
Oregon-92	17%	Reduction in mean amount of arrears
Oregon-92	8%	Reduction of customers classified as problematic
Colorado-95	$7.98 / home	First year arrearage, bad debt, and fewer account write-off savings
Colorado-95	26%	Reduction in monthly carried arrears
Colorado-99&95	$30.56 / home	Reduction in uncollectables and debt write-offs

* *See Table 17 for a more detailed version of this table*

Impacts of Arrearages and Uncollectables on All Customers and Carrying Costs for Energy Suppliers

Arrearage carrying costs occur to the utility when uncollected balances are born by other ratepayers. Skumatz-1997 [44] estimated this benefit to be $0.50-7.50 in annual per participant benefits to ratepayers and the utility for a "generic" low-income weatherization programs (such as PG&E's Venture Partners Pilot). For Cinergy's program, the midpoint of this range ($4 per participant per year) is used and represents the benefit of having less arrearages to carry. The NPV of this is **$60 per home.**

Several other studies on weatherization impacts on arrearages and utility bills are noteworthy:

⇐ Hall-1998 [21] found that 65 percent of participants in a Missouri Gas Energy (MGE) pilot weatherization program were more able to pay their bills as a result of their participation.

⇐ Hall-1997 [19] reported that 80 percent of participants in Detroit Edison's 1995 Low-Income Energy Management Program are now "better able to pay" their bills as a result of their participation.

⇐ Tellus-1995 [6] reported that low-income DSM programs reduce arrearages for $3 to $176 per customer.

Harrigan-1992 [58] reported on results of a post program telephone survey conducted for Niagara Mohawk in 1991 on four sample groups:

⇐ unweatherized control group,

⇐ weatherized only group,

⇐ weatherized plus budget counseling, energy usage education, electric DSM measures installed, and affordable bill payment plan group, and

⇐ all of group 3 plus a real-time minute-to-minute feed back on cost and usage of natural gas for water and space heating.

The results indicate that weatherization has a positive impact on the customer's perception of having "some" or "a lot" of control over his utility bill. Forty-five percent of control group #1 thought they had "some or "a lot" of control, 57 percent of weatherized group #2, 78 percent of group #3, and 80 percent of group #4.

Reduced Size of Bad Debt Written Off and Decreased Number of Accounts Written Off

Skumatz-1997 [44] estimated annual payment-related benefits per participant to ratepayers and the utility for a "generic" low-income weatherization program. These were $1-4 for the reduced size of bad debt, and $1-3 for decreased number of accounts written off. The total for these values is $2-$7, with a midpoint of $4.50 per home per year. This mid-point is used for Cinergy's Weatherization Program. The NPV of benefits accrued from weatherization attributable to the reduction in bad debt and account write-offs is **$68 per home.**

One author estimated the benefit-cost ratio of bad debt conservation programs. Colton-1994 [54] found that the benefit-cost ratio of a bad debt conservation program (based on system avoided cost savings) at 1.857 for electrically heated homes, 2.290 for homes with electric water heaters, but no electric heat, and 1.944 for all "other" non-electric heat and non-electric hot water heated homes.

Fewer Service Terminations

Several authors estimated the savings from fewer service terminations per participant per year. Skumatz-1998 and Howat-1999 proposed a benefit value of $2-$12 for fewer service terminations and reconnections. The midpoint of this range ($7) is used for estimating benefits to Cinergy with an NPV of **$105 per home**. Table 7 below summarizes various estimates for the cost and value of service terminations from a variety of studies.

Table 7
Fewer Service Termination Benefits

Study	Benefit value	Definition
Hill and Blasnik 1998 [56 and 61]	$41.68 / home NPV	The number of service disconnections per year avoided due to the Ohio Home Weatherization Assistance Program is 643 (585 gas and 58 electric ones). The net present value of this is 0.5 million dollars. There were 11,997 housing units served by this program, thus a disconnection savings per unit weatherized is $41.68. The study assumes the cost to the utility is $100 per service disconnection incident and the NPV is computed over 10 years.
Coton-1994 [15] and Howat-1999 [26]	$85.88 / incident	The cost of shutting off and then reconnecting power service for Columbia Gas. This includes: $0.75 for shut-off notice, $1.28 for telephone contact, $18.09 for premise visit, $21.92 for disconnection, and $43.84 of cost for reconnection.
Skumatz-1998 [43] and Howat-1999 [26]	$2-$12 / home / year	Avoided cost of notices, customer calls, service terminations and reconnections due to DSM program per weatherized home.
Pye-1996 [50] and Colton-1994 [15]	$67-$84 / incident	Cost of disconnection and reconnection of utility service per incident. The range is dependent upon weather or not the person is contacted by telephone or in person.
Pye-1996 [50]	$117 / incident	The 1993 marginal cost of each utility service termination

Skumatz-1997 [44] estimated the value of fewer service terminations (annually, per participant) benefits to participant's in a "generic" low-income weatherization program at $0-1 for the cost of restarting service. Howat-1999 [26] reported a value of fewer service terminations due to weatherization of $0 to $100 annually per participating households.

Colton-1994 [54 and 118] reported on a 1989 survey revealing utility termination as the single most frequent legal problem experienced by low-income households representing 11.4 percent of all reported legal problems for this population. However, no cost impacts were reported for this impact. In addition, staff at Detroit Edison Company advised that in an unpublished internal study of low-income terminations, more than 50 percent of disconnects had reconnected their own power within 7 days of the disconnection, resulting in a significant theft of power. No dollar estimate of this theft was reported and no benefit is provided from this report.

Reduced Customer Calls and Service Requirements (Non-Emergency)

Weatherization programs provide clients with new and upgraded systems and technologies that need little repair and maintenance compared to older technologies in unweatherized homes. However, no quantification of this benefit is found in the literature and is therefore excluded from this report.

Reduced Collection Costs/Fewer Payment and Late Payment Notices

Only one study estimated the benefit of reduced credit and collection expenses on a per participant basis. Tellus-1995 [6] and Colton-1994 [15] reported a value of $65-$85[14] per participant attributable to avoided credit and collection expenses associated with unpaid utility bills. The midpoint of this range is **$75 per unit** and is used in the Cinergy Weatherization Program analysis.

Hart-1993 [22] and Colton-1994 [54] reported the per incident cost of credit and collection activities associated with service disconnection and DSM referral for Central Maine Power in 1992. The average cost of one telephone call ($4.61), special payment arrangement ($5.75), premise visit ($18.64), disconnection / reconnection ($18.17), and DSM referral, ($3.09) totals $50.76.[15]

Colton-1994 [15, 26, 54] computed the cost of negotiating payment plans for each incident which takes 0.5 hours of customer service time for Columbia Gas. The hourly rate, including overhead, is $21.62 per hour and an assumed $3.83 of clerical time for each incident. The cost for a half-hour of time is estimated at $14.61. Colton-1994 [15 and 54] reported the average cost range per account of collection agency activity experienced by Columbia Gas from 1987 to 1989 for customers who are not paying utility bills to be $387-$445 per account with a midpoint of $416 per account.

Blasnik-1997 [7] reported the frequency of collection activities (e.g., late payment notices, termination notices, phone calls, referrals to collection agencies, etc.) declined by 6.4 percent for the treatment group while increasing by 20.8 percent for a comparison group over the same time period. This yielded a net 27.2 percent reduction in collection activities due to HWAP (Ohio's Home Weatherization Assistance Program).

Avoided Rate Subsidies

Skumatz-1997 [26, 43, 44] estimated that the rate subsidy avoided due to a "generic" low-income program to be $5-$32 per participant per year. This is based on a low-income rate subsidy program that discounts 15 percent of utility bill costs to participants. Since the Cinergy Weatherization Program does not include a PIPP Program, there is no need to include this benefit.

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[14] Range is based on utility's variable cost.

[15] These costs do not include payroll or administrative overheads and estimates were derived from corporate records of supply costs, wages, and amount of time spent on each service.

Reduced PIPP Program Operations Cost

In some studies, arrearages and bill and payment savings benefits are bundled together with avoided rate subsidies. This was estimated to have an NPV of $1,208 per unit weatherized for a 1994 Ohio ratepayer study.[16] No estimate is developed for Cinergy, from this study, because PIPP Program operating costs are not unbundled from arrearages and bill and payment savings.

Insurance Savings tö Fuel Providers

No quantified data was found on fuel provider insurance savings in the literature.

Transmission, Distribution, Delivery Savings and Fuel Delivery Savings

Electric power transmission and distribution line losses typically average 5-10 percent of the energy delivered to consumers. There is also the avoided cost of new throughput capacity additions to the transmission and distribution system that occurs with energy savings and associated demand reductions. Skumatz-1997 [44] estimated transmission and distribution savings to be worth from $0-$6 per year per participant. However, it is not necessary to add these benefits because line losses and fuel delivery costs are embedded in the retail price for electricity and petroleum heating fuels. We take the conservative assumption with regard to environmental externalities (such as air emissions) as line losses are likely already accounted for in these estimates.

Other Benefits

Several other miscellaneous benefits include reduced transaction costs for participants, DSM spill-over, increased education and customer loyalty.

Reduced Transaction Costs for Participants

Skumatz-1997 [44] estimated the value of reducing transaction costs for participants in a "generic" low-income program to be worth $0-$5 per participant per year. This benefit occurs when customers become more educated about conservation and have energy efficient measures installed as a result of their weatherization experiences. Customers then do not need to shop for these products and spend time obtaining information about them. The midpoint of this range is $2.50 and the estimated NPV of this is **$37.50 per Cinergy Weatherized home**.

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[16] Figure is based on a similar Columbia Gas study of PIPP savings attributable to weatherization. Savings from this study were proportioned to Ohio's HWAP program and estimated accordingly. Savings included PIPP shortfalls, arrearages, and bills and payment expenses.

DSM Spillover and "Take-Back"

Tellus-1995 [6, 122] recommends a 20 percent adder to the energy and capacity savings for "DSM spillover." Spillover occurs when participants adopt non-program DSM measures, when non-participants adopt program measures, and when non-participants adopt non-program measures. "Take-back" occurs when participants engage in behavior after participation in a weatherization program to "recapture" some of the energy savings to improve their comfort levels. One example of this is when participants raise the heating setpoint on their thermostat after weatherization. This potential impact would be subtracted from the energy benefits and proportionally subtracted from related non-energy benefits as well. No quantifiable estimates of "DSM Take-Back" were found in the non-energy benefits literature. When this issue was addressed qualitatively in the literature it was suggested that DSM take-back is a minor phenomenon with minimal effects. Given the lack of quantitative estimates and the fact that spillover and take-back may cancel each other out. No benefit is quantified for Cinergy's Weatherization Program.

Education

Hall-1997 [19] conducted a post program telephone survey of participants in Detroit Edison's 1995 Low-Income Energy Management Program. There was a 50 percent increase in the summed percent of energy efficient actions that can be shown or demonstrated among participants compared to non-participants. Survey mentioned measures were 20 percent more often shown or demonstrated among participants than non-participants. Similarly, participant mentioned measures were shown or described nine percent more often among participants. Though invaluable, education is difficult to quantify for the purposes of this study and is excluded in this analysis.

Customer Loyalty

Customer loyalty is valuable to utility providers that increasingly operate in a competitive marketplace. However, it is difficult to quantify changes in customer loyalty in the context of this study. Harrigan-1992 [58] reported on a Niagara Mohawk 1991 post-program telephone survey of four sample groups:

- ⇐ unweatherized control
- ⇐ weatherized only
- ⇐ weatherized plus budget counseling, energy usage education, electric DSM measures installed, and affordable bill payment plan
- ⇐ group 3 plus a real-time minute-to-minute feed back on cost and usage of natural gas for water and space heating

There was a 212 percent increase (from group #1 & #2 to groups #3 & #4) in the percent who felt that the utility (Niagara Mohawk) was "very concerned" about its customers' well being. No dollar value is provided for this benefit.

Cinergy Results Compared to Other "Meta-Studies"

This study is one of several very inclusive assessment of non-energy benefits reported to date. Cinergy's results are comparable to several other studies. An evaluation of the non-energy impacts of national weatherization was performed in 1993 by ORNL.[4, 10, 11] The non-energy benefits averaged over all 1989 participants in national weatherization totaled $976 [4, 5, 23, 43, 44, 50, 54] per home. Specifically, $126 for enhanced property valuation and extended lifetime of dwelling, $3 for reduced fires, $32 for reduced arrearages, $55 for federal taxes generated from direct employment, $506 for income generated from indirect employment, $82 for avoided costs of unemployment benefits, and $172 for the NPV[17] of environmental externalities.

A meta-study by Howat and Oppenheim-1999 [26] quantified non-energy benefits of low-income programs by borrowing values from other studies and proportioning them to associated program costs to generate a percentage, an "adder."[18] The adder is a percentage of benefits in proportion to the cost of the program on a per home basis. For example, an adder of 100 percent for non-energy benefits, would mean that the value of non-energy benefits equals the cost of the program. He then combined the ranges of values for various benefits into one range for all non-energy benefits and came up with a non-energy benefit adder of 17 percent to 327 percent for all low-income programs. This total is derived from the following: 0.6-8.8 percent for arrearages, 2.2-8.1 percent for uncollectables, 0.3-1.1 percent for termination and reconnection costs, 5.8-37.6 percent for reduced rate discount payments, 0.2 percent for fire prevention, 0-11.7 percent for reduced unemployment insurance payments, 0-75 percent for equity/reduced energy burden concerns, 0-116.8 percent for reduced mobility, 0-59.1 percent for reduced loss of service due to termination, and 8.1 percent for improved maintenance / property values.

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17 The NPV (Net Present Value) is the avoided costs of SOx and NOx emissions assuming a 4.7 percent discount rate and 20 year life of measures. All other benefits for national weatherization occur annually.

18 A non-energy benefit avoided cost adder reflects the ratio of the estimated present value in dollar terms of the benefit to total program costs. This study established benefits from other programs and proportioned them to associated programs costs to derive a proportional percentage. These percentages are summed to yield a total non-energy benefit adder that can be applied to other programs to estimate benefits.

The total NPV non-energy benefit attributable to Ohio's HWAP in 1994 on a per weatherized home basis is reported by Blasnik-1999 [61] at $2,273 per home. This occurred with a program that costs $2,381 per home and that saved participants an average NPV of $1,150 in utility costs. The total NPV of $2,381 per home for non-energy benefits are broken down as follows: $42 for disconnection's avoided, $1,208[19] for ratepayer saving in PIPP from reduced PIPP participation, reduced arrearages, bills and payments, $317 for health and safety, $442 for the "value added" to the Ohio economy, and $22-510 ($264 midpoint) for reduced air emissions.[20]

Lisa Skumatz, performed several analyses of non-energy benefits. Skumatz used an approximated range based on alternative assumptions about "value" and "impacts" related to generic weatherization programs and the range of quantitative results from other authors and other assumptions. Skumatz-1997 [44] estimated the general non-energy (annually, per participant) benefits to utility and ratepayer, society, and participant of a "Generic" Low-Income Weatherization (such as PG&E's Venture Partners Pilot -VPP Program) as follows: $18-81 for utility and ratepayer, $7-176 for society, and $8-566 to the participant. This creates a range of from $33 to $823 for total non-energy benefits annually.

The 1998 Skumatz study [43] summed all non-energy benefits associated with PG&E's VPP Program on a per participant annual basis: $35 for PG&E and rate payers, $60 for society, and $210 for customers. This totals to a point estimate of $305 per participant annually (an approximate NPV of $2,556)[21] NPV for the non-energy benefits of this pilot weatherization and education program.

In 1999 Skumatz performed a similar analyses of PG&E's VPP (Venture Partners Pilot) Program, [45] but enhanced the methodology to include an innovative telephone survey to bolster estimates of participant non-energy benefits. The annual non-energy benefit result was: $34.06 to the utility, $212.30 to society, and $260.63 to participants. The annual total is $506.98 for non-energy benefits per participant for the VPP Program or a NPV of $4,248.[22] This enhanced methodology was also applied to PG&E's Low-Income Weatherization Program

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19 This $1,208 (for ratepayer savings in PIPP from reduced PIPP participation and reduced arrearages, bills, and payment) is taken from a Columbia Gas Study and proportioned to Ohio.

20 Ratepayer savings in PIPP is estimated by using a Columbia Gas study on a similar PIPP program. The health and benefits are based on measure costs, air emissions are based on air emissions from Ohio utilities, and economic value was based on economic sector input-output analysis of Ohio's economy.

21 Skumatz uses a 10 year life of measures and a discount rate of 4% to compute the NPV (8.38 multiplier).

22 Skumatz uses a 10 year life of measures and a discount rate of 4% to compute the NPV (8.38 multiplier).

and yielded a benefit of $268.80 ($2,253 NPV)[23] per participant. The benefit to the utility was $17.81, $110.89 to society, and $140.09 to participants.

Horowitz-1998 [25] recommended a general non-energy benefit "adder"[24] of 15 percent be applied to the total energy and demand savings (from low-income weatherization) for the reduction of bad debt and payment and collection costs and improvements in housing stock.

Cinergy's non-energy benefits are comparable to these "meta-studies."

Summary

In summary, the NPV of non-energy benefits for Cinergy's weatherization program are **$7,326** for natural gas heated homes. For the 1,000 homes per year served by weatherization, this amounts to **$7,326,000** of non-energy benefits over a 20-year period. Adding the energy benefits to this yields a benefit of **$8,707** per home and **$8,707,000** of total annual benefits for the program.

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23 Skumatz uses a 10 year life of measures and a discount rate of 4% to compute the NPV (8.38 multiplier).

24 In this study an "adder" is the ratio of the dollar value of the non-energy benefit to the total program cost.

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Appendix B. Air Emissions

Table 8
Sulfur Dioxide (SO2) Emissions

Study	Benefit	Definition
Ohio WAP-1999[23 and 123]	$0.76/home weatherized or $11 NPV	The value of avoided SO2 emissions at actual market price of trading allowances during 1995-1997
Galvin-1999[51]	$1,080/ton	EPA damage cost estimate in 1999$
Galvin-1999[51 and 6]	$1,784/ton	Tellus Institute control cost estimate in 1994$ for Boston Edison Settlement Board and based upon MA Docket 91-131
Galvin-1999[51]	$1,923/ton	Vermont DPS used control cost from MA Docket 91-131
Galvin-1999[51]	$1,780/ton	CBEE estimate based upon experience with California's "cap and trade" transferable permit system
Tellus-1995[6 and 122]	1.15 cents/kWh	NEPOOL's estimated value of avoided air emissions due to 1994 New England DSM efforts
Ottinger-1990 [36, 53, and 122]	$2.03/lb.	General "starting point"* scenario for the cost of SOx, which includes $1.72 for mortality, $0.05 for morbidity, $0.12 for corrosion to paint and rubber, and $0.14 for visibility. Does not include acid rain costs to ecosystems or historical monuments.
Hill-1999 [23 and 122]	$110-130/ton	Avoided cost of SO2 emissions as determined by the market price of SO2 trading allowances in the 1995-1997 market place.
Hill-1999 [23, 59 and 120]	0.001-2.71 lbs./mmBTU	For residential space heating, there is 0.001-1.09 lbs. SOx/mmBTU for NG, 0.001 for LPG, 0.91 for kerosene, 1.10-2.71 for fuel oil, and 0.029-0.073 for wood
Hill-1999 [23, 59 and 119]	18.57 lbs./MWh	1994 Ohio HWAP avoided SOx emissions per home per year

Table 9
Nitrogen Oxide (NOx) Emissions

Study	Benefit	Definition
Ohio WAP-1999[23 and 123]	$0.60/home weatherized or $10 NPV	Control cost for low NOx burners and overfire technologies
Galvin-1999[51 and 6]	$7,557/ton	Tellus Institute control cost estimate in 1994$ for Boston Edison DSM Programs in 1995
Galvin-1999[51]	$8,143	Vermont DPS used control cost from MA Docket 91-131
Galvin-1999[51]	$1,780	1998 CBEE estimate based upon experience with California's "cap and trade" transferable permit system
Tellus-1995[6 and 122]	1.86 cents/kWh	NEPOOL's estimated value of avoided air emissions due to 1994 New England DSM efforts
Hill-1999 [23, 59 and 120]	0.002-0.98 lbs./mmBTU	For residential space heating, there is 0.02-0.1 lbs. NOx/mmBTU for NG, 0.09-0.10 for LPG, 0.01-0.12 for kerosene, 0.07-0.17 for fuel oil, and 0.09-0.98 for wood
Hill-1999 [23, 59 and 119]	7.58 lbs./MWh	1994 Ohio HWAP avoided emissions per home per year
Hill-1999 [23 and 122]	$400/ton	Avoided control cost based on low NOx burners and overfire air technologies
Ottinger-1990 [36 and 104]	$0.43/lb.	Big City scenario for the cost of NOx, which includes $0.34 for mortality and $0.01 for corrosion, $0.01 for crop loses, and $0.07 for visibility
.tinger-1990 [36 and 104]	$0.022/lb.	Small City scenario for the cost of NOx, which includes $0.016 for mortality and $0.001 for corrosion, $0.002 for crop loses, and $0.003 for visibility
Ottinger-1990 [36 and 53]	$0.82/lb.	General "starting point"* scenario for the cost of NOx, which includes $0.34 for mortality, $0.29 for morbidity, $0.01 for corrosion to paint and rubber, $0.01 for crop loses, and $0.17 for visibility
Hasselman-1997 [53 and 122]	$2700/ton	Control cost from power plant emissions

* "starting point" is the authors main scenario for environmental damage based on the best guess assimilation of values from other studies.

Table 10
Volatile Organic Compounds (VOC's) Emissions

Study	Benefit	Definition
Galvin-1999[51 and 6]	$6,192/ton	Tellus Institute control cost estimate in 1994$ for Boston Edison DSM Programs in 1995
Galvin-1999[51]	$6,673/ton	1997 Vermont DPS Statewide Energy Efficiency Plan
Galvin-1999[51]	$530/ton	1998 CBEE estimate based upon experience with California's "cap and trade" transferable permit system

Table 11
Particulate Matter (PM's) Emissions

Study	Benefit	Definition
Galvin-1999[51 and 6]	$4,618/ton	Tellus Institute control cost estimate in 1994$ for Boston Edison DSM Programs in 1995
Galvin-1999[51]	$9,953/ton	1997 Vermont DPS Statewide Energy Efficiency Plan
Galvin-1999[51]	$910/ton	1998 CBEE estimate based upon experience with California's "cap and trade" transferable permit system
Tellus-1995[6 and 122]	0.19 cents/kWh	NEPOOL's estimated value of avoided air emissions due to 1994 New England DSM efforts
Hill-1999 [23, 59 and 120]	0.001-3.05 lbs./mmBTU	For residential space heating, there is 0.003-0.02 lbs. PM's/mmBTU for NG, 0.021 for LPG, 0.001-0.161 for kerosene, 0.02-0.026 for fuel oil, and 0.50-3.05 for wood
Hill-1999 [23, 59 and 119]	0.31 lbs./MWh	1994 Ohio HWAP avoided PM-10 emissions per home per year
Ottinger-1990 [36 and 104]	$0.36/lb.	Big City scenario for the cost of PM-10s, which includes $0.33 for mortality and $0.03 for morbidity
Ottinger-1990 [36 and 104]	$0.02/lb.	Small City scenario for the cost of PM-10s, which includes $0.02 for mortality
Ottinger-1990 [36, 53 and 122]	$1.19/lb.	General "starting point"* scenario for the cost of PM-10s, which includes $0.33 for mortality, $0.03 for morbidity, and $0.83 for visibility.

Table 12
Carbon Monoxide (CO) Emissions

Study	Benefit	Definition
Galvin-1999[51]	$920/ton	1991 Nevada PSC
Galvin-1999 [51 and 6]	$1,008/ton	Tellus Institute avoided control cost estimate in 1994$ for Boston Edison DSM Programs in 1995
Galvin-1999[51]	$1,086/ton	1997 Vermont DPS Statewide Energy Efficiency Plan
Tellus-1995[6 and 122]	0.02 cents/kWh	NEPOOL's estimated value of avoided air emissions due to 1994 New England DSM efforts
Skumatz-1997 [44]	$0-0.15/part/year	A best guess approximation of the health benefits for a generic low-income weatherization program.
Hill-1999 [23, 59 and 120]	0.001-3.05 lbs./mmBTU	For residential space heating, there is 0.006-0.026 lbs. CO/mmBTU for NG, 0.022 for LPG, 0.001-0.24 for kerosene, 0.032-0.047 for fuel oil, and 0.15-25.8 for wood
Hill-1999 [23, 59 and 119]	0.33 lbs./MWh	CO emissions avoided due to participation in Ohio HWAP in 1994 – weighted average for 5 Ohio utilities based on their share of participants

Table 13
Carbon Dioxide (CO2) Emissions

Study	Benefit	Definition
Ohio WAP-1999[23 and 123]	$32.84/home weatherized or $242 NPV	Estimated control cost to get US CO2 down to 1990 levels by 2010
Galvin-1999[51]	$12-$50/ton carbon*	CEC (California Energy Commission) adopted based on what may result from international trading
Galvin-1999[51]	$30/ton carbon*	CEC adopted in ER-94 proceedings and primarily uses damage cost function
Galvin-1999[51]	$22/ton	1991 Nevada PSC
Galvin-1999[51 and 6]	$25/ton	Tellus Institute control cost estimate in 1994$ for Boston Edison DSM Programs in 1995
Galvin-1999[51]	$27/ton	1997 Vermont DPS Statewide Energy Efficiency Plan
Galvin-1999[51]	$10-$77/ton	A March 17, 1999 memorandum by Tim Woolf of Synapse Energy Economics cited a range of values from other studies.
Tellus-1995[6 and 122]	2.1 cents/kWh	NEPOOL's estimated value of avoided air emissions due to 1994 New England DSM efforts
Hill-1999 [23, 59 and 120]	121-166 lbs./mmBTU	CO2 avoided from reduce residential space heating fuel usage wrought from Ohio WAP in 1994$. 121 lbs./mmBTU for NG, 152 for LPG, 166 for Kerosene, 172 for fuel oil
Hill-1999 [23, 59 and 119]	2,145 lbs./mmBTU	CO2 avoided from reduced electric usage averaged for 1994 WAP Participants over 5 Ohio Utilities
Hill-1999 23 and 122	$12.40/ton	Avoided control cost of keeping CO2 at 1990 levels by 2010
Berry-1997 4, 11, 50, 102	0.25-0.48 tons carbon** /home/year	Tons per household of avoided carbon** emission due to national weatherization. 0.25 tons for NG heated homes, 0.45 for fuel oil homes, 0.26 for LPG homes, 0.48 for electric homes, and 0.31 for kerosene
Skumatz-199945 and 130	$25/ton	Emissions costs of CO2 from NG facilities
Hasselman-1997 53 and 122	$15/ton	Control cost
Hasselman-1997 53 and 36	$54/ton	Emission cost of environmental damage

* Galvin stated this value in tons in "molecular weight carbon" instead of tons of CO2, but this is not entirely clear. A molecule of CO2 weighs 3.67 times that of a carbon atom.

** Figures are in tons of atomic weight carbon, CO2 molecules weigh 3.67 times that of carbon atoms.

Table 14
Methane (CH4) Emissions

Study	Benefit	Definition
Galvin-1999[51]	$220/ton	1991 Nevada PSC
Galvin-1999[51 and 6]	$252/ton	Tellus Institute control cost estimate in 1994$ for Boston Edison DSM Programs in 1995
Tellus-1995[6 and 122]	0.04 cents/kWh	NEPOOL's estimated value of avoided air emissions due to 1994 New England DSM efforts
Hill-1999 [23, 59 and 120]	0.002-4.65 lbs./mmBTU	For residential space heating, there is 0.002-0.003 lbs. CH4/MmBTU for NG, 0.002 for LPG, 0.013 for fuel oil, and 0.085-4.65 for wood
Hill-1999 [23, 59 and 119]	0.02 lbs./mmBTU	Ohio state energy office computed the impact of Ohio HWAP and is weighted based on utility's share of participant enrollment
Berry-1997 [4 and 11]	0.09 tons/home	CH4 emission avoided by national weatherization per home per year
Hasselman-1997 [53 and 122]	$150/ton	The control cost of power plant methane emissions

Table 15
Nitrous Oxide (N2O) Emissions

Study	Benefit	Definition
Galvin-1999[51]	$4,140 / ton	1991 Nevada PSC
Tellus-1995[6 and 122]	0.08 cents / kWh	NEPOOL's estimated value of avoided air emissions due to 1994 New England DSM efforts
Berry-1997 [4 and 11]	0.173 tons / home	N2O emission avoided by national weatherization per electrically heated home per year

Table 16
Heavy Metal Emissions

Study	Benefit	Definition
Galvin-1999[51]	0-247% adder to avoided 4 cent / kWh electric supply	heavy metals include: arsenic, beryllium, cadmium, chromium, copper, lead, manganese, mercury, nickel, and selenium – 0%-247%. This study was done for the Massachusetts DTE.
Tellus-1995[6]	0.015-0.278 cents / kWh	For toxins with known control costs, the marginal control costs are used. The remaining use relative toxicities.*
Tellus-1995[6]	$920 / lb.	1994 cost for Arsenic**
Tellus-1995[6]	$359-94,488 / lb.	1994 cost for Beryllium**
Tellus-1995[6]	$143-37,795 / lb.	1994 cost for Cadmium**
Tellus-1995[6]	$0-55 / lb.	1994 cost for Trivalent Chromium**
Tellus-1995[6]	$1,430 / lb.	1994 cost for Hexavalent Chromium**
Tellus-1995[6]	$0-70 / lb.	1994 cost for Copper**
Tellus-1995[6]	$540 / lb.	1994 cost for Lead**
Tellus-1995[6]	$55-1,404	1994 cost for Manganese**
Tellus-1995[6]	$14-3,779	1994 cost for Mercury**
Tellus-1995[6]	$1-210	1994 cost for Nickel**
Tellus-1995[6]	$0-70	1994 cost for Selenium**

* Includes: (1) 0.005 cents / kWh for arsenic, (2) 0-0.021 for beryllium, (3) 0-0.021 for cadmium, (4) 0-0.07 for trivalent chromium, (5) 0.009 for lead, (6) 0-0.002 for mercury, (7) 0.001-0.17 for nickel. This total to 0.015-0.278 cents/kWh for toxic air emissions.

** Uses relative toxicities from the Massachusetts Allowable Ambient Limits (AAL). It is similar to the EPA's "reference doses" but it includes both non-cancer and cancer health effects.

Appendix C. Arrearages

Table 17

Arrearage Benefits of Low-Income and Weatherization Programs

Location/Study	Benefit value	Definition	Methodology	Baseline
National Brown-1993 [11, 26, 4, 50]	$32/home	The average reduction in arrears in the year following national weatherization per dwelling.	Use of available data on payment histories for dwellings in the national weatherization study sample were used. Unlike many arrearage studies, the national one did not specifically target high arrearage low-income weatherized people.	
Ohio Blasnik-1997 [7]	65%	Average annual customer bill payment shortfalls declined by 65% after HWAP (Ohio's Home Weatherization Assistance Program) participation among (PIPP-Only) customers	Billing analysis	Shortfalls went form $217/yr to $77/yr.
Ohio Blasnik-1997 [7]	63%	Average annual customer bill payment shortfalls declined by 63% after HWAP (Ohio's Home Weatherization Assistance Program) participation.	Billing analysis	For all HWAP participants, average payment shortfalls went from $114/yr to $42/yr.
Ohio Blasnik-1998 [56]	$1,200/home	NPV in 1994$ of the amount of ratepayer savings in PIPP due to Ohio" HWAP		
Detroit Edison RLW Analytic-1997 [42]	0.5%	The gross change in customer bills paid o time after participation in Detroit Edison's 1995 Residential Energy Management Program	Billing analysis	

Location/Study	Benefit value	Definition	Methodology	Baseline
Detroit Edison Colton-1994 [54 and 116]	$150	On average account balances were reduced by $150 over a period from July to December 1992.	Detroit Edison offered high use, high arrears customers extensive energy management program (Energy Options), where participants received usage comparisons in monthly bill to show what they used this month compared to what they used in the same month last year and they also received a) 10 cent/kWh arrearage reduction for each kWh they had reduced.	
Milwaukee Brown-1993 [11, 24, 39]	$232/home	Weatherization participants took part in a Milwaukee Low Income Budget Payment Plan (LIBP) and experienced reduced arrearages when compared to a weatherized comparison group of LIBP non-participants.	Arrearage levels averaged before participation in a LIBP Payment Plan (which is based on affordability) and compared to average arrearage levels after participation. Time trends in arrearage and statistical comparisons of pre and post treatment arrearage level (to see if weatherization had an effect on arrearage) were used as a methodology.	The arrearages of LIBP participants who did not receive weatherization went up $176 and this compares to LIBP participants who did receive weatherization and who's arrears went down by $56. The net difference is $232 of arrears.
Wisconsin Gas Co / Milwaukee. Hoch-1991 [24, 39]	56%	A control adjusted net reduction in un-recovered gas charges for weatherized customers of 56% occurred.	Analysis of the aggregate recovery of incurred gas charges by customer payments and energy assistance. This study was done on LIBP (Low-Income Bill Payment) plan Wisconsin Gas Company customers from 1986 through 1989. Both comparison groups were on a LIBP plan.	There was a 64% reduction (dropping $311 from $484 to $173) in un-recovered gas charges for the weatherized treatment group, compared to an 8% reduction (dropping $30) for the un-weatherized comparison group.
Wisconsin Gas Co. Colton-1994 [54 and 113]	20%	The utility's return on investment in 1998 weatherization, strictly from the reduced nonpayment and before considering traditional avoided costs, in the first year of the program.		

Location/Study	Benefit value	Definition	Methodology	Baseline
Wisconsin Gas Co. Colton-1994 [54 and 113]	$353	The annual reduction in arrears resulting from weatherization in single family dwelling from a 1988 Wisconsin Gas Company study.		
Wisconsin Gas Co. Colton-1994 [54 and 113]	$502	The annual reduction in arrears resulting from weatherization in two-family dwelling from a 1988.		
Missouri Gas Energy Hall-1998 [21]	-$5.02/ month/home	Change in monthly utility bill balance before and after weatherization retro-fit for Missouri Gas Energy customers	Computed average change in monthly utility bill balance for a group of weatherization pilot participants	
Connecticut Light & Power Co. Colton-1994 [54, 114]	$9.73-$18.77	The average monthly arrears were reduced by $9.73 in 1989 and $18.77 in 1990 as a result of DSM.		
Connecticut Light & Power Co. Colton-1994 [54, 114]	$40-$28	The average monthly arrears were reduced by $9.73 in 1989 and $18.77 in 1990 as a result of DSM. Specifically from the "E4" Plan.		
Niagara Mohawk Harrigan-1992 [58]	23%	There was a 23% increase in the total dollars paid by the group #4 customers to the utility from $968 before the program up to $1188 after participation. Also for group #4, the number of payments per unit of time doubled after participation. During this same time period the control group #1 paid less to the utility, $844 before and $895 after.	Niagara Mohawk 1991 post program telephone survey of four groups: 1) unweatherized control group, 2) weatherized only group, 3) weatherized plus budget counseling, energy usage education, electric DSM measures installed, and affordable bill payment plan group, and 4) all of the above plus a real-time minute-to-minute feed back on cost and usage of natural gas for water and space heating.	

Location/Study	Benefit value	Definition	Methodology	Baseline
Niagara Mohawk Harrigan-1992 [58]	33%	There was a 33% increase in the total dollars paid by the group #3 customers to the utility from $883 before the program up to $1174 after participation. Also for group #3, the number of payments per unit of time doubled after participation. During this same time period the control group #1 paid less to the utility, $844 before and $895 after.	Niagara Mohawk 1991 post program telephone survey of four groups: 1) unweatherized control group, 2) weatherized only group, 3) weatherized plus budget counseling, energy usage education, electric DSM measures installed, and affordable bill payment plan group, and 4) all of the above plus a real-time minute-to-minute feed back on cost and usage of natural gas for water and space heating.	
Niagara Mohawk Howat-1999 [26]	$469/home	Customers (with the ability to pay) reduced arrearages by an average of $469 after delivery of Niagara Mohawk's low-income DSM program per household.		
Columbia Gas Ramos-1993 [35]	12%	There was a stratified (with similar arrearage patterns) control group adjusted reduction of 12% in arrearage change over pre- and post-program periods in a comprehensive Low-Income Usage Reduction Program (LIURP).	Weatherization participant bill payment behaviors were compared to a control group that was stratified with similar bill payment behaviors.	
Columbia Gas Ramos-1993 [35]	15%	There was a control group adjusted reduction of 15% in customer billing deficit of the average monthly billing over pre- and post-program periods in a comprehensive LIURP.	Weatherization participant's bill payment behaviors were compared to a control group.	
Columbia Gas Ramos-1993 [35]	5%	There was a control group adjusted reduction of 5% in utility shortfalls of the average monthly billing over pre- and post- program periods in a comprehensive Columbia Gas Low-Income Usage Reduction Program (LIURP).	Weatherization participant's bill payment behaviors were compared to a control group.	

Location/Study	Benefit value	Definition	Methodology	Baseline
Columbia Gas Colton-1994 [54 and 35]	5%	Control adjusted improvement in utility shortfalls paid to the utility due to participation in a 1990 LIURP (Low-Income Usage Reduction Program) for Columbia Gas Company of Pennsylvania.		The control group had an average monthly utility shortfall equal to 3% of the average monthly bill during the pre-program period. This rose to a 10% surplus during post program period. Similarly, program participants went from a 3% utility shortfall to a 15% surplus. This is a control adjusted improvement of 5%, which is statistically significant.
Columbia Gas Colton-1994 [54 and 35]	19%	There was a control adjusted net reduction of 19% in customer billing deficit as a result of LIURP participation..	This is control adjusted and statistically significant.	LIURP participants paid 58% of their average monthly bills prior to participation and 75% after. The control group paid 64% before and 67% after
PG&E Skumatz-1997 [44]	$0.50-7.50	Reduced carrying cost of arrearages for generic low-income program such as PG&E's Venture Partners Pilot Program on a per household basis.	Point estimate for PG&E's VPP Program based on an assumed reduction of 26% in arrears.	
PG&E Howat-1999 [26]	$4-63/home	Reduced carrying charges on arrearages for PG&E's low-income weatherization and education on a per household basis.		
Washington Brown-1993 [11, 39]	$84/home	Average amount of monthly arrears reduced per home after participation in the Yakima Valley Energy Savings Partnership (YVESP).*	In Washington, for the YVESP Program in 1988/89, clients received weatherization, energy assistance, education and access to budget billing as a part of YVESP.	Prior to participation, the average home was in arrears by $93 per month, and after participation in YVESP, it went down to $9, for a net reduction of $84 per home.
Washington Quaid-1991 [39]	69%	In Washington, the Yakima Valley Energy Savings Partnership (YVESP) Program in 1988/89 where clients received weatherization, energy assistance, education and access to budget billing.*	YVESP participants were compared before and after their participation for the percent sample still in arrears.	Percent of sample in arrears prior to participation in YVESP program. Thus, YVESP participation is attributed to reducing percent in arrears from 58% to 18%.

Location/Study	Benefit value	Definition	Methodology	Baseline
Washington Khawaja-1992 [29]	15%	There was a (internal control group) adjusted decrease in the percentage of customers classified as problematic in their bill payment behavior by 15% in a Washington study as a result of weatherization..		Participants increased from 62% with good payments in the pre-program period to 72% in the post program period, while the internal control group went from 77% with good payments up to 78%. This represents a control adjusted increase of 15% of those exhibiting good payment behavior.
Washington Khawaja-1992 [29]	8.5%	There was a (external control group) adjusted decrease in the percentage of customers classified as problematic in their bill payment behavior by 8.5% in a Washington study as a result of weatherization.		Participants increased from 62% with good payments in the pre-program period to 72% in the post program period, while the internal control group went from 78% with good payments up to 84%. This represents a control adjusted increase of 15% of those exhibiting good payment behavior.
Washington Khawaja-1992 [29]	61%	There is a control adjusted percentage decrease of 61% in the dollar value of mean arrearages after participation in a Washington weatherization program.		The treatment groups mean arrears were $48.99 prior to participation and $21.85 afterwards ($27.14 decrease), while the control groups arrears went from $14.07 pre-program to $16.70 after ($2.63 increase). Thus a total net shift of $29.77, which is a net 61% reduction of arrearages off of the $48.99 pre-program treatment group level.

Location/Study	Benefit value	Definition	Methodology	Baseline
Oregon Khawaja-1992 [29]	17%	There is a control adjusted percentage decrease of 17% in the dollar value of mean arrearages after participation in a Oregon weatherization program.		The treatment groups mean arrears were $29.56 prior to participation and $27.06 afterwards ($2.50 decrease), while the control groups arrears went from $4.95 pre-program to $7.53 after ($2.58 increase). Thus a total net shift of $5.08, which is a net 17% reduction of arrearages off of the $29.56 pre-program treatment group level.
Oregon Khawaja-1992 [29]	8%	There was a control adjusted decrease in the percentage of customers classified as problematic in their bill payment behavior by 8% in a 1992 Oregon study as a result of weatherization.		Participants increased from 63% with good payments in the pre-program period to 65% in the post program period, while the control group went from 74% with good payments down to 71%. This represents a control adjusted increase of 8% of those exhibiting good payment behavior.
Colorado Magouirk-1995 [30]	$7.98	First year savings from reduced arrears and bad debt and fewer account write-offs and shut-offs to the 1993 Colorado Public Service's Energy Savings Partners Program (low-income weatherization) on a per household weatherized basis. $3.29 for the reduction in the size of bad debt written off, $2.77 savings from decreased number of accounts written-off for bad debt, $0.74 savings from fewer shut-offs for delinquency, and $1.18 savings from carry cost of the reduction in arrearages.	Arrears were summed for both the pre- and post-weatherization (14 month periods) and a mean was found. The before and after arrearage level carrying costs were based upon an interest rate of 8.18%. The mean bad debt written off before weatherization was compared to the mean bad debt written off afterwards.	

Location/Study	Benefit value	Definition	Methodology	Baseline
Colorado Magouirk-1995 [30]	26%	Monthly carried arrears were reduced by weatherization by the 1993 Colorado Public Service's Energy Savings Partners Program (low-income weatherization) on a per household weatherized basis		from a mean of $55.55 prior to weatherization and $41.08 afterwards, for a net reduction of $14.47 or 26%.
Colorado Howat-1999 and Magouirk-1995 [30 and 26]	$30.56	Uncollectables and bad debt write-offs were reduced by $30.65 per participating household in Colorado		

* Percent reduction of households in arrears following weatherization only was 2% (or $6 less per month) and EAP only 3% (or $3 less per month)

Appendix D. Bibliography of Non-Energy Benefits

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A Study of the Feasibility of Energy Efficiency as an Eligible Resource as Part of a Renewable Portfolio Standard for the State of North Carolina

December 2006

Report for the North Carolina Utilities Commission

Prepared and Submitted by:

GDS Associates, Inc.
Engineers and Consultants

GDS Associates, Inc. • 1850 Parkway Place • Suite 800 • Marietta, GA 30067 • **www.gdsassociates.com**
Marietta, GA • Austin, TX • Auburn, AL • Manchester, NH • Madison, WI

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1.0 EXECUTIVE SUMMARY – ELECTRIC ENERGY EFFICIENCY POTENTIAL

This study estimates the achievable cost-effective potential for electric energy and peak demand savings from energy efficiency measures in North Carolina. The cost-effectiveness test used for screening of energy efficiency measures is the levelized cost per lifetime kWh saved of each energy efficiency measure. Energy efficiency opportunities typically are physical, long-lasting changes to buildings and equipment that result in decreased energy use while maintaining the same or improved levels of energy service. Only measures costing less than $.05 per lifetime kWh saved[1] were considered to be cost-effective. The cost used in the calculations is the incremental cost of energy efficient options relative to equivalent conventional (not high efficiency) technologies.

The study shows that there is still significant savings potential in North Carolina for cost-effective electric energy efficiency and fuel conversion measures. The technical potential savings for electric energy efficiency measures in North Carolina is **33** percent of projected 2017 kWh sales in the State, and the achievable savings potential (before cost-effectiveness screening) is **20** percent of projected 2017 kWh sales.

Based on cost-effectiveness screening, capturing the achievable cost-effective potential for energy efficiency in North Carolina would reduce electric energy use by **14** percent by 2017. The magnitude of the potential savings is consistent with results reported for recent studies for many other States (see Table 1-7 for the results of other recent studies). In addition, a November 2006 electric energy efficiency potential study just completed for North Carolina by Appalachian State University Energy Center also found that the achievable cost-effective potential for electricity savings for the State is 14%.[2] Load reductions from load management and demand response measures, which were not analyzed in this study, would be in addition to these energy efficiency savings. Table 1-1 below provides a summary of the achievable cost-effective energy efficiency potential savings for North Carolina by the year 2017. It is important to note that for the RPS 10% scenario where energy efficiency is included in the portfolio, the maximum level of energy efficiency is assumed to be only 2.5 percent of total

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[1] The levelized cost per lifetime kWh saved for each energy efficiency measure was determined by calculating an annual installment loan payment to represent the annualized cost of the measure over its useful life, and then dividing this annualized cost by the annual kWh savings of the measure.

[2] Appalachian State University Energy Center and Department of Technology, report titled "Evaluation of Energy Efficiency Opportunities in the State of North Carolina", Executive Summary, October 18, 2006, study Sponsored by State Energy Office, North Carolina Department of Administration. The High Impact Scenario in this report estimates an achievable cost-effective potential of 14 percent by 2020.

kWh sales (25% of 10% RPS Target) in the year 2017, much less than the achievable cost-effective potential of 14 percent.

In developing the estimates of achievable cost-effective savings potential, GDS considered savings opportunities from market driven energy efficiency program strategies. This report presents estimates of the achievable cost-effective potential for North Carolina based upon screening using the levelized cost per kWh saved of each energy efficiency measure included in this study. The key conclusion of this study is that the achievable cost-effective potential for energy efficiency in North Carolina should easily be able to meet 25% of either a 5% or 10% RPS for the State. Table 1-1 below presents the energy efficiency potential GWh savings by 2017 for North Carolina (GWh savings shown at the customer meter).

Table 1-1: All Sectors Potential Electricity Savings by 2017		
Level of Potential Savings	Cumulative Annual Electricity Savings Potential by 2017 (GWh)	% of 2017 GWh Sales
Technical Potential	58,968	32.7%
Achievable Potential	36,234	20.1%
Achievable Cost Effective Potential ($.05 per lifetime kWh saved or lower)	25,132	13.9%

This Study is not meant to be a detailed exploration of every possible demand-side management or energy efficiency program that can be implemented in the State, but rather an overview of cost-effective potential for commercially available energy efficiency measures in the context of this RPS study. The focus, for the purposes of the RPS analysis, was to examine energy efficiency measures that could provide the greatest energy reductions in a cost-effective manner. Table 1-2 below lists the total number of energy efficiency measures examined in the GDS study by sector.[3]

Table 1-2 – Number of Energy Efficiency Measures in the GDS Study by Sector	
Sector	Number of Energy Efficiency Measures
Residential sector	34
Commercial sector	81
Industrial sector	12
All Sectors - Total	127

[3] The measure numbers shown in Table 1-2 include all of the measures considered in this study, including measures that were not cost-effective.

The analysis of potential was broken into three customer classes: residential, commercial and industrial. GDS used different technical approaches to estimate the cost-effective energy efficiency potential for each customer class.

For the residential sector, this study assesses the existing level of electric energy efficiency that has already been accomplished in North Carolina. This assessment included collecting data on the penetration of ENERGY STAR appliances and ENERGY STAR homes in the State for the period from 1998 through 2004. For each electric energy efficiency measure, this analysis assessed how much energy efficiency has already been accomplished as well as the remaining potential for energy efficiency savings for a particular electric end use.[4] For the residential sector, GDS addressed the new construction market as a separate market segment, with a program targeted specifically at the new construction market.[5] Additionally, GDS assumed an achievable long-term penetration rate of 80 percent by 2017 for energy efficiency measures in the residential sector in North Carolina. This penetration rate is achieved over a ten-year period, not immediately.

For the commercial and industrial sectors, GDS developed an estimate of the achievable cost-effective potential for North Carolina by calculating an average from eight other recent studies. The average achievable cost-effective potential savings in these other studies is 12.1% for the commercial sector and 10.8% for the industrial sector. GDS concludes that these estimates of 12.1% and 10.8% are reasonable proxies for opportunities in these sectors in North Carolina.

Section 4 of this report provides further detailed information on the technical approach used to estimate the achievable cost-effective potential for energy efficiency savings for each customer class.

1.1 Level of Financial Incentives for the Achievable Potential Base Case Scenario

In the base case developed for this North Carolina Energy Efficiency Potential Report, GDS selected a target incentive level of 50 percent of energy efficiency measure costs as the incentive level necessary in order to achieve high rates of program participation necessary to achieve the savings potential. This incentive level assumption is based upon a thorough review by GDS of numerous energy efficiency potential studies recently conducted in the US, and a review of the

[4] For example, if 100 percent of the homes in North Carolina currently have electric lighting, and 30 percent of light bulb sockets already have high efficiency compact fluorescent bulbs (CFLs), then the remaining potential for energy efficiency savings for this measure is 70 percent.

[5] In the residential new construction market segment, for example, detailed energy savings estimates for the ENERGY STAR Homes program were used as a basis for determining electricity savings for this market segment in North Carolina.

December 2004 National Energy Efficiency Best Practices Study.[6] Examples of the energy efficiency potential studies reviewed by GDS are listed in Table 1-7 of this report. This table also provides the incentive levels assumed for each study.

There are several reasons why an incentive level of 50% of measure costs (and not 100% of measure costs) was assumed for the base case for this study.

First, the incentive level of 50% of measure costs assumed in this North Carolina energy efficiency potential study for the base case scenario is a reasonable target based on a thorough review by GDS of incentive levels used in other recent technical potential studies. The incentive levels used in the studies reviewed by GDS as well as actual experience with incentive levels in other regions of the country confirm that an incentive level assumption of 50% is commonly used. As noted above, the very recent study (February 2006) conducted by Quantum Consulting for the Los Angeles Water and Power Department assumed incentives of 50% of measure costs for its maximum achievable savings scenario. It is interesting to note also that the majority of energy efficiency programs offered by the New York State Energy Research and Development Authority offer no financial incentives to consumers.

Second, and most important, the highly recognized and recently published National Energy Efficiency Best Practices Study concludes that use of an incentive level of 100% of measure costs **is not recommended as a program strategy**.[7] This national best practices study concludes that it is very important to **limit** incentives to participants so that they do not exceed a pre-determined portion of average or customer-specific incremental cost estimates. The report states that this step is critical to avoid grossly overpaying for energy savings. This best practices report also notes that if incentives are set too high, free-ridership problems will increase significantly. Free riders dilute the market impact of program dollars.

Third, financial incentives are only one of many important programmatic marketing tools. Program designs and program logic models also need to make use of other education, training and marketing tools to maximize consumer awareness and understanding of energy efficient products. A program manager can ramp up or down expenditures for the mix of marketing tools to maximize program participation and savings.

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6 See "National Energy Efficiency Best Practices Study, Volume NR5, Non-Residential Large Comprehensive Incentive Programs Best Practices Report", prepared by Quantum Consulting for Pacific Gas and Electric Company, December 2004, page NR5-51.

7 See "National Energy Efficiency Best Practices Study, Volume NR5, Non-Residential Large Comprehensive Incentive Programs Best Practices Report", prepared by Quantum Consulting for Pacific Gas and Electric Company, December 2004, page NR5-51.

In summary, this study does not recommend an incentive level of 100% of measure costs for the above reasons. Furthermore, actual program experience has shown that very high levels of market penetration can be achieved with aggressive energy efficiency programs that combine education, training and other programmatic approaches along with incentive levels in the 50% range.

Appendices A, B, and C of this report provide detailed information on the costs, savings and useful lives of the electric energy efficiency measures examined in this study. Wherever available, GDS used energy efficiency measure costs, savings and useful life data specific to North Carolina. Year-by-year information on MWh savings by sector and peak demand (MW) savings for the achievable cost-effective potential base case are provided in Appendix D of this report. Appendix E lists assumptions used in this study for the discount rate, inflation rate, and line loss factors.

The cost-effectiveness screening (using the levelized cost per lifetime kWh saved for each energy efficiency measure) is based upon a nominal discount rate of 10% provided to GDS by LaCapra Associates. Table 1-3 below shows the estimates of technical potential, achievable potential, and the achievable cost-effective potential for electricity savings in North Carolina by 2017. This table provides savings potential results by sector.

Table 1-3: All Sectors Potential Electricity Savings by 2017

Level of Potential Savings	Cumulative Annual Electricity Savings Potential by 2017 (GWh)	% of 2017 GWh Sales
Technical Potential	58,968	32.7%
Achievable Potential	36,234	20.1%
Achievable Cost Effective Potential ($.05/kWh or lower)	25,132	13.9%

Residential Sector Potential Electricity Savings by 2017

Level of Potential Savings	Cumulative Annual Electricity Savings Potential by 2017 (GWh)	% of 2017 GWh Sales
Technical Potential	28239	39.7%
Achievable Potential	14,528	20.4%
Achievable Cost Effective Potential ($.05/kWh or lower)	12,006	16.9%

Commercial Sector Potential Electricity Savings by 2017

Level of Potential Savings	Cumulative Annual Electricity Savings Potential by 2017 (GWh)	% of 2017 GWh Sales
Technical Potential	18,439	31.7%
Achievable Potential	12,794	22.0%
Achievable Cost Effective Potential	6,950	11.9%

Industrial Sector Potential Electricity Savings by 2017

Level of Potential Savings	Cumulative Annual Electricity Savings Potential by 2017 (GWh)	% of 2017 GWh Sales
Technical Potential	12,290	24.1%
Achievable Potential	8,912	17.5%
Achievable Cost Effective Potential	6,176	12.1%

The base case projection for the achievable cost-effective potential electricity savings is based upon cost-effectiveness screening using the levelized cost per lifetime kWh saved calculation for each efficiency measure.

1.2 Study Scope

The objective of the study was to estimate the achievable cost-effective potential for energy efficiency resources over the ten-year period from 2008 through 2017 in North Carolina. The definitions used in this study for energy efficiency potential estimates are the following:

- **Technical potential** is defined in this study as the complete penetration of all measures analyzed in applications where they were deemed technically feasible from an engineering perspective.

- **Achievable potential** is defined as the achievable penetration of an efficient measure that would be adopted given aggressive funding, and by determining the achievable market penetration that can be achieved with a concerted, sustained campaign involving highly aggressive programs and market interventions. The State of North Carolina would need to undertake an extraordinary effort to achieve this level of savings. The term "achievable" refers to efficiency measure penetration, and means that the GDS Team has based our estimates of efficiency potential on the realistic penetration level that can be achieved by 2017.

- **Achievable cost-effective potential** is defined as the potential for the realistic penetration of energy efficient measures that are cost-effective according to a calculation of the levelized cost per lifetime kWh saved, and would be adopted given aggressive funding levels, and by determining the level of market penetration that can be achieved with a concerted, sustained campaign involving highly aggressive programs and market interventions. As demonstrated later in this report, the State of North Carolina would need to continue to undertake an aggressive effort to achieve this level of electricity savings.

The main outputs of this study are summary data tables and graphs reporting the total cumulative achievable cost-effective potential for electric energy efficiency over the ten-year period, and the annual incremental achievable potential and cumulative potential, by year, for 2008 through 2017.

This study makes use of over 100 existing studies conducted in North Carolina and throughout the US on the potential energy savings, costs and penetration of energy efficiency measures. These other existing studies provided an extensive foundation for estimates of electric energy savings potential in existing residential, commercial and industrial facilities.

1.3 Implementation Costs

Realizing the achievable cost-effective energy efficiency savings by 2017 would require programmatic support. Programmatic support includes financial incentives to customers, marketing, administration, planning, and program evaluation activities provided to ensure the delivery of energy efficiency products and services to consumers. As noted above, the base case projection for the achievable cost-effective potential electricity savings in North Carolina assumes that the program administrator pays financial incentives equivalent to fifty percent of measure incremental costs. This incentive level assumption is based upon a review of numerous energy efficiency potential studies recently conducted in the US and a review by GDS of the December 2004 National Energy Efficiency Best Practices Study. Examples of the energy savings potential studies from other states reviewed by GDS are listed in Table 1-7.

For the RPS energy efficiency scenario (where energy efficiency is included in the RPS as a resource), GDS developed cost estimates for program planning, administration, marketing, reporting and evaluation ("other program costs") based upon historical experience at other energy efficiency organizations, as well as financial incentives to electric consumers in order to realize the achievable cost-effective potential savings for the RPS energy efficiency scenario. It is clear that to realize all of the energy efficiency savings for the RPS energy efficiency scenario, a program administrator in North Carolina would have to undertake steps to add staffing (either in-house staff or contractors), and this program administrator would have to spend approximately $409 million (this figure includes staffing and financial incentives to program participants) in today's dollars in total over the next two decades to achieve such results (or $20.5 million a year in 2006 dollars, assuming the program administrator pays 50% of measure incremental costs).[8] Table 1-4 shows the annual GWh and GW savings, Total Resource costs, Program Administrator costs (including financial incentives), Program Administrator costs (excluding financial incentives) and Participant costs necessary to achieve the energy efficiency savings included in the RPS 10% scenario (with energy efficiency).
The annual energy efficiency GWh and GW savings and energy efficiency costs for the RPS 5% scenario (with energy efficiency) are 50% of the values shown in Table 1-4.

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[8] This cost estimate is based on the key assumption that the North Carolina Program Administrator would pay at least 50% of the incremental costs of energy efficiency measures.

Table 1-4: Costs and Savings for the RPS 10% Scenario With Energy Efficiency Included

Year	Total Cumulative Annual GWh Saved From Energy Efficiency Programs - Generation Level	Total GW Savings - Generation Level	Total Energy Efficiency Costs (Nominal Dollars) = Sum of All Costs (Program Administration, Program Administator Measure Costs, Participant Measure Costs)	Total Program Administrator Costs with financial incentives (Included in Total Energy Efficiency Costs - Excludes Participant Costs)	Administrator Costs just for administration, marketing, data tracking and reporting (Included in Total Energy Efficiency Costs, Equal to $.02 per first year kWh saved)	Total Measure Costs (excludes administative costs for staffing, marketing, etc.)
2008	384.688	0.078	$81,399,026	$44,475,130	$7,551,234	$73,847,792
2009	782.226	0.159	$83,938,942	$45,954,749	$7,970,555	$75,968,387
2010	1,195.269	0.243	$86,863,664	$47,653,502	$8,443,341	$78,420,323
2011	1,622.891	0.330	$89,864,660	$49,402,677	$8,940,694	$80,923,966
2012	2,067.215	0.420	$93,199,962	$51,345,432	$9,490,902	$83,709,060
2013	2,524.069	0.513	$95,725,573	$52,849,259	$9,972,946	$85,752,628
2014	2,995.400	0.609	$98,778,887	$54,654,475	$10,530,063	$88,248,823
2015	3,479.415	0.707	$102,593,157	$56,775,798	$10,958,439	$91,634,718
2016	3,989.113	0.811	$108,406,553	$60,137,107	$11,867,662	$96,538,891
2017	4,509.666	0.917	$111,822,115	$62,095,625	$12,369,135	$99,452,980
2018	4,510.846	0.917	$44,217,241	$24,667,899	$5,118,557	$39,098,683
2019	4,510.353	0.917	$64,218,701	$35,907,753	$7,596,805	$56,621,896
2020	4,509.747	0.917	$67,529,384	$37,846,627	$8,163,869	$59,365,516
2021	4,510.917	0.917	$72,165,999	$40,540,695	$8,915,391	$63,250,608
2022	4,510.394	0.917	$76,629,257	$43,151,334	$9,673,411	$66,955,846
2023	4,510.221	0.917	$79,401,221	$44,821,353	$10,241,485	$69,159,736
2024	4,510.376	0.917	$82,447,065	$46,656,061	$10,865,058	$71,582,007
2025	4,510.769	0.917	$83,505,450	$47,296,580	$11,087,710	$72,417,740
2026	4,509.815	0.917	$89,232,277	$50,637,817	$12,043,356	$77,188,921
2027	4,509.981	0.917	$90,687,965	$51,540,110	$12,392,254	$78,295,711
Present Value in 2006 $			$739,102,267	$409,135,707	$79,169,146	$659,933,121

Based on a discount rate of 10%

The annual energy efficiency GWh and GW savings and energy efficiency costs for the RPS 5% scenario (with energy efficiency) are 50% of the values shown in Table 1-4.

Table 1-5 provides the effective levelized cost per lifetime kWh saved for each major market sector (residential, commercial and industrial sectors) for the RPS 10% scenario with energy efficiency. One factor causing the levelized cost per lifetime kWh saved to differ among sectors is differences in the incremental costs of energy efficient equipment by sector. It is common for these levelized costs to differ by sector. The levelized cost per lifetime kWh saved is a standard metric used by public utilities commissions and energy efficiency organizations in the US and other energy efficiency organizations to compare the value of the avoided energy production and power plant construction to the total costs of energy efficiency measures and program activities necessary to deliver them.

Table 1-5: Calculation of Cost per Lifetime kWh Saved by Sector for the RPS Energy Efficiency Scenario

	Present Value of Total Costs (2006 $)	Value of Lifetime kWh Savings - Customer Meter Level	Levelized Cost per Lifetime kWh Saved
Residential Sector	$262,528,658	9,673,701,174	$0.027
Commercial Sector	$352,185,339	8,702,321,930	$0.040
Industrial Sector	$124,388,270	6,805,459,342	$0.018
Total - All Sectors	$739,102,267	25,181,482,446	$0.029

A January 2005 report[9] published by the American Council for an Energy Efficient Economy (ACEEE) found that there is considerable research from leading energy efficiency states to document that a portfolio of electric energy efficiency programs can save electricity at a cost of **3 cents** per lifetime kWh saved, very comparable to the average $.029 per lifetime kWh saved measure cost[10] that GDS has estimated for the RPS energy efficiency scenario for this study for North Carolina.

1.4 Definition of Electric Avoided Costs

As noted on page 1 of this report, the levelized cost per lifetime kWh saved for each energy efficiency measure included in this study was compared to the levelized cost of electric generation in North Carolina (including capital and operating costs). The **avoided electric supply costs** for this North Carolina energy efficiency potential study consist of the electric supply costs avoided due to the implementation of electric energy efficiency programs. The costs that are avoided depend on the amount of electricity that is saved, and when it is saved (in peak heating season periods, seasonal or annual, etc.). Only measures costing less than $.05 per lifetime kWh saved were considered to be cost-effective.[11]

9 See the American Council for an Energy Efficient Economy report titled "Examining the Potential for Energy Efficiency to Help Address the Natural Gas Crisis in the Midwest", page 33, January 2005. The ACEEE Report Number is U051.

10 For this RPS study for North Carolina, the initial levelized cost per lifetime kWh saved for each energy efficiency measure was calculated by calculating an annual installment loan payment to represent the annualized cost of the measure cost over its useful life, and then dividing this annualized cost by the first year kWh savings of the measure. This levelized cost per lifetime kWh saved for each energy efficiency measure can then be compared to the levelized cost of electric generation in North Carolina (including capital and operating costs). The levelized cost calculations shown in Table 1-5 include all costs, including program administration and financial incentives.

11 The levelized cost per lifetime kWh saved for each energy efficiency measure was determined by calculating an annual installment loan payment to represent the annualized cost of the measure over its useful life, and then dividing this annualized cost by the annual kWh savings of the measure.

Second, it is very important to note that the electricity avoided costs used in this study do not represent the retail rate for each customer class. The actual retail rate is not the avoided electric cost used in this study to determine cost-effectiveness of energy efficiency measures.

1.5 Spending Per Customer on Energy Efficiency Programs

In order to provide a context for program administrator spending on energy efficiency programs in other states, GDS collected data on annual spending per customer on energy efficiency programs by various energy efficiency organizations. GDS examined data from US electric utilities available on the Energy Information Administration web site (www.eia.doe.gov) relating to kWh and kW savings from electric utility energy efficiency programs, and data on utility spending on energy efficiency programs. Listed below in Table 1-6 is data on utility spending per customer on energy efficiency by the top 20 DSM utilities in the US and for Efficiency Vermont. The top 20 are defined as those US electric utilities that have saved the largest percentage of annual kWh sales by 2004 with energy efficiency programs. The average spending per customer by the top 20 DSM utilities on energy efficiency programs ranges from $1.01 to $47.16 per customer. These twenty utilities had the highest kWh savings based on energy efficiency savings as a percent of annual kWh sales in 2004. Note that Efficiency Vermont's 2004 spending per capita was higher than each of the twenty top DSM utilities.

Table 1-6: 2004 US Electric Utility Annual Spending Per Customer On Energy Efficiency Programs

Name of Electric Utility of Energy Efficiency Organization	2004 Dollars spent on Energy Efficiency	Number of Customers in Service Area	2004 Spending Per Customer
Efficiency Vermont	$16,200,000	342,142	$47.35
Seattle, City of	$17,474,000	370,499	$47.16
Western Mass. Elec Company	$9,043,000	203,223	$44.50
Burlington, City of	$846,000	19,696	$42.95
Eugene, City of	$3,397,000	83,118	$40.87
United Illuminating Co	$12,968,000	320,800	$40.42
Connecticut Light & Power Co	$45,130,000	1,165,140	$38.73
Massachusetts Electric Co	$46,295,000	1,198,696	$38.62
Avista Corp	$3,846,000	110,293	$34.87
Boulder City, City of	$246,000	7,580	$32.45
Redding, City of	$1,216,000	42,080	$28.90
Granite State Electric Co	$1,090,000	39,785	$27.40
Wisconsin Power & Light Co	$11,401,000	431,669	$26.41
Northern States Power Co	$31,944,000	1,352,175	$23.62
Minnesota Power Inc	$3,105,000	135,649	$22.89
Puget Sound Energy Inc	$20,869,000	990,020	$21.08
Sacramento Municipal Util Dist	$11,238,000	560,991	$20.03
Southern California Edison Co	$68,922,000	4,597,577	$14.99
Tallahassee, City of	$799,000	95,604	$8.36
Northern States Power Co	$1,285,000	238,065	$5.40
Springfield, City of	$70,000	69,082	$1.01

1.6 Comparison of Results to Other Energy Efficiency Potential Studies

Table 1-7 presents a comparison of the results of this study to other recent electric energy efficiency potential studies. As shown in this table, the achievable cost-effective potential for electricity savings ranges from 6 percent by 2023 in the service area of Puget Sound Energy to 24 percent in Massachusetts by 2007. Five of the thirteen studies listed in Table 1-7 report achievable cost-effective potential in the range of 9 to 13 percent of annual electricity sales. It is very interesting to note that the incentive level assumptions for these thirteen studies range from a low of 15% to a high of 100% of measure costs.

Table 1-7: Comparison of Potential Electrcity Savings from Recent Studies in Other States

Percent of Total Electricity (GWh) Sales

Sector	Conn. 2012[1]	California 2011[2,3]	Vermont 2012[4]	Mass. 2007[5]	Southwest 2020[6]	Big Rivers (KY) 2015[7]	Georgia 2015[8]	New York 2012[9]	Oregon 2013[10]	Puget Sound (WA) 2023[11]	NJ/NH/ PA 2011[12]	Wisconsin 2015[13]
Technical Potential												
Residential	21%	21%	40%		26%	26%	33%	37%	28%			
Commercial	25%	17%	40%		37%		33%	41%	32%			
Industrial	20%	13%	21%		33%	11%	17%	22%	35%			
Total	***24%***	***19%***	***35%***		***33%***		***29%***	***37%***	***31%***			
Maximum Achievable Potential												
Residential	17%	15%	26%			18%	21%	26%		17%	35%	
Commercial	17%	13%	24%				22%	38%		7%	35%	
Industrial	17%	12%	15%			9%	15%	16%		0%	41%	
Total	***17%***	***14%***	***22%***				***20%***	***30%***		***12%***		
Maximum Achievable Cost Effective Potential												
Residential	13%	10%	21%	31%		16%	9%			7%		4.9%
Commercial	14%	10%	21%	21%		10%	10%			6%		4.8%*
Industrial	13%	11%	15%	21%		9%	7%			0%		
Total	***13%***	***10%***	***19%***	***24%***		***12%***	***9%***			***6%***		**9.2%**

Incentive Level as a Percent of Incremental Cost

Percentage	51%-70%	25%, 40%, 55%, 100%	50%	N/A	15%-25%	50%	25%, 50%, 100%	20% - 50%	N/A			
	pg 30	pg 5-11			pg 5-10		pg 2-11	pg 3-7				

Notes to Table 1-7
1. Independent Assessment of Conservation and Energy Efficiency Potential for Connecticut and the Southwest Connecticut Region, Appendix B." Prepared by GDS Associates. June 2004
2. California's Secret Energy Surplus: The Potential For Energy Efficiency – Final Report. Prepared for The Energy Foundation and The Hewlett Foundation, prepared by XENERGY Inc. Sept. 23, 2002.
3. California Statewide Residential Sector Energy Efficiency Potential Study. Study ID #SW063; Final Report Volume 1 OF 2; Prepared for Rafael Friedmann, Project Manager Pacific Gas & Electric Company San Francisco, California; Principal Investigator.
4. Vermont Department of Public Service, "Vermont Electric Energy Efficiency Potential Study, Final Report", July 21, 2006, preapred and submitted by GDS Associates, Inc. Note , this study includes fuel shfting programs to sift residential customers away from electric space and water heating appliances, and away from electric clothes dryers.
5. The Remaining Electric Energy Efficiency Opportunities in Massachusetts; Final Report. Prepared for Program Administrators and Massachusetts Division of Energy Resources by RLW Analytics, Inc. and Shel Feldman Management Consulting. June 7, 2001.
6. The New Mother Lode: The Potential for More Efficient Electricity Use in the Southwest. Prepared for: Hewlett Foundation Energy Series; prepared by Southwest Energy Efficiency Project. November 2002
7. The Maximum Achievable Cost Effective Potential for Electric Energy EfficiencyIn the Service Territory of the Big Rivers Electric Corporation. Prepared for Big Rivers Electric Cooperative (BREC) By GDS Associates. Nov. 2005.
8. Georgia Environmental Facilities Authority, "Assessment of Energy Efficiency Potential in Georgia - Final Report" prepared by ICF Consulting, May 5, 2005.
9. New York State Energy Research and Development Authority, "Energy Efficiency and Renewable Energy Resource Development Potential in New York State - Final Report" prepared by Optimal Energy, Inc., August, 2003.
10. Energy Efficiency and Conservation Measure Resource Assessment For The Residential, Commercial, Industrial, and Agricultural Sectors. Prepared for the Energy Trust of Oregon, Inc. By Ecotope, Inc., ACEEE, Tellus Institute, Inc. January 2003.
11. Assessment of Long Term Electricity and Natural Gas Conservation Potential in Puget Sound Energy Service Area 2003-2024. Prepared for Puget Sound Energy by KEMA-XENERGY/Quantec. August 2003.
12. Energy Efficiency and Economic Development in New York, New Jersey, and Pennsylvania. Prepared by ACEEE. 1997.
13. Wisconsin reported combined results for commercial and industrial sectors as C&I.

2.0 INTRODUCTION

This study provides estimates of the savings potential for achievable and cost-effective electric energy efficiency measures for residential, commercial and industrial electric customers in North Carolina. The main outputs of this study include the following deliverables:

- A concise, fully documented report on the work performed and the results of the analysis of opportunities for achievable, cost-effective electric energy efficiency in North Carolina.
- An overview of the impacts that energy efficiency measures and programs can have on electric use in North Carolina.
- A summary of the economic costs, kWh savings and kW savings of potential energy efficiency measures and programs for the RPS 5% and 10% scenarios with energy efficiency.
- A summary of the program administrator costs necessary to achieve the identified cost-effective electricity savings for the RPS 5% and 10% scenarios with energy efficiency.

2.1 Summary of Approach

A comprehensive discussion of the study methodology is presented in Section 4. GDS first developed estimates of the technical potential and the achievable potential for electric energy efficiency opportunities for the residential, commercial and industrial sectors in North Carolina. Then GDS analysis utilized the following models and information:

(1) an existing GDS electric and natural gas energy efficiency potential spreadsheet model;[12]

(2) detailed information relating to the current and potential saturation of electric energy efficiency measures in North Carolina; and

(3) available data on electric energy efficiency measure costs, saturations, energy savings, and useful lives.

The technical potential for electric energy efficiency was based upon calculations that assume one hundred percent penetration of all energy efficiency measures analyzed in applications where they were deemed to be technically feasible from an engineering perspective.

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[12] GDS has developed a detailed Excel spreadsheet model and used it to estimate the energy efficiency potential for electric energy efficiency measures in North Carolina. It operates on a PC platform using the Microsoft Windows operating system, is documented, and can be followed by a technician with expertise. This model can assess up to 110 separate energy efficiency measures in a single Excel file and it can calculate all of the benefit/cost ratios included in the latest California Standard Practice manual.

The achievable potential for electric energy efficiency was estimated by determining the highest realistic level of penetration of an efficient measure that would be adopted given aggressive funding, and by determining the highest realistic level of market penetration that can be achieved with a concerted, sustained campaign involving highly aggressive programs and market intervention.

The third level of energy efficiency examined is the achievable cost-effective potential. The calculation of the cost-effective achievable potential is based, as the term implies, on the assumption that energy efficiency measures/bundles will only be included in North Carolina electric efficiency programs when it is cost-effective to do so.

All calculations of the levelized cost per lifetime kWh saved for energy efficiency measures were done using an Excel worksheet.

2.2 Report Organization

The remainder of this report is organized as follows:

- Section 3 – Load Forecast for North Carolina
- Section 4 – Methodology for Determining Electric Energy Savings Potential
- Section 5 – Electric Energy Efficiency Potential – Residential Sector
- Section 6 – Electric Energy Efficiency Potential – Commercial Sector
- Section 7 – Electric Energy Efficiency Potential – Industrial Sector

3.0 ELECTRIC LOAD FORECAST FOR THE STATE OF NORTH CAROLINA

This section of the report provides a short description of the latest available electric load forecast for the State of North Carolina. This load forecast was developed by La Capra Associates by adding together the individual electric load forecasts for all of the electric utilities in North Carolina. In order to develop estimates of electricity savings potential, it is important to understand the forecast of the demand for electricity in North Carolina, as well as electric end-use saturation data.

3.1 Historical kWh Sales and Electric Customers in North Carolina

Table 3-1 and 3-2 show historical data for North Carolina for annual kWh sales and electric customers by class of service.[13] Total annual kWh sales in North Carolina grew at an annual rate of 2.3% from 1994 to 2004. As one can see from the kWh sales data, the commercial sector kWh sales grew the fastest from 1994 to 2004 (at 4.6% per year on average), while the residential sector annual kWh sales grew at 3.3% per year and total industrial sales declined slightly at an annual rate of 0.7%.[14] From 1990 to 2004, the number of electric customers in the State increased at an average annual rate of 87,045 customers per year.

Table 3-1: North Carolina Sales to Ultimate Customers by Customer Class (Megawatt-hours)

YEAR	Residential	Commercial	Industrial	Other	Total Sales
1990	33,144,040	23,834,909	31,264,700	1,680,838	89,924,487
1991	34,390,834	24,675,721	31,514,220	1,735,708	92,316,483
1992	34,761,066	25,142,413	32,521,880	1,769,972	94,195,331
1993	37,742,397	26,747,461	33,487,659	1,800,037	99,777,554
1994	37,206,780	27,457,860	33,307,132	1,817,410	99,789,182
1995	39,506,250	29,194,750	34,062,921	1,908,835	104,672,756
1996	41,591,843	30,662,155	34,141,749	1,900,647	108,296,394
1997	40,611,106	31,388,363	35,095,124	1,955,432	109,050,025
1998	42,890,314	33,637,195	34,985,931	2,082,866	113,596,306
1999	43,648,445	35,068,684	34,164,871	2,133,125	115,015,125
2000	46,536,517	36,858,836	34,251,859	2,208,244	119,855,456
2001	46,200,716	37,744,147	32,931,139	2,150,941	119,026,943
2002	49,854,417	39,276,813	31,381,089	2,174,149	122,686,468
2003	49,348,767	41,672,018	30,314,336	-	121,335,121
2004	51,717,380	42,864,261	31,075,166	-	125,656,807
Annual Rate of Growth - 1998-2004	3.2%	4.1%	-2.0%		1.7%
Annual Rate of Growth - 1994-2004	3.3%	4.6%	-0.7%		2.3%

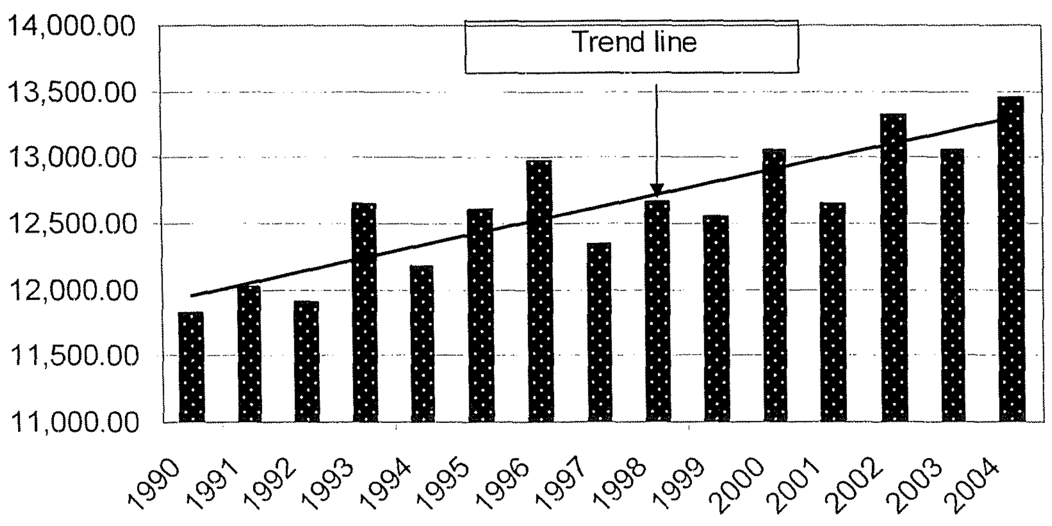
[13] This historical kWh sales data for North Carolina is taken directly from the Energy Information Administration, Electric Power Annual 2004 – State Data Tables. (www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html)

[14] Beginning in 2003 the Other Sector has been eliminated. Data previously assigned to the Other Sector have been reclassified into the commercial and industrial sectors.

Table 3-2: Number of Customers by Customer Class - North Carolina					
YEAR	Residential	Commercial	Industrial	Other	Total Customers
1990	2,801,451	388,208	14,687	28,086	3,232,432
1991	2,860,309	396,182	14,679	31,024	3,302,194
1992	2,917,260	402,376	13,578	29,905	3,363,119
1993	2,983,653	412,420	13,150	28,238	3,437,461
1994	3,055,129	423,619	13,141	25,975	3,517,864
1995	3,133,798	435,840	12,993	23,972	3,606,603
1996	3,206,116	452,013	13,686	22,108	3,693,923
1997	3,289,364	465,180	12,691	22,705	3,789,940
1998	3,383,932	480,830	12,385	23,310	3,900,457
1999	3,474,399	500,602	12,771	18,331	4,006,103
2000	3,561,203	513,727	12,577	18,204	4,105,711
2001	3,652,769	528,310	12,142	19,060	4,212,281
2002	3,741,959	543,212	11,645	18,973	4,315,789
2003	3,778,470	575,864	11,358	-	4,365,692
2004	3,845,187	594,424	11,444	-	4,451,055

Figure 3-1 below shows historical data for North Carolina for average annual kWh use per residential customer for the period 1990 to 2004. There has been a gradual upward trend in electric use per residential customer since 1992. Average annual use per customer in 2004 was 14 percent higher than in 1992. Average annual kWh use per residential customer in North Carolina is below the South Atlantic region average but above the US average.

Figure 3-1: Residential Sector Average Annual kWh use Per Customer



3.2 Forecast of kWh Sales and Peak Demand for the State of North Carolina

La Capra Associates provided GDS with the electric energy and peak load forecast for the State of North Carolina. La Capra developed this forecast by summing the load forecast of individual electric utilities in North Carolina. Sales in North Carolina are forecast to grow at an average annual rate of 1.8% over the period from 2006 to 2017. The data used by La Capra to develop this statewide load forecast is listed below in Table 3-3.

Table 3-3: Electric Energy Load Forecast for North Carolina - 2008 to 2017 (GWh)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Progress	38,909	39,667	40,492	41,285	42,062	42,812	43,573	44,352	45,166	45,958
Duke	79,081	80,134	81,402	82,715	84,097	85,416	86,701	88,020	89,398	90,779
Dominion	4,607	4,680	4,766	4,852	4,955	5,029	5,111	5,199	5,347	5,463
NC Electric Membership Corp.	12,030	12,273	12,528	12,814	13,100	13,380	13,684	13,884	14,280	14,589
Western Carolina Energy	6,203	6,410	6,619	6,831	7,047	7,266	7,442	7,622	7,850	8,084
Municipal Utilitiles (ElectriCities)	13,044	13,269	13,536	13,803	14,096	14,359	14,642	14,932	15,244	15,526
North Carolina Total	153,874	156,433	159,343	162,300	165,357	168,261	171,153	174,009	177,285	180,400
IOU Total	122,597	124,481	126,660	128,852	131,114	133,257	135,385	137,571	139,912	142,200
Non-IOU Total	31,277	31,952	32,683	33,448	34,243	35,005	35,768	36,438	37,374	38,200

Table 3-4 below shows a breakdown of total kWh sales by class of service. GDS developed this breakdown based on a detailed load forecast prepared in 2003 by Global Insight for the North Carolina State Energy Office.

Table 3-4: Electric Utilities Energy Load Forecast for North Carolina by Sector - 2008 to 2017 (GWh)

Sector	Percent of Total	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Residential	39.40%	60,627	61,635	62,781	63,946	65,151	66,295	67,434	68,559	69,850	71,078
Commercial	32.30%	49,701	50,528	51,468	52,423	53,410	54,348	55,282	56,205	57,263	58,269
Industrial	28.30%	43,546	44,270	45,094	45,931	46,796	47,618	48,436	49,244	50,172	51,053
North Carolina Total	100.00%	153,874	156,433	159,343	162,300	165,357	168,261	171,153	174,009	177,285	180,400

4.0 OVERALL APPROACH TO ASSESS ACHIEVABLE POTENTIAL FOR ENERGY EFFICIENCY MEASURES IN NORTH CAROLINA

This section of the report presents an overview of the approach and methodology that was used to determine the achievable cost-effective potential for electric energy efficiency measures in the State of North Carolina. The key formulas and calculations that have been used by GDS to complete this assessment are described in this section. Following the descriptions, the three levels of potential energy savings are shown graphically in a Venn diagram[15] in Figure 4-1.

When preparing an assessment of the achievable potential for electricity savings in a state or a region, it is standard practice to develop three levels of savings potential: technical potential, achievable potential, and achievable cost-effective potential.

- **Technical potential** is defined as the complete and instantaneous penetration of all measures analyzed in applications where they are deemed to be technically feasible from an engineering perspective. The total technical potential for electric energy efficiency for each sector is usually developed from estimates of the technical potential of individual energy efficiency measures applicable to each sector (energy efficient space heating, energy efficient water heating, etc.). In the residential sector, for example, GDS calculated the electricity savings technical potential that could be captured if 100 percent of inefficient electric appliances and equipment were replaced instantaneously (where they are deemed to be technically feasible).

- The second savings potential level is the achievable energy efficiency potential. **Achievable potential** is defined in this study as the achievable penetration of an efficient measure that would be adopted given aggressive funding, and by determining the achievable market penetration that can be achieved with a concerted, sustained campaign involving highly aggressive programs and market interventions. The State of North Carolina would need to undertake an extraordinary effort to achieve this level of savings. The term "achievable" refers to efficiency measure penetration, and means that the GDS Team has based our estimates of efficiency potential on the realistic penetration level that can be achieved by 2017.

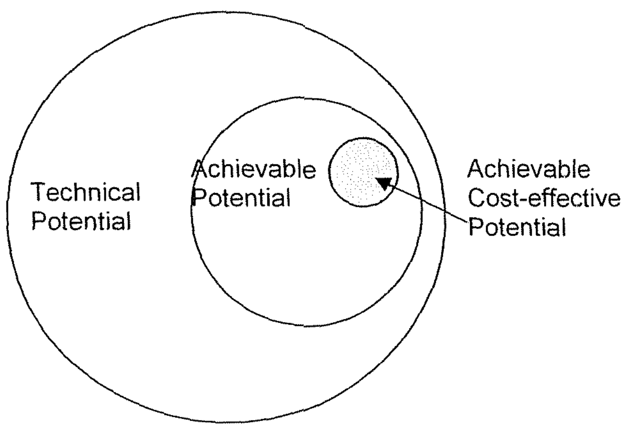
- **Achievable cost-effective potential** is defined as the potential for the realistic penetration of energy efficient measures that are cost-effective based on calculations of the cost of conserved energy, and it is the level of savings that would occur with aggressive funding levels, and by

[15] A Venn diagram is a graph that employs circles to represent logical relations between sets and subsets.

determining the highest level of realistic market penetration that can be achieved with a concerted, sustained campaign involving highly aggressive programs and market interventions. As demonstrated later in this report, the State of North Carolina would need to undertake an aggressive effort to achieve this level of savings.

To develop the cost-effective achievable potential, the GDS Team only retained those electric energy efficiency measures in the analysis that have a levelized cost per lifetime kWh saved of $.05 per kWh or lower. Energy efficiency measures with a levelized cost per lifetime kWh saved higher than $.05 were excluded from the estimate of cost-effective achievable electric energy efficiency potential. Figure 4-1 below shows these three levels of the electric energy savings potential (this Venn diagram figure is for illustrative purposes only and does not reflect actual data for North Carolina).

Figure 4-1 – Venn Diagram of the Stages of Energy Savings Potential



4.1 Overview of Methodology for the Residential Sector

Our analytical approach began with a careful assessment of the existing level of electric energy efficiency that has already been accomplished in North Carolina. This assessment included collecting data on the penetration of ENERGY STAR appliances in the State for the eight-year period from 1998 through 2004. For each electric energy efficiency measure, this analysis assessed how much energy efficiency has already been accomplished as well as the remaining potential for energy efficiency savings for a particular electric end use. For example, if 100 percent of the homes in North Carolina currently have electric lighting, and 30 percent of light bulb sockets already have high efficiency compact fluorescent bulbs (CFLs), then the remaining potential for energy efficiency savings is the 70 percent of light bulbs in the residential sector that are not already high efficiency fluorescent bulbs.

The general methodology used for estimating the potential for electric energy efficiency in the residential sector included the following steps:

1. Identification of data sources for electric energy efficiency measures.
2. Identification of electric energy efficiency measures to be included in the assessment.
3. Determination of the characteristics of each energy efficiency measure including its incremental cost, electric energy savings, operations and maintenance savings, current saturation, the percent of installations that are already energy efficient, and the useful life of the measure.
4. Calculation of initial cost-effectiveness screening metrics (e.g., calculation of the levelized cost per lifetime kWh saved) and sorting of measures from least-cost to highest cost per kWh saved.
5. Collection and analysis (where data was available) of the baseline and forecasted characteristics of the electric end use markets, including electric equipment saturation levels and consumption, by market segment and end use over the forecast period. It is important to note that GDS assumed that recent trends from 1998 to 2004 relating to penetration of ENERGY STAR appliances in the State would continue during the forecast period.
6. Integration of measure characteristics and baseline data to produce estimates of cumulative costs and savings across all measures (supply curves).
7. Determination of the cumulative technical and achievable potentials using supply curves.
8. Determination of the annual achievable cost-effective potential for electricity savings over the forecast period.

A key element in this approach is the use of energy efficiency supply curves. The advantage of using an energy efficiency supply curve is that it provides a clear, easy-to-understand framework for summarizing a variety of complex information about energy efficiency technologies, their costs, and the potential for energy savings. Properly constructed, an energy efficiency supply curve avoids the double counting of energy savings across measures by accounting for interactions between measures. The supply curve also provides a simplified framework to compare the costs of electric energy efficiency measures with the costs of electric energy supply resources.

The supply curve is typically built up across individual measures that are applied to specific base-case practices or technologies by market segment. Measures are sorted on a least-cost basis and total savings are calculated incrementally with respect to measures that precede them. Supply curves typically, but not always, end up reflecting diminishing returns, i.e., costs increase rapidly and savings decrease significantly at the end of the curve. There are a number of other advantages and limitations of energy efficiency supply curves (see, for example, Rufo 2003).[16]

For the residential sector, the GDS Team addressed the new construction market as a separate market segment, with a program targeted specifically at the new construction market. In the residential new construction market segment, for example, detailed energy savings estimates for the ENERGY STAR Homes program were used as a basis for determining electricity savings for this market segment in North Carolina.

4.2 Overview of Methodology for the Commercial and Industrial Sectors

Due to budget constraints for this study, GDS used a simplified methodology for estimating the savings potential for electric energy efficiency in the commercial and industrial sectors. In these two sectors, the following steps were used:

1. Identification of data sources for commercial and industrial electric energy efficiency measures.
2. Identification of electric energy efficiency measures to be included in the assessment.
3. Determination of the characteristics of each commercial and industrial energy efficiency measure including its incremental cost, electric energy savings, operations and maintenance savings, current saturation, the percent of installations that are already energy efficient, and the useful life of the measure.
4. Calculation of initial cost-effectiveness screening metrics (e.g., calculation of the levelized cost per lifetime kWh saved) and sorting of measures from least-cost to highest levelized cost per kWh saved.
5. Review of electric energy efficiency potential studies from other states to determine the achievable cost-effective potential in North Carolina.

In the commercial sector, for example, the achievable cost-effective potential for electricity savings (as shown in other potential studies for eight other states) ranges from 6 percent by 2023 in the service area of Puget Sound Energy to 24 percent in Massachusetts by 2007. GDS developed an estimate of the achievable cost-effective potential for North Carolina in the commercial sector by calculating an average from eight other recent energy efficiency potential studies. The average achievable cost-effective potential savings is 12.1%. The results of these eight studies are listed in Section 6 of this report.

[16] Rufo, Michael, 2003. *Attachment V – Developing Greenhouse Mitigation Supply Curves for In-State Sources, Climate Change Research Development and Demonstration Plan,* prepared for the California Energy Commission, Public Interest Energy Research Program, P500-03-025FAV, April. http://www.energy.ca.gov/pier/reports/500-03-025fs.html

4.3 General Methodological Approach for the Residential Sector

This section describes the calculations used by GDS to estimate the electric energy efficiency potential in the residential sector for this study. There is a core equation, shown in Tables 4-1 and 4-2, used to estimate the technical potential for each individual electric efficiency measure and it is essentially the same for each sector. However, for the residential sector, the equation is applied to a "bottom-up" approach where the equation inputs are displayed in terms of the number of homes or the number of high efficiency units (e.g., compact fluorescent light bulbs, high efficiency air conditioning systems, programmable thermostats, etc.). For the commercial and industrial (C&I) sectors, an alternative approach was used for developing the technical potential estimates.

4.3.1 Core Equation for Estimating Technical Potential

The core equation used to calculate the electric energy efficiency technical potential for each individual efficiency measure for the residential sector is shown below in Table 4-1.

Table 4-1 – Core Equation for Residential Sector

Technical Potential of Efficient Measure	=	Total Number of Residential Households	X	Base Case Equipment End Use Intensity (annual kWh use per home)	X	Base Case Factor	X	Remaining Factor	X	Convertible Factor	X	Savings Factor

where:

- **Number of Households** is the number of residential electric customers in the market segment.

- **Base-case equipment end use intensity** is the electricity used per customer per year by each base-case technology in each market segment. This is the consumption of the electric energy using equipment that the efficient technology replaces or affects. For example purposes only, if the efficient measure were a high efficiency light bulb (CFL), the base end use intensity would be the annual kWh use per bulb per household associated with an incandescent light bulb that provides equivalent lumens to the CFL.

- **Base Case factor** is the fraction of the end use electric energy that is applicable for the efficient technology in a given market segment. For example, for residential lighting, this would be the fraction of all residential electric customers that have electric lighting in their household.

- **Remaining factor** is the fraction of applicable dwelling units that have not yet been converted to the electric energy efficiency measure; that is, one minus the fraction of households that already have the energy efficiency measure installed.

- **Convertible factor** is the fraction of the applicable dwelling units that is technically feasible for conversion to the efficient technology from an *engineering* perspective (e.g., it may not be possible to install CFLs in all light sockets in a home because the CFLs may not fit in every socket in a home).

- **Savings factor** is the percentage reduction in electricity consumption resulting from application of the efficient technology.

GDS normally uses the following core equation to calculate the electric energy efficiency technical potential for each individual efficiency measure for the commercial and industrial sectors (see Table 4-2). GDS did not use this approach in the commercial and industrial sectors for this study due to budget constraints for this project.

Table 4-2 – Core Equation for C&I Sectors

Technical Potential of Efficient Measure	=	Total End Use kWh Sales by Industry Type	X	Base Case Factor	X	Remaining Factor	X	Convertible Factor	X	Savings Factor

where:

- **Total end use kWh sales (by segment)** is the forecasted level of electric sales for a given end-use (e.g., space heating) in a commercial or industrial market segment (e.g., office buildings).

- **Base Case factor** is the fraction of the end use electric energy that is applicable for the efficient technology in a given market segment. For example, for fluorescent lighting, this would be the fraction of all lighting kWh in a given market segment that is associated with fluorescent fixtures.

- **Remaining factor** is the fraction of applicable kWh sales that are associated with equipment that has not yet been converted to the electric energy efficiency measure; that is, one minus the fraction of the market segment that already have the energy efficiency measure installed.

- **Convertible factor** is the fraction of the equipment or practice that is technically feasible for conversion to the efficient technology from an *engineering* perspective (e.g., it may not be possible to install VFDs on all motors in a given market segment).

- **Savings factor** is the percentage reduction in electricity consumption resulting from application of the efficient technology.

4.3.2 Rates of Implementation for Energy Efficiency Measures

For new construction, energy efficiency measures can be implemented when each new home is constructed, thus the rate of availability is a direct function of the rate of new construction. For existing buildings, determining the annual rate of availability of savings is more complex. Energy efficiency potential in the existing stock of buildings can be captured over time through two principal processes:

1. as equipment replacements are made normally in the market when a piece of equipment is at the end of its useful life (we refer to this as the "market-driven" or "replace-on-burnout" case); and,
2. at any time in the life of the equipment or building (which we refer to as the "retrofit" case).

Market-driven measures are generally characterized by *incremental* measure costs and savings (e.g., the incremental costs and savings of a high-efficiency versus a standard efficiency air conditioner); whereas retrofit measures are generally characterized by full costs and savings (e.g., the full costs and savings associated with retrofitting ceiling insulation into an existing attic). A specialized retrofit case is often referred to as "early replacement" or "early retirement." This refers to a piece of equipment whose replacement is accelerated by several years, as compared to the market-driven assumption, for the purpose of capturing energy savings earlier than they would otherwise occur.

For the market driven measures, we assumed that existing equipment will be replaced with high efficiency equipment at the time a consumer is shopping for a new appliance or other energy using equipment, or if the consumer is in the process of building or remodeling. Using this assumption, equipment that needs to be replaced (replaced on burnout) in a given year is eligible to be upgraded to high efficiency equipment. For the retrofit measures, savings can theoretically be captured at any time; however, in practice it takes many years to retrofit an entire stock of buildings, even with the most aggressive of efficiency programs.

As noted above, a special retrofit case is "**early retirement**" of electrical equipment that is still functioning well, and replacing such equipment with high efficiency equipment. GDS did not examine any early retirement programs or measures for this study.

4.3.3 Development of Achievable Cost-effective Potential Estimates for Energy Efficiency

To develop the **achievable cost-effective potential** for electric energy efficiency, energy efficiency measures that were found to be cost-effective (according to the levelized cost per lifetime kWh saved) were retained in the analysis. Electric energy efficiency measures that were not cost-effective (such as residential solar water heating) were excluded from the estimate of achievable cost-effective energy efficiency potential for the residential sector.

4.3.4 Free-Ridership and Free-Driver Issues

Free-riders are defined as participants in an energy efficiency program who would have undertaken the energy efficiency measure or improvement in the absence of a program or in the absence of a monetary incentive. Free-drivers are those who adopt an energy efficient product or service because of the intervention, but are difficult to identify either because they do not collect an incentive or they do not remember or are not aware of exposure to the intervention.[17]

The issue of free-riders and free-drivers is important. For the commercial and industrial sectors, where GDS used an alternative approach to estimate electricity savings potential, free-riders are accounted for through the electric energy and peak demand forecast provided by electric utilities in North Carolina. This electric kWh sales forecast already includes the impacts of naturally occurring energy efficiency (including impacts from vintaging of electric appliances, electric price impacts, and electric appliance efficiency standards). For the commercial and industrial sectors, because naturally occurring energy savings are already reflected in the electricity sales forecast used in this study, these electric savings will not be available to be saved again when GDS applies savings percentages obtained from other recent energy efficiency potential studies. GDS used this process to ensure that there is no "double-counting" of energy efficiency savings. This technical methodology for accounting for free-riders for the commercial and industrial sectors is consistent with the standard practice used in other recent technical potential studies, such as those conducted in California, Connecticut, Florida, Georgia, Idaho, Kentucky, New Mexico, Utah and Vermont.

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[17] Pacific Gas and Electric Company, "A Framework for Planning and Assessing Publicly Funded Energy Efficiency Programs", Study ID PG&E-SW040, March 1, 2001.

4.3.5 Adjustments to Savings for the Residential Sector

As noted above, GDS used a "bottom-up" approach to estimate potential kWh savings remaining in the residential sector in North Carolina. Because a detailed residential end use forecast for electricity sales in North Carolina was not available to GDS for this study, GDS examined whether it would be necessary to adjust projected electricity savings for free-ridership, spillover and other market effects. GDS collected data on energy efficiency program realization rates from programs at NYSERDA, National Grid and Wisconsin Focus on Energy. As a result of this review, and using NYSERDA's most recent data, GDS used an adjustment factor of 1.0 at this time for the residential sector for North Carolina to capture the impacts reflected in realization rates and net to gross ratios for this sector. The definitions of these terms are provided below.

- **net to gross ratio:** this is an adjustment factor that accounts for the amount of energy savings, determined after adjusting for free ridership and spillover (market effects), attributable to the program.

- **realization rate:** this factor is calculated as the energy or demand savings measured and verified divided by the energy or demand savings claimed by NYSERDA. A rate of 1.0 means that the savings measured and verified aligned exactly with the savings claimed. A rate greater than 1.0 means that the savings were under-reported, while a rate less than 1.0 means the savings were over-estimated.

The May 2006 NYSERDA Program evaluation study relied upon (to obtain net to gross ratio and realization rate data) by GDS is available on the NYSERDA web site at www.nyserda.org, at the New York Energy $mart program evaluation section of the web site. GDS obtained the adjustment factor to allow for actual realization rates, free-ridership and spill-over from the May 2006 NYSERDAS Program Evaluation Report titled "**New York Energy $mart Program Evaluation and Status Report, Report to the Systems Benefits Charge Advisory Group, May 2006**", pages 5-6 and 5-7. NYSERDA's Measurement and Verification (M&V) contractor assessed the energy and peak demand savings reported for its residential programs. Methods used in this assessment included on-site verification of equipment installation and functionality, and review of NYSERDA's files for reasonableness and accuracy. Based on this review, the M&V contractor adjusted the savings reported by NYSERDA. In turn, the Market Characterization, Assessment and Causality/Attribution (MCAC) contractor further adjusted these figures to account for free-ridership and spillover. A summary of the energy and peak demand savings from the Residential Programs is presented in Table 5-2, Table 5-3, and Table 5-4 of this May 2006 Report. These numbers show the savings after adjustments by the M&V and MCAC evaluation contractors. Annual MWh savings before adjustment for realization, free-ridership and spillover were 305.698 MWh. Savings after adjustment for realization, free-ridership and spillover were 324,384 MWh annually. The overall adjustment factor is thus 1.06 time gross reported savings. GDS has used an adjustment factor of 1.0 for this study for North Carolina.

4.4 Basis for Long Term Achievable Market Penetration Rate for High Efficiency Equipment and Building Practices

This section explains the basis used in this study for the achievable penetration rate that cost-effective electric energy efficiency programs can attain over the long-term (ten years) with well-designed programs and aggressive funding. GDS is using an achievable penetration rate of **80 percent** by 2017 for the residential sector in North Carolina.

The achievable electric energy efficiency potential is a subset of the technical potential estimates. The GDS Team has based the estimates of efficiency potential on the highest realistic penetration that can be achieved by 2017 based on aggressive funding and an incentive level equal to 50% of measure costs.

The achievable potential estimate for energy efficiency defines the upper limit of savings from market interventions. For the residential sector, the GDS Team developed the initial year (2008) and terminal year (2017) penetration rate that is likely to be achieved over the long term for groups of measures (space heating equipment, water heating equipment, etc.) by end use for the "naturally occurring scenario" and the "aggressive programs and unlimited funding" scenario. GDS reviewed penetration rate forecasts from other recent energy efficiency technical potential studies, actual penetration experience for electric and natural gas energy efficiency programs operated by energy efficiency organizations (Efficiency Vermont, Efficiency Maine, Pacific Gas and Electric, KeySpan Energy Delivery, Northeast Energy Efficiency Partnerships, NYSERDA, Northwest Energy Efficiency Alliance, BPA, Wisconsin, Focus on Energy, other electric and gas utilities, etc.), and penetration data from other sources (program evaluation reports, market progress reports, etc.) to estimate terminal penetration rates in 2017 for the achievable scenario. In addition, the GDS Team conducted a survey of nationally recognized energy efficiency experts requesting their estimate of the achievable penetration rate over the long-term for a state or region, assuming implementation of aggressive programs and assuming aggressive funding. The terminal year (2017) penetration estimates used by GDS in this study are based on the information gathered through this process. Based on a thorough review of all of this information, GDS used an achievable penetration rate of **80 percent** by 2017 for the residential, commercial and industrial sectors.

4.4.1 Examples of US Efficiency Programs with High Market Penetration

GDS also collected information on electric and gas energy efficiency programs conducted during the past three decades where high penetration has been achieved. Examples of such programs are listed below:

1. The Residential Multifamily/Low-Income Program in Vermont achieved a market share of over 90 percent for new construction and nearly 30 percent for existing housing.[18]
2. The residential water heater bundle-up program conducted by Central Maine Power Company has achieved a market penetration of over 80 percent of residential electric water heaters in the Company's service area. This program has been operated by CMP since the 1980's.
3. The Northwest Energy Efficiency Alliance reported that the market share of ENERGY STAR windows in the Northwest reached 75 percent by mid-2002 and is continuing to increase.[19]
4. Vermont Gas Systems' reported that 68 percent of new homes in their service territory were ENERGY STAR Homes in 2002.[20]
5. Gaz Metro in Quebec reported that the national market share of high efficiency furnaces in Canada has reached 40 percent due to years of energy efficiency programs.[21]
6. Residential weatherization and insulation programs implemented by electric and gas utilities in New England have achieved high participation rates.
7. In the State of Wisconsin, a natural gas energy efficiency program to promote high efficiency gas furnaces attained a penetration rate of over 90 percent.[22]
8. KeySpan Energy Delivery's high efficiency residential furnace program has achieved a market share of approximately 70 percent over eight years (1997-2005).[23]

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18 York, Dan; Kushler, Martin; America's Best: Profiles of America's Leading Energy Efficiency Programs," published by the American Council for an Energy Efficient Economy, March 2003. Report Number U032.

19 Id.

20 American Council for an Energy Efficient Economy, "America's Best Gas Energy Efficiency Programs", 2003.

21 Id.

22 Hewitt, David. C., "The Elements of Sustainability", paper presented at the 2000 ACEEE Summer Study on Energy Efficiency in Buildings. Washington: American Council for an Energy Efficient Economy. Pages 6.179-6.190. The Wisconsin furnaces case study data can be found in the 2000 ACEEE Summer Study Proceedings on pages 6.185-6.186.

23 American Council for an Energy Efficient Economy, "America's Best Gas Energy Efficiency Programs", 2003.

GDS finds that the actual market penetration experience from electric and gas energy efficiency programs in other States is useful and pertinent information that should be used as a basis for developing long-term market penetration estimates for electric energy efficiency programs in North Carolina. In addition, recent technical potential studies in such states as California, Connecticut, Florida, Georgia, Kentucky, New Mexico, Utah and Vermont also have used a maximum achievable penetration rate of 80 percent.

4.4.2 Lessons Learned from America's Leading Efficiency Programs

GDS also reviewed program participation and penetration data included in ACEEE's March 2003 report on America's leading energy efficiency programs.[24] The information presented in this ACEEE report clearly demonstrates the wide range of high-quality energy efficiency programs that are being offered in various areas of the United States today. A common characteristic of the programs profiled in this ACEEE report is their success in reaching customers with their messages and changing behavior, whether regarding purchasing of new appliances, designing new office buildings, or operating existing buildings. GDS considered this information in the development of assumptions for maximum penetration rates achievable over the long term with aggressive programs.

4.5 Development of Program Budgets

GDS reviewed the latest available data from several States with active energy efficiency programs to obtain documentation of actual costs per first year kWh saved relating to program administration, marketing, staffing, and evaluation. These costs, excluding incentives paid to participants or market actors, are referred to as "overhead administrative costs" throughout the remainder of this report. Then GDS calculated a ratio for such programs in other states as follows:

Overhead Cost Ratio = Overhead administrative costs/first year kWh savings for a program

GDS used this data as a basis to develop program budgets for the next ten years (2008 to 2017) for "overhead administrative costs" for energy efficiency programs in North Carolina. Using this methodology to develop program budgets ensures that the budgets are tied directly to actual cost experience. The overhead administrative cost rate used in this study is $.02 per first year kWh saved.

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24 York, Dan; Kushler, Martin; "America's Best: Profiles of America's Leading Energy Efficiency Programs," published by the American Council for an Energy Efficient Economy, March 2003, Report Number U032

4.6 Development of Program Budgets for Financial Incentives to Program Participants

Incentives to program participants are an important component of budgets for energy efficiency programs implemented by utilities and other program administrator organizations. The incentive levels utilized in other recent energy efficiency potential studies are described below.

- In February 2006, Quantum Consulting completed an analysis of the maximum achievable cost effective electricity savings for the Los Angeles Department of Water and Power (LAWPD). For the maximum achievable electricity savings potential scenario, this analysis assumed incentives covering 50 percent, on average, of incremental measure costs, and marketing expenditures sufficient to create maximum market awareness over the forecasting period.
- The 2002 California "Secret Surplus" Report examined savings potential scenarios based on incentive levels (incentives as a percent of measure costs) of 33%, 66% and 100% of measure costs.
- The June 2004 Connecticut Energy Conservation Management Board (ECMB) electric energy efficiency potential study assumed incentive levels ranging from 50% to 70% of measure costs.
- The Southwest Energy Efficiency Project potential study assumed incentive levels of 15% to 25% of measure costs.
- The January 2003 Vermont energy efficiency potential study assumed an incentive level of 100% of full measure costs for retrofit programs, and 100% of incremental costs for retail and new construction programs.
- The 2005 Big Rivers Electric Cooperative (Kentucky) potential study assumed an incentive level of 50% of incremental measure costs.
- The 2005 Georgia potential study examined scenarios with incentive levels of 25%, 50% and 100%.
- A recent electric energy efficiency achievable potential study in New York state performed by Optimal Energy assumed incentive levels in the range of 20% to 50%.

There are several reasons why an incentive level of 50% of measure costs (and not 100% of measure costs) was assumed for the base case for this study.

First, the incentive level of 50% of measure costs assumed in this North Carolina energy efficiency potential study for the base case scenario is a reasonable target based on a thorough review by GDS of incentive levels used in other recent technical potential studies. The incentive levels used in the studies reviewed by GDS as well as actual experience with incentive levels in other regions of the country confirm that an incentive level assumption of 50% is commonly used. As noted above, the very recent study (February 2006) conducted by Quantum Consulting for the Los Angeles Water and Power

Department assumed incentives of 50% of measure costs for its maximum achievable savings scenario. It is interesting to note also that the majority of energy efficiency programs offered by the New York State Energy Research and Development Authority offer no financial incentives to consumers.

Second, and most important, the highly recognized and recently published National Energy Efficiency Best Practices Study concludes that use of an incentive level of 100% of measure costs **is not recommended as a program strategy**.[25] This national best practices study concludes that it is very important to **limit** incentives to participants so that they do not exceed a pre-determined portion of average or customer-specific incremental cost estimates. The report states that this step is critical to avoid grossly overpaying for energy savings. This best practices report also notes that if incentives are set too high, free-ridership problems will increase significantly. Free riders dilute the market impact of program dollars.

Third, financial incentives are only one of many important programmatic marketing tools. Program designs and program logic models also need to make use of other education, training and marketing tools to maximize consumer awareness and understanding of energy efficient products. A program manager can ramp up or down expenditures for the mix of marketing tools to maximize program participation and savings.

In summary, this study does not recommend an incentive level of 100% of measure costs for the above reasons. Furthermore, actual program experience has shown that very high levels of market penetration can be achieved with aggressive energy efficiency programs that combine education, training and other programmatic approaches along with incentive levels in the 50% range.

[25] See "National Energy Efficiency Best Practices Study, Volume NR5, Non-Residential Large Comprehensive Incentive Programs Best Practices Report", prepared by Quantum Consulting for Pacific Gas and Electric Company, December 2004, page NR5-51.

5.0 RESIDENTIAL SECTOR ELECTRIC EFFICIENCY SAVINGS POTENTIAL IN NORTH CAROLINA

This section of the report presents the estimates of electric technical, achievable and achievable cost-effective energy efficiency potential for the existing and new construction market segments of the residential sector in North Carolina. According to this analysis, there is still a large remaining potential for electric energy efficiency savings in this sector. Thirty-four energy efficiency measures were examined for the residential sector analysis. Table 5-1 below summarizes the technical, achievable and achievable cost-effective savings potential by the year 2017.

***Table 5-1*: Summary of Residential Electric Energy Efficiency Savings Potential in North Carolina**

	Estimated Cumulative Annual Savings by 2017 (kWh)	Savings in 2017 as a Percent of Total 2017 Residential Sector Electricity Sales
Technical Potential	28,239,190,475	39.7%
Achievable Potential	14,528,641,666	20.4%
Achievable Cost Effective Potential ($0.10/kWh)	13,213,996,282	18.6%
Achievable Cost Effective Potential ($0.05/kWh)	12,006,267,489	16.9%

The achievable cost-effective potential at a levelized cost per kWh saved of $0.10 per kWh in the residential sector is 13,214 GWh, or 18.6 percent of the North Carolina residential kWh sales forecast in 2017. The achievable cost-effective potential at a levelized cost per kWh saved of $0.05 per kwh in the residential sector is 12,006 GWh, or 16.9 percent of the North Carolina residential kWh sales forecast in 2017.

5.1 Residential Sector Electric Energy Efficiency Programs

Thirty-four residential electric energy efficiency programs or measures were included in the analysis for the residential sector energy efficiency savings potential. In order to develop the list of energy efficiency measures to be examined, GDS reviewed numerous electric energy efficiency technical potential studies that have been conducted in the US. The set of electric energy efficiency programs or measures considered was pre-screened to only include those measures that are currently commercially available. Thus, emerging technologies were not included in the analysis. Tables 5-2, 5-3, and 5-4 below list the residential sector electric energy efficiency programs or measures included in the technical, achievable, and achievable cost-effective potential analyses. The portfolio of measures reflects mainly a replace on burnout programmatic approach to achieve energy efficiency savings. To obtain up-to-date appliance saturation data, GDS obtained state specific and regional saturation data from sources such as the US Census, the Energy Information Administration Residential Energy Consumption Survey, and ENERGY STAR market tracking data obtained from D&R International.

Characteristics of Energy Efficiency Measures

GDS collected data on the electric and other energy savings, incremental costs, useful lives and other key "per unit" characteristics of each of the residential electric energy efficiency measures. Estimates of the size of the eligible market were also developed for each efficiency measure. For example, electric water heater efficiency measures are only applicable to those homes in North Carolina that have electric water heaters.

For the residential new construction market segment, GDS obtained census data of the number of new homes built in North Carolina in 2005 from the ENERGY STAR Homes Program. The sizes of various end-use market segments were based on saturation estimates obtained from a variety of sources, including the US Department of Commerce Bureau of the Census of Housing Characteristics.

Achievable market penetrations were estimated assuming that consumers would receive a financial incentive equal to 50% of the incremental cost of the electric energy efficiency measure in most programs.

In the residential new construction market, market penetration in the near term was based on actual penetration data for the ENERGY STAR Homes Program in North Carolina (1.3%). It was assumed that the penetration rate for this program would reach 80% of new homes built by 2017 (a decade from now).

In this report we also present the achievable technical potential results in the form of electric supply curves. The supply curve for residential electric energy efficiency savings is shown in Figure 5-1, found after Tables 5-1 through 5-4. This analysis is based on a residential electric sales forecast based upon load forecasts provided by electric utilities in North Carolina.[26] Energy efficiency measures were analyzed for the most important electric consuming end uses: space heating, water heating, refrigeration, and lighting.

[26] The load forecast for North Carolina used in this study is described in detail in Section 3 of this report.

Table 5-2: Total Cumulative Annual Maximum Technical Potential kWh Savings for Electric Energy Efficiency In North Carolina By 2017
Residential Sector - Market Driven and Retrofit Savings

1	2	3	4	5
Measure #	Measure Description	Single-Family	Multi-Family	Total
1	Refrigerator Turn-in	175,541,516	33,685,559	209,227,075
2	Freezer Turn-in	32,276,474	6,193,698	38,470,172
3	Room AC Turn-in without Replacement	0	0	0
4	Room AC Turn-in with ES Replacement	0	0	0
5	Energy Star Single Room Air Conditioner	31,004,896	5,949,688	36,954,584
6	Energy Star Compliant Top Freezer Refrigerator	115,752,558	22,212,350	137,964,908
7	Energy Star Compliant Bottom Mount Freezer Refrigerator	22,084,370	4,237,883	26,322,253
8	Energy Star Compliant Side-by-Side Refrigerator	65,110,814	12,494,447	77,605,261
9	Energy Star Compliant Upright Freezer (Manual Defrost)	24,838,274	4,766,343	29,604,617
10	Energy Star Compliant Chest Freezer	22,102,080	4,241,281	26,343,361
11	Energy Star Built-In Dishwasher (Electric)	85,050,502	16,039,383	101,089,885
12	Energy Star Clothes Washers with Electric Water Heater	422,510,413	81,077,683	503,588,096
13	Energy Star Clothes Washers with Non-Electric Water Heater	23,368,344	4,484,271	27,852,615
14	Energy Star Dehumidifier (40 pt)	27,574,469	5,291,406	32,865,875
15	Standby-Power	664,862,902	127,583,942	792,446,844
16	Pool Pump & Motor	151,818,972	29,133,319	180,952,291
17	Energy Star Compliant Programmable Thermostat	1,241,702,266	238,276,597	1,479,978,863
18	High Efficiency Central AC	1,127,524,836	216,366,506	1,343,891,342
19	CFL's. Homes with partial CFL installation	974,191,659	186,942,619	1,161,134,278
20	CFL's. Homes without CFL installation	1,088,952,457	208,964,655	1,297,917,112
21	Water Heater Blanket	0	0	0
22	Low Flow Shower Head	0	0	0
23	Pipe Wrap	0	0	0
24	Low Flow Faucet Aerator	0	0	0
25	Solar Water Heating	6,034,824,050	1,158,053,244	7,192,877,294
26	Efficient Water Heating	0	0	0
27	Efficient Furnace Fan Motor (Fuel Oil)	162,577,796	31,197,885	193,775,681
28	Efficient Furnace Fan Motor (Natural Gas)	325,155,593	62,395,769	387,551,362
29	Efficient Furnace Fan Motor (Propane)	176,125,946	33,797,708	209,923,654
30	Energy Star Windows	5,050,537,691	484,586,751	5,535,124,442
31	Insulation and Weatherization	4,206,124,909	403,567,408	4,609,692,317
32	Residential New Construction (Electric)	1,112,783,315	0	1,112,783,315
33	Residential New Construction (Non-Electric)	829,374,258	0	829,374,258
34	Low Income Insulation & Weatherization	663,878,720	0	663,878,720
	Total kilowatt hours (kWh)	24,857,650,080	3,381,540,395	28,239,190,475
	Forecast 2017 North Carolina Residential kWh Sales			71,078,000,000
	As a percent of forecasted residential sales 2017			39.7%

Note: Maximum Technical potential kWh savings were obtained from Appendix A of this report, column 29

A Study of the Feasibility of Energy Efficiency as an Eligible Resource as Part of a Renewable Portfolio Standard for the State of North Carolina - December 2006

Table 5-3: Total Cumulative Annual Achievable Potential kWh Savings for Electric Energy Efficiency In North Carolina By 2017

Residential Sector - Market Driven and Retrofit Savings

1	2	3	4	5
Measure #	Measure Description	Single-Family	Multi-Family	Total
1	Refrigerator Turn-in	136,532,290	26,199,879	162,732,169
2	Freezer Turn-in	25,103,924	4,817,320	29,921,244
3	Room AC Turn-in without Replacement	0	0	0
4	Room AC Turn-in with ES Replacement	0	0	0
5	Energy Star Single Room Air Conditioner	17,366,130	3,332,476	20,698,606
6	Energy Star Compliant Top Freezer Refrigerator	68,333,352	13,112,836	81,446,188
7	Energy Star Compliant Bottom Mount Freezer Refrigerator	13,037,284	2,501,791	15,539,075
8	Energy Star Compliant Side-by-Side Refrigerator	38,437,511	7,375,970	45,813,481
9	Energy Star Compliant Upright Freezer (Manual Defrost)	17,562,416	3,370,142	20,932,558
10	Energy Star Compliant Chest Freezer	15,627,733	2,998,886	18,626,619
11	Energy Star Built-In Dishwasher (Electric)	60,398,183	11,390,287	71,788,470
12	Energy Star Clothes Washers with Electric Water Heater	299,682,710	57,507,648	357,190,358
13	Energy Star Clothes Washers with Non-Electric Water Heater	16,574,950	3,180,652	19,755,602
14	Energy Star Dehumidifier (40 pt)	17,872,341	3,429,615	21,301,956
15	Standby-Power	355,897,201	68,294,934	424,192,135
16	Pool Pump & Motor	78,720,948	15,106,165	93,827,113
17	Energy Star Compliant Programmable Thermostat	941,411,512	180,652,269	1,122,063,781
18	High Efficiency Central AC	626,402,686	120,203,614	746,606,300
19	CFL's: Homes with partial CFL installation	514,537,848	98,737,299	613,275,147
20	CFL's: Homes without CFL installation	681,660,380	130,602,909	812,263,289
21	Water Heater Blanket	340,917,493	65,420,401	406,337,894
22	Low Flow Shower Head	463,647,790	88,971,745	552,619,535
23	Pipe Wrap	45,001,109	8,635,493	53,636,602
24	Low Flow Faucet Aerator	77,729,188	14,915,851	92,645,039
25	Solar Water Heating	0	0	0
26	Efficient Water Heating	0	0	0
27	Efficient Furnace Fan Motor (Fuel Oil)	84,299,598	16,176,681	100,476,279
28	Efficient Furnace Fan Motor (Natural Gas)	168,599,196	32,353,362	200,952,558
29	Efficient Furnace Fan Motor (Propane)	91,324,565	17,524,738	108,849,303
30	Energy Star Windows	3,928,195,982	376,900,806	4,305,096,788
31	Insulation and Weatherization	2,523,674,946	242,140,445	2,765,815,391
32	Residential New Construction (Electric)	496,134,441	0	496,134,441
33	Residential New Construction (Non-Electric)	369,776,513	0	369,776,513
34	Low Income Insulation & Weatherization	398,327,232	0	398,327,232

Maximum Achievable kWh Savings by 2015	12,912,787,452	1,615,854,214	14,528,641,666
Forecast 2017 North Carolina Residential kWh Sales			71,078,000,000
As a percent of forecasted residential sales 2015			20.4%

Note: Achievable potential kWh savings were obtained from Appendix A of this report, column 32

A Study of the Feasibility of Energy Efficiency as an Eligible Resource as Part of a Renewable Portfolio Standard for the State of North Carolina - December 2006

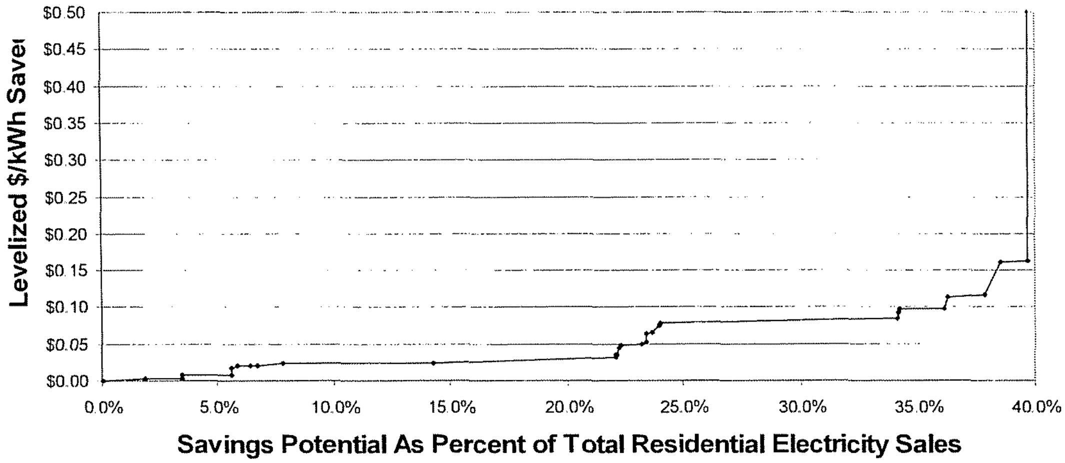
Table 5-4: Total Annual Achievable Cost-Effective Potential kWh Savings for Electric Energy Efficiency In North Carolina By 2017

Residential Sector - Market Driven and Retrofit Savings

1	2	5	6	7	8
Measure #	Measure Description	Levelized Cost Per kWh Single-Family ($ per kWh Saved)	Levelized Cost Per kWh Multi-Family ($ per kWh Saved)	Total Cumulative Annual kWh Savings by 2017 (Levelized Cost $0.10 per kWh)	Total Cumulative Annual kWh Savings by 2017 (Levelized Cost $0.05 per kWh)
1	Refrigerator Turn-in	$0.075	$0.075	162,732,169	0
2	Freezer Turn-in	$0.078	$0.078	29,921,244	0
3	Room AC Turn-in without Replacement	$0.818	$0.818	0	0
4	Room AC Turn-in with ES Replacement	$2.338	$2.338	0	0
5	Energy Star Single Room Air Conditioner	$0.036	$0.036	20,698,606	20,698,606
6	Energy Star Compliant Top Freezer Refrigerator	$0.053	$0.053	81,446,188	0
7	Energy Star Compliant Bottom Mount Freezer Refrigerator	$0.049	$0.049	15,539,075	15,539,075
8	Energy Star Compliant Side-by-Side Refrigerator	$0.045	$0.045	45,813,481	45,813,481
9	Energy Star Compliant Upright Freezer (Manual Defrost)	$0.092	$0.092	20,932,558	0
10	Energy Star Compliant Chest Freezer	$0.098	$0.098	18,626,619	0
11	Energy Star Built-In Dishwasher (Electric)	$0.113	$0.113	0	0
12	Energy Star Clothes Washers with Electric Water Heater	$0.162	$0.162	0	0
13	Energy Star Clothes Washers with Non-Electric Water Heater	$1.593	$1.593	0	0
14	Energy Star Dehumidifier (40 pt)	$0.000	$0.000	21,301,956	21,301,956
15	Standby-Power	$0.023	$0.023	424,192,135	424,192,135
16	Pool Pump & Motor	$0.065	$0.065	93,827,113	0
17	Energy Star Compliant Programmable Thermostat	$0.008	$0.008	1,122,063,781	1,122,063,781
18	High Efficiency Central AC	$0.098	$0.098	746,606,300	0
19	CFL's: Homes with partial CFL installation	$0.003	$0.003	613,275,147	613,275,147
20	CFL's: Homes without CFL installation	$0.003	$0.003	812,263,289	812,263,289
21	Water Heater Blanket	$0.008	$0.008	406,337,894	406,337,894
22	Low Flow Shower Head	$0.008	$0.008	552,619,535	552,619,535
23	Pipe Wrap	$0.064	$0.064	53,636,602	0
24	Low Flow Faucet Aerator	$0.018	$0.018	92,645,039	92,645,039
25	Solar Water Heating	$0.085	$0.085	0	0
26	Efficient Water Heating	$0.035	$0.035	0	0
27	Efficient Furnace Fan Motor (Fuel Oil)	$0.021	$0.021	100,476,279	100,476,279
28	Efficient Furnace Fan Motor (Natural Gas)	$0.021	$0.021	200,952,558	200,952,558
29	Efficient Furnace Fan Motor (Propane)	$0.021	$0.021	108,849,303	108,849,303
30	Energy Star Windows	$0.033	$0.033	4,305,096,788	4,305,096,788
31	Insulation and Weatherization	$0.024	$0.024	2,765,815,391	2,765,815,391
32	Residential New Construction (Electric)	$0.116	N/A	0	0
33	Residential New Construction (Non-Electric)	$0.163	N/A	0	0
34	Low Income Insulation & Weatherization	$0.049	N/A	398,327,232	398,327,232
	Maximum Achievable Cost Effective kWh Savings			13,213,996,282	12,006,267,489
	Forecast 2017 North Carolina Residential kWh Sales			71,078,000,000	71,078,000,000
	Savings as a percent of forecasted residential sales in 2017			18.6%	16.9%

Note: The levelized costs were obtained from Appendix A, column 17 The kWh savings shown above are from table 5-3, and kWh savings in the last column in the above table are counted only for those measures that have a levelized cost less than $0.05/kwh saved.

Figure 5-1 Residential Electric Energy Efficiency Supply Curve for North Carolina



Figures 5-2 to 5-8 provide information on the potential electric savings in the residential sector. About thirty-eight percent of the technical potential savings by 2017 is for high efficiency space heating measures including weatherization and insulation for low income homes, twenty-five percent is for high efficiency water heating including solar water heating, and ten percent is related to efficient cooling measures. Figures 5-9 and 5-10 presents the cost of conserved energy (CCE) for residential electric energy efficiency measures included in this study. Note that the CCE figures shown in Figures 5-9 and 5-10 only include electric savings, and do not include savings of other fuels (gas, oil, wood, etc.) or water. Note that Figures 5-9 and 5-10 are not supply curves; rather, they simply provide a picture of the relative cost of conserved energy for the electric energy efficiency and fuel shifting measures examined in this study. Note that there are **seven** residential energy efficiency measures having a cost of conserved energy less than $.02 per kWh saved.

Figure 5-2 Summary of Potential Savings

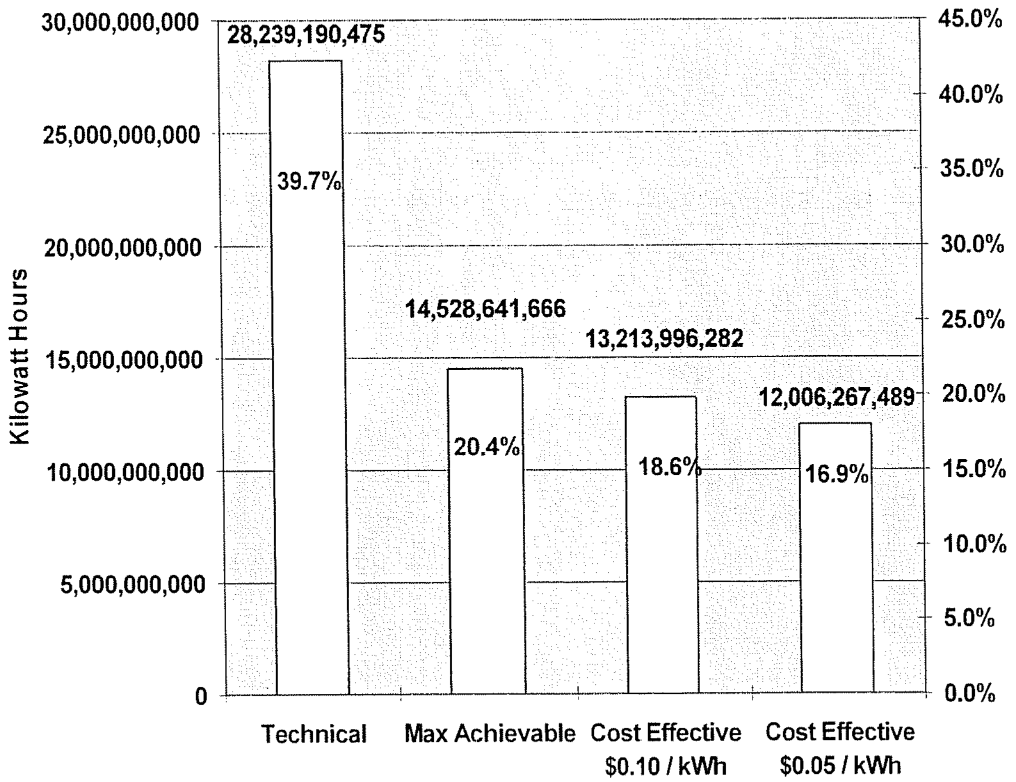


Figure 5-3 Residential Sector Technical Potential Savings By Measure Type - Kilowatt Hours

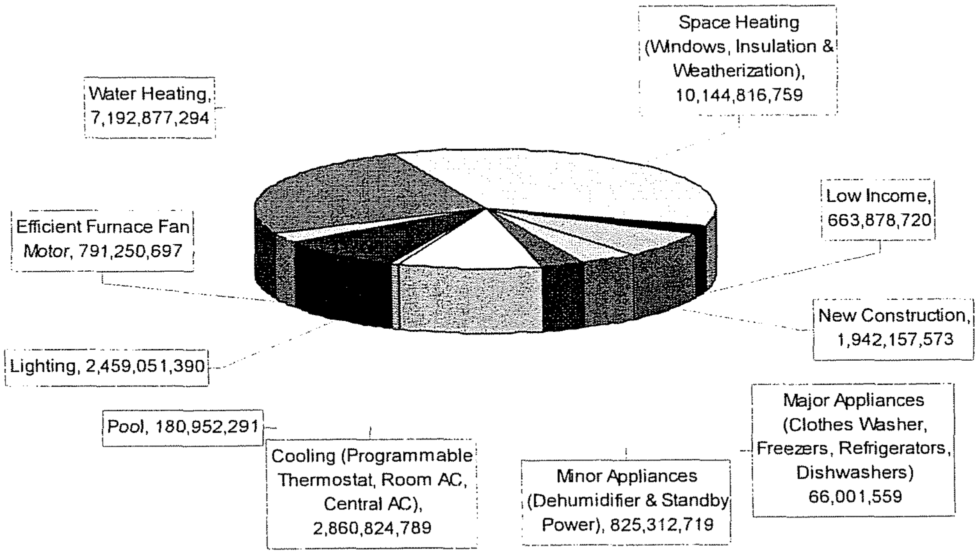


Figure 5-4 Residential Sector Technical Potential Savings By Measure Type - Percent of Total Savings

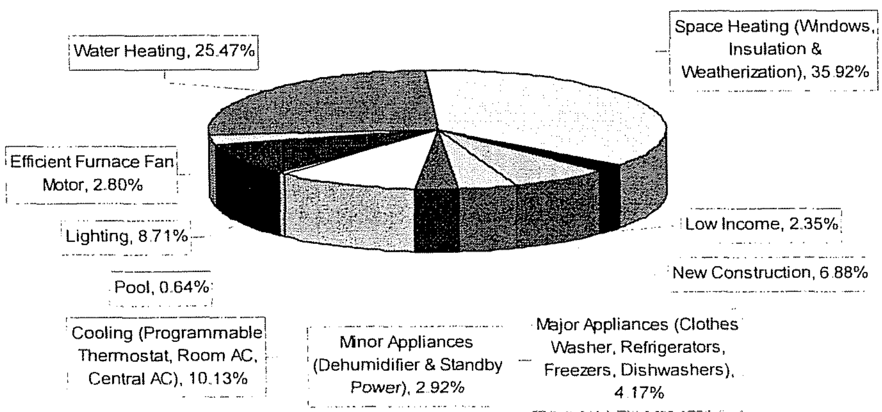


Figure 5-5 Residential Sector Achievable Savings By Measure Type - Kilowatt Hours

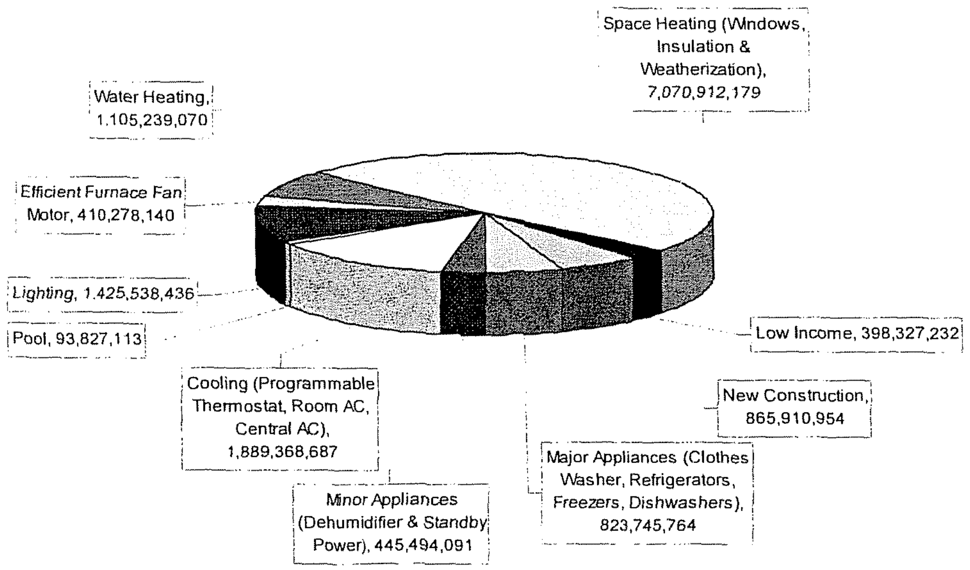


Figure 5-6 Residential Sector Achievable Savings by Measure Type - Percent of Total Savings

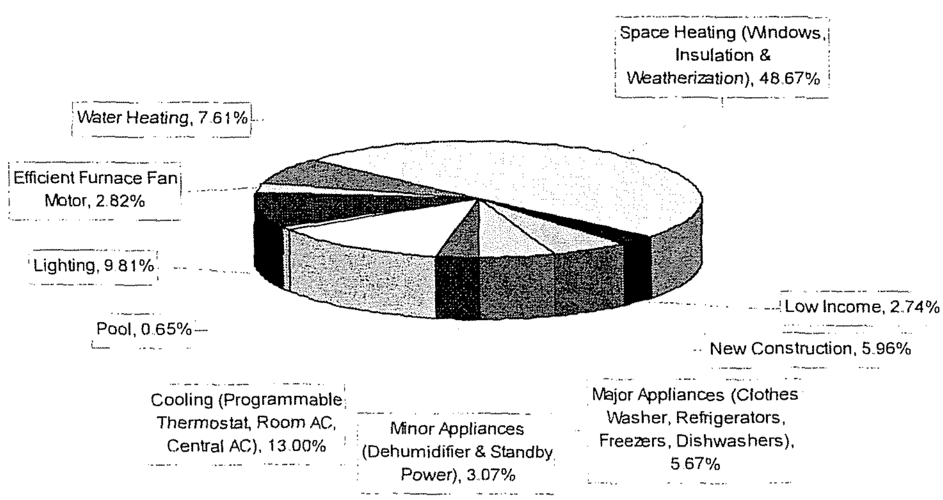


Figure 5-7 Residential Sector Achievable Cost Effective Savings (based on screened at $0.05 per kWh saved) by Measure Type - Kilowatt Hours

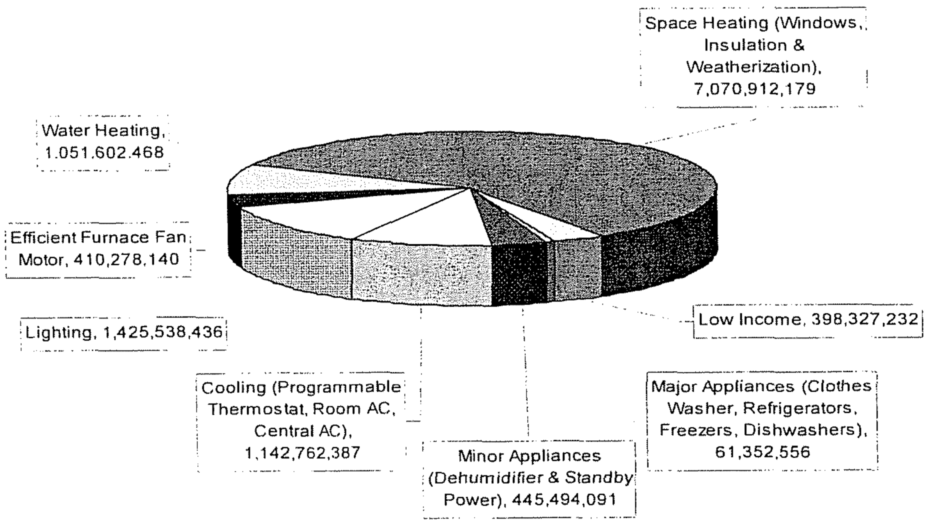


Figure 5-8 Residential Sector Achievable Cost Effective Savings (based on screening at $0.05 per kWh saved) by Measure Type - Percent of Total Savings

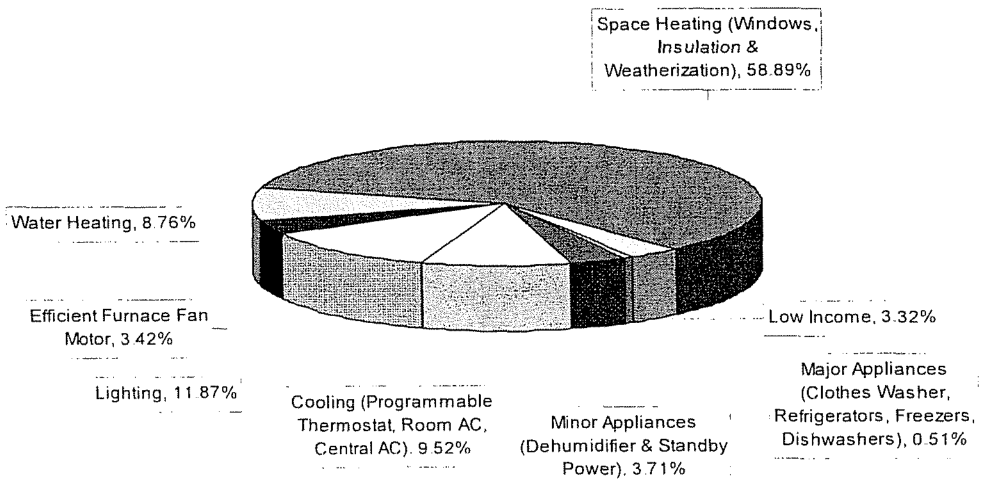


Figure 5-9: Cost Effective Residential Electric Energy Efficiency Measures (Measures under $.05 Per Lifetime kWh Saved)

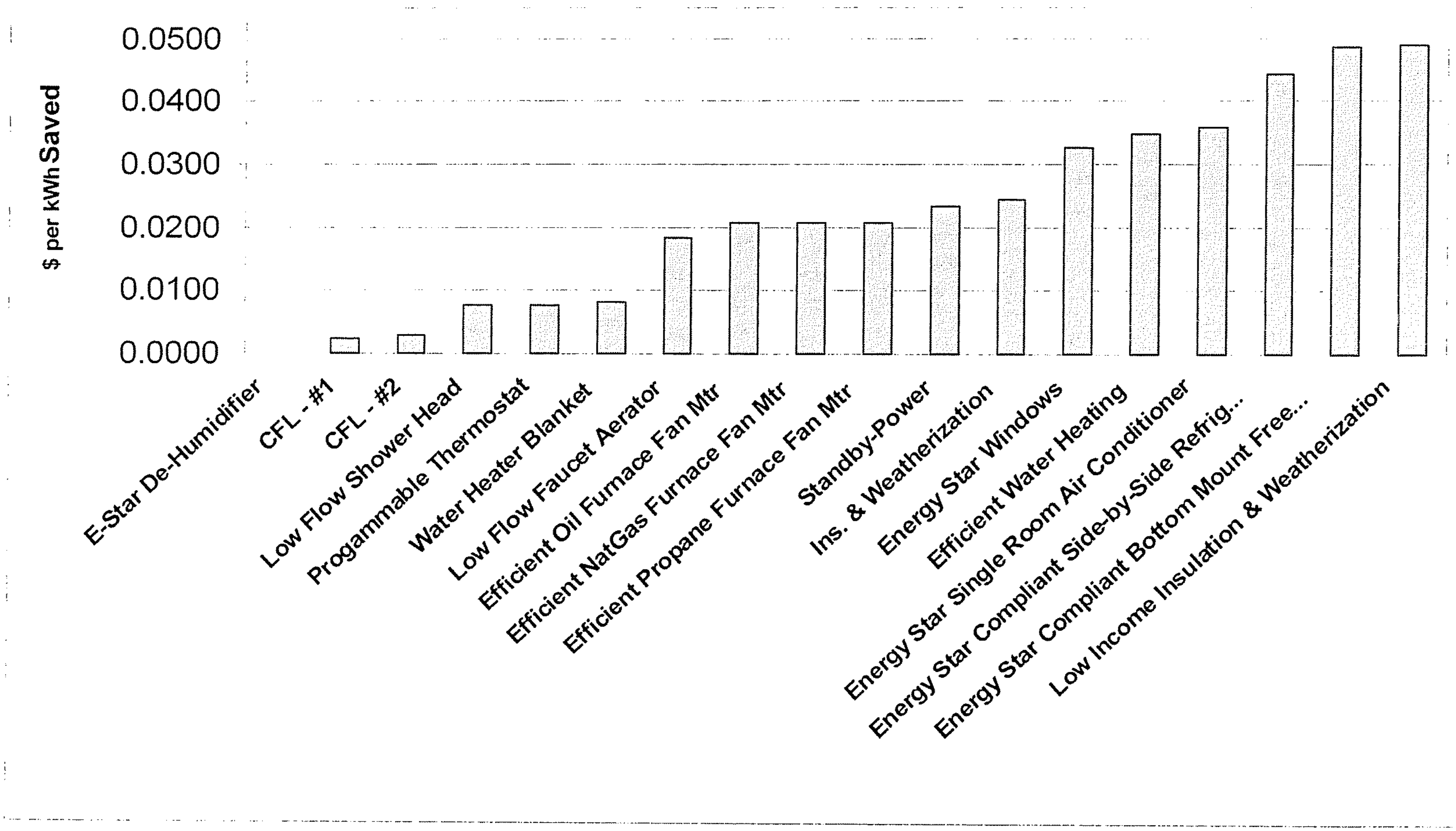
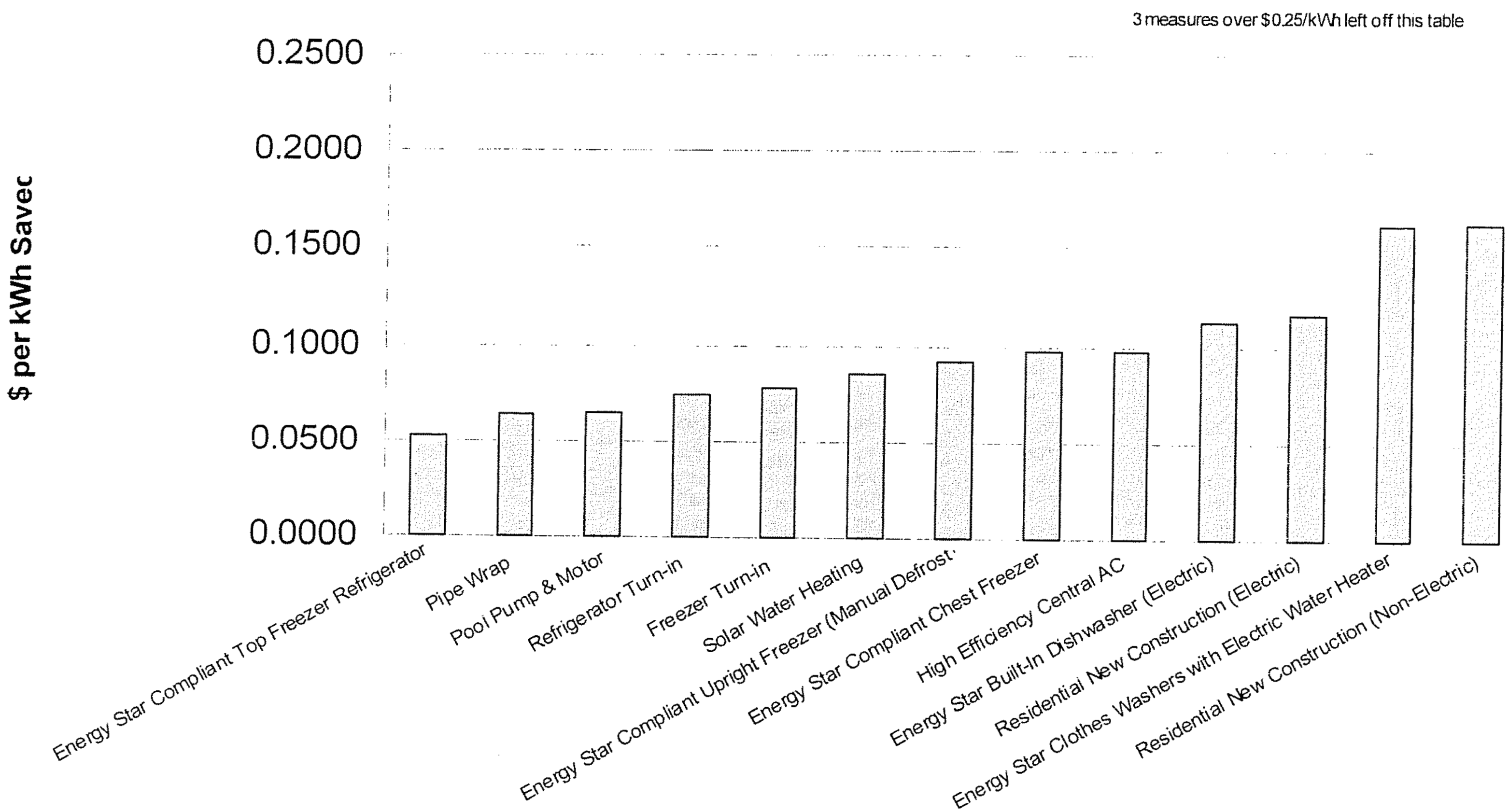


Figure 5-10
Cost of Conserved Energy - Residential Electric Energy Efficiency Measures (Measures over $.05 & under $.25 Per kWh Saved)



6.0 COMMERCIAL SECTOR ENERGY EFFICIENCY POTENTIAL

6.1 Introduction

For the commercial sector in North Carolina, the electric lighting end use likely represents the largest savings potential in absolute terms for both energy and peak demand, despite the adoption of high-efficiency lighting throughout the 1990's. Refrigeration represents a second electric end-use category for likely kWh savings potential and space cooling is a third end use with significant potential for kWh and kW demand savings. Eighty-one energy efficiency measures were examined for the commercial sector analysis.

This section of the report provides the estimates of technical, achievable and achievable cost-effective energy efficiency potential for electric energy efficiency measures for the commercial sector in North Carolina. Cumulative annual technical electricity savings potential for the commercial sector is estimated to be approximately 18,439 GWh by the year 2017. Achievable potential is estimated to be approximately 12,794 GWh and achievable cost-effective potential is estimated to be 6,950 GWh by 2017. Table 6-1 shows the potential savings in cumulative annual GWh and in percentage terms for the commercial sector.

Table 6-1: Commercial Sector Potential Electricity Savings by 2017

Level of Potential Savings	Cumulative Annual Electricity Savings Potential by 2017 (GWh)	% of 2017 GWh Sales
Technical Potential	18,439	32.2%
Achievable Potential	12,794	22.3%
Achievable Cost-effective Potential	6,950	12.1%

Table 6-2 presents a comparison of the achievable cost-effective potential savings results for the commercial sector for numerous energy efficiency potential studies. As shown in this table, the achievable cost-effective potential for electricity savings ranges from 6 percent by 2023 in the service area of Puget Sound Energy to 21 percent in Massachusetts by 2007. GDS based the estimate the achievable cost-effective potential for North Carolina for the commercial sector on the average of the results of the eight studies shown in the table below.

Table 6-2: Comparison of Achievable Cost-effective Potential Electricity Savings from Recent Studies for the Commercial Sector

Percent of Total Electricity (GWh) Sales												
Conn.	California	Mass.	Southwest	Big Rivers (KY)	Georgia	New York	Oregon	Puget Sound (WA)	NJ/NH/ PA	Wisconsin	Vermont	Average of All Studies
2012[1]	2011[2,3]	2007[4,5]	2020[6]	2015[7]	2015[8]	2012[9]	2013[10]	2023[11]	2011[12]	2015*	2015[13]	
14%	10%	21%		10%	10%			6%		4.8%	21.3%	12.09%

1. Independent Assessment of Conservation and Energy Efficiency Potential for Connecticut and the Southwest Connecticut Region, Appendix B." Prepared by GDS Associates. June 2004

2. California's Secret Energy Surplus: The Potential For Energy Efficiency – Final Report. Prepared for The Energy Foundation and The Hewlett Foundation, prepared by XENERGY Inc. Sept. 23, 2002.

3. California Statewide Residential Sector Energy Efficiency Potential Study. Study ID #SW063; Final Report Volume 1 OF 2; Prepared for Rafael Friedmann, Project Manager Pacific Gas & Electric Company San Francisco, California; Principal Investigator.

4. Electric and Economic Impacts of Maximum Achievable Statewide Efficiency Savings; 2003-2012 – Results and Analysis Summary. Public Review Draft of May 29, 2002; prepared for the Vermont Department of Public Service by Optimal Energy, Inc.

5. The Remaining Electric Energy Efficiency Opportunities in Massachusetts; Final Report. Prepared for Program Administrators and Massachusetts Division of Energy Resources by RLW Analytics, Inc. and Shel Feldman Management Consulting. June 7, 2001.

6. The New Mother Lode: The Potential for More Efficient Electricity Use in the Southwest. Prepared for: Hewlett Foundation Energy Series; prepared by Southwest Energy Efficiency Project. November 2002

7. The Maximum Achievable Cost-effective Potential for Electric Energy EfficiencyIn the Service Territory of the Big Rivers Electric Corporation. Prepared for Big Rivers Electric Cooperative (BREC) By GDS Associates. Nov. 2005.

8. Georgia Environmental Facilities Authority, "Assessment of Energy Efficiency Potential in Georgia - Final Report" prepared by ICF Consulting, May 5, 2005.

9. New York State Energy Research and Development Authority, "Energy Efficiency and Renewable Energy Resource Development Potential in New York State - Final Report" prepared by Optimal Energy, Inc., August, 2003.

10. Energy Efficiency and Conservation Measure Resource Assessment For The Residential, Commercial, Industrial, and Agricultural Sectors. Prepared for the Energy Trust of Oregon, Inc. By Ecotope, Inc., ACEEE, Tellus Institute, Inc. January 2003.

11. Assessment of Long Term Electricity and Natural Gas Conservation Potential in Puget Sound Energy Service Area 2003-2024. Prepared for Puget Sound Energy by KEMA-XENERGY/Quantec. August 2003.

12. Energy Efficiency and Economic Development in New York, New Jersey, and Pennsylvania. Prepared by ACEEE. 1997.

13. Vermont Electric Energy Efficiency Potential Study. Prepared for the Vermont Department of Public Service by GDS Associates, Inc., July 21, 2006

*Wisconsin reported combined results for commercial and industrial sectors as C&I.

6.2 Efficiency Measures Examined

In order to develop a list of commercial technologies to be included in this analysis, GDS reviewed several relevant data sources. Table 6-3 shows a list of the commercial sector energy efficiency measures included in this analysis, and the levelized cost per lifetime kWh saved for each measure. Detailed descriptions of these energy efficiency measures are provided in Appendix B of this report. Note that several measures have a levelized cost per kWh saved of less than $.05 per kWh saved.

Table 6-3: Commercial Measures – Levelized Cost per kWh Saved

Measure	Levelized cost per kWh saved
Space Heating	
High Efficiency Heat Pump	$0.0050
Ground Source Heat Pump - Heating	$0.3420
Water Heating End Use	
Heat Pump Water Heater	$0.0390
Booster Water Heater	$0.2477
Point of Use Water Heater	$0.0504
Solar Water Heating System	$0.0242
Solar Pool Heating	$0.0802
Envelope	
Double Pane Low Emissivity Windows	$0.0077
Space Cooling - Chillers	
Centrifugal Chiller, 0.51 kW/ton, 300 tons	$0.0513
Centrifugal Chiller, 0.51 kW/ton, 500 tons	$0.0513
Centrifugal Chiller, Optimal Design, 0.4 kW/ton, 500 tons	$0.0513
Space Cooling - Packaged AC	
DX Packaged system EER = 10.9, 10 tons	$0.0266
DX Packaged System, CEE Tier 2, <20 Tons	$0.0179
DX Packaged System, CEE Tier 2, >20 Tons	$0.0265
Packaged AC - 3 tons, Tier 2	$0.0488
Packaged AC - 7.5 tons, Tier 2	$0.0425
Packaged AC - 15 tons, Tier 2	$0.0405
Ground Source Heat Pump - Cooling	$0.2589
Space Cooling - Maintenance	
Chiller Tune Up/Diagnostics - 300 ton	$0.0339
Chiller Tune Up/Diagnostics - 500 ton	$0.0335
DX Tune Up/ Advanced Diagnostics	$0.1013

Measure	Levelized cost per kWh saved
HVAC Controls	
Retrocommissioning	$0.0145
Programmable Thermostats	$0.0038
EMS install	$0.0951
EMS Optimization	$0.2968
Ventilation	
Dual Enthalpy Economizer - from Fixed Damper	$0.0483
Dual Enthalpy Economizer - from Dry Bulb	$0.0329
Heat Recovery	$0.2215
Fan Motor, 40hp, 1800rpm, 94.1%	$0.0178
Fan Motor, 15hp, 1800rpm, 92.4%	$0.0064
Fan Motor, 5hp, 1800rpm, 89.5%	$0.0127
Variable Speed Drive Control, 15 HP	$0.0339
Variable Speed Drive Control, 5 HP	$0.0565
Variable Speed Drive Control, 40 HP	$0.0231
Motors	
Efficient Motors	$0.0153
Variable Frequency Drives (VFD)	$0.0979
Lighting End Use	
Super T8 Fixture - from 34W T12	$0.0494
Super T8 Fixture - from standard T8	$0.0427
T5 Fluorescent High-Bay Fixtures	$0.0315
T5 Troffer/Wrap	$0.0570
T5 Industrial Strip	$0.0626
T5 Indirect	$0.0570
CFL Fixture	$0.0234
Exterior HID	$0.0716
LED Exit Sign	$0.0461
Lighting Controls	$0.0308
LED Traffic / Pedestrian Signals	$0.0644
Electronic HID Fixture Upgrade	$0.0341
Halogen Infra-Red Bulb	$0.0996
Integrated Ballast MH 25W	$0.0643
Induction Fluorescent 23W	$0.0257
CFL Screw-in	$0.0023
Metal Halide Track	$0.0548

Measure	Levelized cost per kWh saved
Lighting Controls	
Bi-Level Switching	$0.0783
Occupancy Sensors	$0.0296
Daylight Dimming	$0.0834
Daylight Dimming - New Construction	$0.1169
5% More Efficient Design	$0.0522
10% More Efficient Design	$0.0522
15% More Efficient Design - New Construction	$0.0174
30% More Efficient Design - New Construction	$0.0174
Refrigeration End Use	
Vending Miser for Soft Drink Vending Machines	$0.0159
Refrigerated Case Covers	$0.0098
Refrigeration Economizer	$0.5605
Commercial Reach-In Refrigerators	$0.0217
Commercial Reach-In Freezer	$0.0248
Commercial Ice-makers	$0.0260
Evaporator Fan Motor Controls	$0.0531
Permanent Split Capacitor Motor	$0.0562
Zero-Energy Doors	$0.1627
Door Heater Controls	$0.0116
Discus and Scroll Compressors	$0.0610
Floating Head Pressure Control	$0.0597
Anti-sweat (humidistat) controls (refrigerator)	$5.0209
Anti-sweat (humidistat) controls (freezer)	$2.5439
High Efficiency Ice Maker	$0.0179
Compressed Air End Use	
Compressed Air – Non-Controls	$0.0205
Compressed Air – Controls	$0.0990
Monitor Power Management	
EZ Save Monitor Power Management Software	$0.5883
Water/Wastewater Treatment	
Improved equipment and controls	$0.0593
Transformer End Use	
ENERGY STAR Transformers	$0.0187

7.0 INDUSTRIAL SECTOR ENERGY EFFICIENCY POTENTIAL IN NORTH CAROLINA

7.1 Introduction

There are several cost-effective energy efficiency measures applicable to the industrial sector. Twelve energy efficiency measures were examined for the industrial sector analysis. For the manufacturing sector, GDS Associates focused on several crosscutting measures that represent the majority of the savings potential:

- Sensor and Controls
- Advanced lubricants
- Electric supply system improvements
- Pump system efficiency improvements
- Advanced Air compressor Controls
- Industrial motor management
- Air compressor system management
- Fan system improvements
- Advanced motor designs
- Motor system optimization (including Adjustable Speed Drives)
- Transformers (National Electrical Manufacturers Association Tier II)
- Efficient industrial lighting

Since this list is not comprehensive, due to budget and time constraints, the resulting savings should be viewed as a bounded technical potential. Industry and site specific opportunities clearly exist, but represent a small fraction of the total potential. Thus GDS focused on cross cutting measures. Listed below in Table 7-1 are the levelized cost per kWh saved figures for each industrial sector energy efficiency measure considered in this study. As in the residential and commercial sectors, there are several measures that have a levelized cost per kWh saved of less than $.05 per kWh saved.

Table 7-1: Industrial Sector Measure Levelized Cost Per Lifetime kWh Saved	
Measures	Levelized Cost Per kWh Saved
Industrial Sector Program - Non Lighting	
Sensors and controls	-$0.0500
Advanced lubricants	-$0.0636
Electric supply system improvements	-$0.0060
Pump system efficiency improvements	-$0.0007
Advanced Air compressor Controls	$0.0002
Industrial motor management	$0.0013
Air compressor system management	$0.0015
Fan system improvements	$0.0023
Advanced motor designs	$0.0025
Motor system optimization (including ASD)	$0.0025
Transformers (NEMA Tier II)	$0.0050
Industrial Lighting Program	
Efficient industrial lamps and fixtures	$0.0114
Other industrial energy efficiency measures	$0.0100

The specific data sources used by GDS for industrial energy efficiency measures are listed below:

Brown, E. and R.N. Elliott. 2005. *Potential Energy Efficiency Savings in the Agriculture Sector*, http://aceee.org/pubs/ie053full.pdf. Washington, D.C.: American Council for an Energy-Efficient Economy.

[Census] Bureau of the Census. 2005. *2002 Economic Census Manufacturing Geographic Area Series: North Carolina*,. Washington, D.C.: U.S. Department of Commerce.

2002 Economic Census Mining Geographic Area Series: North Carolina, Washington, D.C.: U.S. Department of Commerce.

Elliott, R.N. 1994. Electricity Consumption and the Potential for Electric Energy Savings in the Manufacturing Sector, ACEEE Report #IE942. Washington, D.C.: American Council for an Energy-Efficient Economy.

[EIA] Energy Information Administration. 2005a. *Manufacturing Energy Consumption Survey*, http://www.eia.doe.gov/emeu/mecs/contents.html. Washington, D.C.: U.S. Department of Energy.

Electric Sales, Revenue, and Average Price 2004, http://www.eia.doe.gov/cneaf/electricity/esr/esr_sum.html. Washington, D.C.: U.S. Department of Energy.

Martin, N., et al. 2000. *Emerging Energy-Efficient Industrial Technologies*, ACEEE Report #IE003. Washington, D.C.: American Council for an Energy-Efficient Economy.

Nadel, S., A. Shipley and Elliott, R.N. 2004. "The Technical, Economic and Achievable Potential for Energy efficiency in the U.S. - A Meta-Analysis of Recent Studies," in the *Proceedings of the 2004 ACEEE Summer Study on Energy Efficiency in Buildings*, http://aceee.org/conf/04ss/rnemeta.pdf. Washington, D.C.: American Council for an Energy-Efficient Economy.

Table 7-2 shows the potential savings in cumulative annual GWh and in percentage terms for the industrial sector. Cumulative annual technical electricity savings potential for the industrial sector is estimated to be approximately 12,290 GWh by the year 2017. Achievable potential is estimated to be approximately 8,912 GWh and achievable cost-effective potential is estimated to be 6,176 GWh by 2017.

Table 7-2: Industrial Sector Potential Electricity Savings by 2017

Level of Potential Savings	Cumulative Annual Electricity Savings Potential by 2017 (GWh)	% of 2017 GWh Sales
Technical Potential	12,290	21.5%
Achievable Potential	8,912	15.6%
Achievable Cost-effective Potential	6,176	10.8%

Table 1-7 in the Executive Summary presents a comparison of the technical, achievable and achievable cost-effective potential savings results for the industrial sector of numerous energy efficiency potential studies. As shown in this table, the achievable cost-effective potential for industrial electricity savings ranges from 6 percent by 2023 in the service area of Puget Sound Energy to 21 percent in Massachusetts by 2007. GDS based the estimates of the technical, achievable and achievable cost-effective electricity savings potential for North Carolina for the industrial sector on the average of the results of the studies shown in Table 1-7.

Appendix A

Descriptions of Residential Energy Efficiency Measures

Descriptions of Residential Energy Efficiency Measures

This technical appendix describes a broad range of residential sector energy efficiency measures and programs where GDS has assessed the technical and achievable potential for electric energy savings in North Carolina. The purpose of this technical appendix is to describe these energy efficiency measures and to provide data on their costs, energy savings and useful lives. The calculations of the potential savings are provided in a separate Excel file that is a separate appendix to this study. Listed below in Table 1 are the saturation levels of appliances in the South Atlantic region of the United States.

Table A-4: Latest South Atlantic Data for Saturation Levels of Appliances[27]

	Survey Year								
Survey Category	1980	1981	1982	1984	1987	1990	1993	1997	2001
Number of Households (millions)	14	14	14	15	16	17	17	19	20
	(percent of households)								
Air Conditioners[1, 2]									
Central	37	41	37	45	52	62	65	72	81
Individual Room Units	31	28	31	27	28	25	22	21	14
None	32	30	31	28	21	13	12	7	5
Electric Appliances									
Clothes Dryer	51	48	49	49	59	64	66	68	69
Clothes Washer	76	70	72	75	78	81	80	83	85
Computer, Personal	N/A	N/A	N/A	N/A	N/A	18	22	32	57
Dehumidifier	6	5	6	5	6	8	5	N/A	N/A
Dishwasher	35	29	33	35	43	48	47	53	58
Evaporative Cooler	1	(s)	(s)	(s)	(s)	(s)	(s)	N/A	(s)
Fan, Ceiling	N/A	N/A	N/A	N/A	N/A	N/A	63	69	73
Fan, Whole House	N/A	N/A	11	11	12	12	5	N/A	N/A
Fan, Window or Ceiling	N/A	N/A	34	45	55	62	68	N/A	N/A
Freezer, Separate	42	39	41	36	31	32	34	35	33
Oven, Microwave	12	13	15	31	60	80	84	84	88
Pump for Swimming Pool[3]	4	2	4	N/A	N/A	6	7	9	9
Pump for Well Water	N/A	N/A	N/A	N/A	N/A	22	19	20	19
Range (stove-top burner)	68	68	66	67	71	72	78	78	74
Refrigerator (one)[4]	89	91	89	90	88	89	89	87	84
Refrigerator (two or more)	11	8	11	10	12	11	11	12	16
Television Set (any type)	97	98	98	98	98	98	99	N/A	N/A
Television Set (b/w)	51	51	52	48	36	31	18	N/A	N/A
Television Set (color)	79	77	79	86	92	95	97	99	99
Waterbed Heaters	N/A	N/A	N/A	5	10	13	12	7	5
Gas Appliances[5]									
Clothes Dryer	5	5	7	10	6	7	4	5	7
Heater for Swimming Pool[6]	(s)	(s)	(s)	(s)	1	(s)	(s)	1	1
Outdoor Gas Grill	7	6	11	12	19	25	30	N/A	N/A
Outdoor Gas Light	1	1	2	1	1	(s)	1	(s)	(s)
Range (stove-top burner)	31	32	33	32	28	28	21	20	25
Kerosene Appliance									
Portable Heater	(s)	1	6	14	13	10	7	5	4

[1] Air-conditioning units may be powered by electricity or natural gas.
[2] Households with both central air-conditioning and individual room units are counted only under "Central."
[3] In all survey years except 1993, all reported swimming pools were assumed to have electric pumps for filtering and circulating water In 19
[4] Less than 0.5 percent of households lacked a refrigerator
[5] "Gas" means natural gas or liquefied petroleum gases
[6] For the years 1984 and 1987, the heater-for-swimming-pool category includes heaters for Jacuzzis and hot tubs.
NA = Not Available.
(s) = Less than 0.5 percent of households
Note: Data are available only for the 9 years shown above (years for which surveys were conducted)
Sources: Energy Information Administration, Form EIA-457, "Residential Energy Consumption Survey" for each year shown

[27] Residential Energy Consumption Survey 2001, Energy Information Administration (Table D5)

Table A-5: Saturation of four ENERGY STAR® appliances in North Carolina[28]

Saturation of ENERGY STAR® Room AC	39%
Saturation of ENERGY STAR® Refrigerators	14%
Saturation of ENERGY STAR® Dishwashers	31%
Saturation o ENERGY STAR® Clothes Washers	09%

1.1 Appliance Turn-In Program

1.1.1 Description of Measure – Appliance Turn in Program

The two primary goals of an appliance turn in program are:

1. To remove older, secondary freezers and/or refrigerators from customer homes so to prevent these appliances from entering the secondary market.
2. To encourage customers to replace older room air conditioners by providing incentives for new ENERGY STAR qualified room air conditioners.

In other programs conducted in the US, typical incentive amounts for appliance turn-in programs are $50 for the refrigerators/freezers, $25 for customers turning in a room AC and $35 for those customers turning in a room AC and buying an ENERGY STAR qualified replacement. This type of program has been run in Connecticut, for example, with an overall annual savings of 4,504 MWh.[29] Table A-12 below lists the typical average annual kWh savings for each of these three appliances (room air conditioners, refrigerators, freezers).

Table A-6 – Typical Annual kWh Savings per Appliance from a Turn-In Program

Appliance	Typical Annual kWh Savings Per Appliance from a Turn-In Program[30]
Refrigerator (from turn-in of old unit)	413 kWh
Freezer (from turn-in of old unit)	450 kWh
Room Air Conditioner (without replacement)	40 kWh
Room Air Conditioner (with replacement)	14 kWh

[28] Saturation based on market share tracking data. Saturation of ENERGY STAR appliances completed by Bill McNary, September 2006.

[29] Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report. December 23, 2005. Page 4.

[30] Impact, Process, and Market Study of the Connecticut Appliance Retirement Program: Overall Report. December 23, 2005 Nexus Market Research, Inc. & RLW Analytics, Inc Page 3, Table ES.4

1.2 High Efficiency Room Air Conditioners

1.2.1 Description of Measure – High Efficiency Room Air Conditioners

Room air conditioner units are typically mounted in a window so that part of the unit is outside and part is inside. An insulated divider to reduce heat transfer losses typically separates the two sides. The outdoor portion generally includes a compressor, condenser, condenser fan, fan motor, and capillary tube. The indoor portion generally includes an evaporator and evaporator fan.[31] The key program currently promoting high efficiency room air conditioners is DOE's ENERGY STAR® program. Currently, units with Energy Efficiency Ratios (EERs) of 9.4 to 10.8 (depending on model type and capacity) are eligible for the ENERGY STAR® label. The federal minimum electric efficiency standard for the most popular room air conditioner types and sizes have an EER of 9.7 and 9.8.[32] CEE's Super-Efficient Home Appliance (SEHA) program is defined as the upper end of the ENERGY STAR® spectrum, based on energy efficiency. SEHA promotes room air-conditioners that use 17-38 percent less electricity than the federal minimum standard.[33] Room air conditioners qualifying for this program have an EER of 10.5 or greater and represent the top 24 percent (in EER) of those models meeting the ENERGY STAR® requirements.

1.2.2 Market Barriers

Among the market barriers in this market are lack of consumer awareness of high efficiency equipment and lack of information about this equipment.

1.2.3 ENERGY STAR® Room Air Conditioners - Measure Data

Description – ENERGY STAR® labeled air conditioners feature high-efficiency compressors, fan motors, and heat transfer surfaces. In an air conditioner, air is cooled when it passes over refrigerant coils, which have fins similar to an automobile radiator. The compressor sends cooled refrigerant through the coils, which draws heat from the air as it is forced over the coils. By using advanced heat transfer technologies, more heat from the air is transferred into the coils than in conventional models, saving energy required to compress the refrigerant. ENERGY STAR labeled room air conditioners must exceed minimum federal standards for energy consumption by at least 10 percent.[34]

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31 Technology Summary. CEE website. www.cee1.org

32 Products and Specifications, Room Air Conditioners. http://www.ceeformt.org/resid/seha/seha-spec.php3

33 SEHA Specifications on Residential Appliances. http://www.cee1.org/resid/seha/rm-ac/rm-ac-main.php3

34 ENERGY STAR website http://www.energystar.gov/products/roomac/

Measure savings – An ENERGY STAR labeled Single Room A/C Unit saves an average of 134 kWh per year based on climate data specific to North Carolina.[35]

Measure incremental cost – The comparison between a very high efficiency room air conditioner unit and a conventional unit yields about a $30 incremental cost.[36]

Measure useful life – The useful life of a high efficiency room air conditioner is 12 years.[37]

Estimated baseline saturation in North Carolina – Of homes with room air conditioners, the saturation of high efficiency units is estimated to be 39% in North Carolina.[38]

Table A-7 - Summary of Data Sources for High Efficiency Room AC Technology

Cost of high efficiency room AC	ENERGY STAR website
Cost of standard efficiency room AC	ENERGY STAR website
Energy use of high efficiency room AC	ENERGY STAR website
Energy use of standard efficiency room AC	ENERGY STAR website
Useful life of room AC	ENERGY STAR website
Saturation of efficient residential room AC	D&R International
Market barrier information	ACEEE, CEE
National and regional programs	NEEP, MEEA, NEEA

1.3 High Efficiency Refrigerators

1.3.1 Description of Measure –High Efficiency Refrigerators

As of July 1, 2001, new federal minimum efficiency standards went into effect that reduced the average energy use of a new refrigerator to approximately 496 kWh per year. This corresponds to a typical 20 cubic foot unit with a top-mounted freezer and no ice-maker. Very high efficiency refrigerators use a number of technologies to achieve energy savings (more efficient compressors, insulation, door seals, etc.). Additional efficiency improvements, however, are possible beyond this new standard.

There are a few variations of high efficiency refrigerator models. There are top freezer models, side by side models, and bottom freezer models. Top freezer models account for 2/3 of refrigeration sales, the side-by-side models are second

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35 Savings Calculator-Room Air Conditioners (xls), found on the EnergyStar website (www energystar gov)
36 ibid
37 ibid
38 Email exchange with Bill McNary, D&R International September 2006.

in sales volume across the U.S., and bottom freezers, although growing in popularity, are still low in sales volume.[39]

1.3.2 Market Barriers

Barriers to improved refrigerator efficiency are several fold, including the useful life of refrigerators of approximately 13 years, limited consumer interest in improved efficiency (due in part to limited understanding of the benefits of high efficiency products), and the fact that many refrigerators are purchased by landlords and builders who care only about purchase price as someone else (home buyers and renters) pay the energy bills. Activities that can address these barriers include improved appliance efficiency labels, increased promotion of the ENERGY STAR® label, and further improvements in federal minimum efficiency standards.

1.3.3 ENERGY STAR® Residential Refrigerators - Measure Data

Description – The refrigerator is the single biggest power consumer in most households.[40] There are a few different models of refrigerators, the top freezer model accounts for almost 57% of refrigerator sales in the South Atlantic region, with side-by-side models coming in second for sales, and bottom freezers being last.[41]

Measure savings – An annual kWh savings of 80 kWh for top freezer models, 95 kWh for side-by-side models, and 87 for bottom freezer models was determined for this analysis.[42]

Measure incremental cost – The average incremental costs for an ENERGY STAR® refrigerator over a standard model is $30.[43]

Measure useful life – The useful life of a refrigerator is 13 years.[44]

Estimated baseline saturation in North Carolina – The saturation of energy efficient refrigerators in North Carolina is 14%.[45]

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[39] "Refrigerators. Buying Advice", (www.consumerreports.org)

[40] ENERGY STAR website. http://www.energystar.gov/products/refrigerators/

[41] Residential Energy Consumption Survey 2001, Energy Information Administration. Table HC5-11a.

[42] Savings Calculator-Residential Refrigerators (.xls), found on the EnergyStar website (www.energystar.gov)

[43] ibid

[44] ibid

[45] Email exchange with Bill McNary, D&R International. September 2006.

Table A-8 - Summary of Data Sources for High Efficiency Refrigerator Technology

Cost of very high efficiency refrigerator	ENERGY STAR website
Cost of standard refrigerator	ENERGY STAR website
Energy use of high efficiency refrigerator	ENERGY STAR website
Energy use of standard refrigerator	ENERGY STAR website
Useful life of refrigerator	ENERGY STAR website
Saturation of ENERGY STAR refrigerators	D&R International
Market barrier information	ACEEE, CEE
National and regional programs	NEEP, MEEA, NEEA

1.4 High Efficiency Freezers

1.4.1 Description of Measure

As with refrigerators, new federal minimum efficiency standards for freezers went into effect in July 2001. The increase in the freezer energy efficiency standard was relatively modest, primarily because the new standards were negotiated between manufacturers and efficiency advocates, resulting in a compromise where high savings were agreed to for high volume products (e.g. top-mount and side-by-side refrigerators) in exchange for modest savings on lower volume products such as freezers. As a result, there is substantial room for improving freezer efficiency.

The energy savings gained in purchasing an energy efficient freezer come from replacing an older model with a newer, more up to date model. Today's freezers are all similar in energy usage; therefore savings between the different models is not an issue.

1.4.2 Market Barriers

Freezer sales in the U.S. are relatively modest and largely stagnant. Due to these factors, manufacturers claim that they cannot make the investments needed to improve freezer efficiency and still make a profit. To buttress their claims, they note that following the last increase in freezer efficiency standards, several manufacturers stopped making freezers, leaving only two major manufacturers to serve the North American market. Other barriers to improved freezer efficiency are similar to those discussed previously for refrigerators.

Given the small size of the freezer market and past improvements in freezer efficiency, national energy savings from additional freezer improvements will be modest. Still improvements to the FTC Energy Guide labels may have some impact, as could extension of the ENERGY STAR® program to freezers.

1.4.3 ENERGY STAR® Freezers - Measure Data

Description – Freezers account for 5% of residential electricity consumption in the U.S., with more than 33 million households having at least one freezer.[46] Unlike refrigerators that offer several styles to choose from, freezers come in only two styles; Chest and Upright. Chest style models have a door on top that opens upward while Upright models have the door on the front opening outward. The market is split fairly evenly between the two styles. Upright freezers offer the advantage of easier access; you don't have to bend over and reach down into the unit, but tend to be slightly less efficient than chest freezers. In a chest freezer, there is little exchange of hot and cold air, since hot air rises. An upright freezer uses about 25 percent more electricity than a chest model.

Measure savings – A savings of 55 kWh was determined for upright freezer models and a 52 kWh savings was determined for chest freezer models.[47]

Measure incremental cost – Incremental costs were found to be about $33 for all freezer models.[48]

Measure useful life – The useful life of a freezer is approximately 11 years.[49]

Estimated baseline saturation in North Carolina – 10% of all homes with freezers in North Carolina currently satisfy ENERGY STAR efficiency requirements.[50]

Table A-9 - Summary of Data Sources for High Efficiency Freezer Technology

Cost of high efficiency freezer	ENERGY STAR website
Cost of standard efficiency freezer	ENERGY STAR website
Energy use of high efficiency freezer	ENERGY STAR website
Energy use of standard efficiency freezer	ENERGY STAR website
Useful life of freezer	ENERGY STAR website
Saturation of high efficiency freezers	GDS Assumption
Market barrier information	ACEEE, CEE
National and regional programs	NEEP, MEEA, NEEA

46 Food Storage/Cooking: Freezers. www.energyguide.com/library
47 Savings Calculator-Residential Freezers (.xls), found on the EnergyStar website (www.energystar.gov)
48 ibid
49 ibid
50 GDS Assumption

1.5 High Efficiency Dishwashers – Residential Sector

1.5.1 Description of Measure

DOE requires dishwasher manufacturers to meet a minimum energy efficiency standard of 2.17 kWh per cycle, equivalent to an energy factor (EF) of 0.46, for residential standard-capacity dishwashers.[51] About 80% of the total energy used by dishwashers goes towards heating the water. So, the best way to improve the efficiency of a dishwasher is to reduce the amount of water needed to clean the dishes. Some dishwashers take advantage of European technology, using a spray system that activates the upper and lower spray arms alternately instead of simultaneously, and thereby reducing water use. A "normal" load for this high efficiency equipment requires 6 gallons of water, instead of 8 to 10 gallons used in competitive models.

To enable consumers to identify dishwashers that are more efficient, DOE has established energy efficiency targets for dishwashers (as well as other products) under its ENERGY STAR® program. The program promotes the purchase of highly efficient appliances through product labeling, advertising, sales staff training, and promotional activities. Utilities participating in the program share the costs of promoting ENERGY STAR® products in their service territories. Under the ENERGY STAR® program, however, the efficiency targets for dishwashers have been set at an EF of 0.58. Similar to clothes washers, ENERGY STAR® is raising their efficiency requirements on dishwashers effective January 2007 to an EF of .65. These revised standards will further increase the energy savings of efficient models.[52]

To drive the market toward higher-efficiency targets, CEE also developed the Super Efficient Home Appliance (SEHA) Initiative that will add on to the DOE ENERGY STAR® program. Through this initiative, CEE encourages its members to support both the ENERGY STAR® appliance levels as well as higher efficiency tiers established by CEE. Participants in the initiative will work with retailers, providing information, tools, and incentives to increase the sales of products that qualify for CEE's more aggressive tiers. To avoid sending mixed messages to consumers, the distinction between ENERGY STAR® product levels and CEE levels will be transparent to the consumer. DOE is planning to review the ENERGY STAR® qualifying levels for several products including dishwashers; at this time there is a good chance that the qualifying efficiencies will be raised.

Ultimately, however, customer demand for high efficiency products and ancillary benefits of these products (i.e., low noise, better cleaning, etc.) will drive the market. National and regional market transformation initiatives can play a

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51 ENERGY STAR Program Requirements for Dishwashers, found on the EnergyStar website (www.energystar.gov)

52 ENERGY STAR Program Requirements for Dishwashers, found on the EnergyStar website (www.energystar.gov)

significant role in spurring consumer demand by promoting consumer awareness and knowledge of efficient dishwashers and their benefits. These educational efforts could be incorporated into current energy education efforts.

Educating consumers about the availability of high efficiency dishwashers, and working with retailers to ensure that they are adequately prepared to market high efficiency dishwashers will be key to successful market transformation efforts. Furthermore, actions to increase the availability and market share of high efficiency dishwashers can influence the new standard.

1.5.2 Market Barriers

Among the market barriers in the dishwasher market are lack of consumer awareness of high efficiency equipment and lack of information about this equipment.

1.5.3 ENERGY STAR® - Measure Data

Description –ENERGY STAR® labeled dishwashers save energy by using both improved technology for the primary wash cycle, and by using less hot water to clean. Construction includes more effective washing action, energy efficient motors and other advanced technology such as sensors that determine the length of the wash cycle and the temperature of the water necessary to clean the dishes.[53]

Measure savings – Annual savings of an electric heated ENERGY STAR® dishwasher are approximately 72 kWh. ENERGY STAR® dishwashers also save approximately 860 gallons of water annually. All estimates are based on an estimate of 4 cycles per week.[54]

Measure incremental cost – The average incremental cost of a high efficiency ENERGY STAR® dishwasher and a standard model is $50.[55]

Measure useful life – The useful life of an ENERGY STAR dishwasher is 10 years.[56]

Estimated baseline saturation in North Carolina – The saturation of energy efficient dishwashers in the North Carolina is approximately 31%.[57]

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53 ENERGY STAR® website. http //www.energystar.gov/products/dishwashers/#design
54 Savings Calculator-Dishwasters (.xls), found on the EnergyStar website (www.energystar.gov)
55 ibid
56 ibid
57 Email exchange with Bill McNary, D&R International. September 2006.

Table A-10 - Summary of Data Sources for High Efficiency Dish Washer Technology

Cost of high efficiency DW	ENERGY STAR website
Cost of standard DW	ENERGY STAR website
Energy use of high efficiency DW	ENERGY STAR website
Energy use of standard DW	ENERGY STAR website
Useful life of DW	ENERGY STAR website
Saturation of ENERGY STAR DW	D&R International
Market barrier information	ACEEE, CEE
National and regional programs	NEEP, MEEA, NEEA

1.6 High Efficiency Clothes Washers

1.6.1 Description of Measure

About 76 percent of homes in the South Atlantic region have top-loading clothes washers that spin on a vertical axis.[58] To wash clothes, the washtub must be filled so that all clothes are covered. In Europe the dominant type of washer is the horizontal axis machine. Horizontal axis machines reduce water use by 50 percent because the washtub is only partially filled. With each rotation of the tub, clothes are dipped in the water at the bottom of the half filled tub. When replacing vertical axis machines that meet the 2006 U.S. energy efficiency standard with H-axis machines, energy use can be reduced by up to 50 percent.[59] Many horizontal axis units are front-loading machines, but some units sold in the US are top loading, consisting of a conventional top loading door with a second door in the rotating metal drum. Additional energy savings can be derived from faster spin speeds. The spin cycle in standard American clothes washers spins clothes at approximately 600 rpm, which reduces the moisture content of the load from 100 percent to approximately 50 to 75 percent (depending on fabric). Typically, this laundry is moved to a dryer, to reduce the moisture content to 2.5 to 5 percent.[60] However, a study by the National Institute of Standards and Technology (NIST) found that to reduce moisture content of a typical laundry load from 70 percent to 40 percent, a spin cycle is approximately 70 times more energy efficient (i.e., requires 1/70th the energy) than a dryer thermal cycle. For 7 pound loads, increasing the spin speed to 900 rpm reduced dryer energy use by 28 to 47 percent depending on the fabric.[61] Many of the new high-efficiency washers that have recently entered the U.S. market have spin speeds significantly higher than conventional U.S. machines. To reduce wrinkling, these machines typically have complex cycles - slow spin, re-balancing, fast spin, and a final slow spin to ventilate the clothes. High spin speeds are also common in

[58] "Phase 2 Evaluation of the Efficiency Vermont Residential Programs." KEMA, Inc. Dec.2005. pg 3-20.

[59] Partnership for Advancing Technology in Housing. March 10, 2006. (www.toolbase.org/techinv/)

[60] An Evaluation of Assigning Credit/Debit to the Energy Factor of Clothes Washers Based On Water Extraction Performance." NBSIR 81-2309. 1981.

[61] ibid

Europe, with many machines having spin speeds over 800 rpm, and some machines operating as high as 1500 rpm.

Studies of horizontal-axis clothes washer performance indicate that these products produce substantial energy savings in the field, not just in the laboratory. In 2000, the U.S. Department of Energy and Maytag Appliances conducted field studies in Reading, Massachusetts. This study was done to assess savings in an urban setting experiencing rapid growth in water and sewer rates. The results were 50 percent energy savings and 44 percent water savings.[62]

In addition to saving water and energy, horizontal-axis machines may offer several other advantages. First, customers who own horizontal-axis washers are highly satisfied with their purchases (e.g. 81 to 95 percent in a study of the Northwest WashWise program).[63] Second, by eliminating the agitator, these units may create less wear and tear on clothes (however, some manufacturers dispute these claims). Third, they may use less detergent than vertical axis machines. This issue is complex and controversial, and may come down to consumer choices about whether they want better cleaning performance than standard machines (in which case there are unlikely to be detergent savings) or whether current cleaning performance is acceptable (in which case there may be some detergent savings). Finally, they are not as prone to load imbalance problems as some vertical axis machines.[64]

The analysis that follows is based on a high-efficiency machine meeting current ENERGY STAR® qualifications. At these performance levels, washer energy use is reduced by greater than 50 percent relative to the average vertical-axis washer now being sold. In addition, substantial savings on water and sewer bills contribute to the economic benefits of high-efficiency washers. ENERGY STAR® is raising their current standards effective January 2007 from a Modified Energy Factor (MEF) of 1.42 to 1.72. These revised ratings will result in even greater energy savings compared to their standard counterparts.[65]

There are currently many on-going efforts to promote high-efficiency washers. The CEE's Residential Clothes Washer Initiative, launched in 1993, promotes the manufacture and sales of energy-efficient clothes washers. CEE has developed a set of specifications and a qualifying product list to define energy efficiency and works with Initiative participants (utilities and energy organizations) to promote

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62 E Source Technology Atlas Series, Residential Appliances, section 6.2, "Study Finds Conservation Benefits in Switching to High-Efficiency Appliances," Maytag press release (October 2000), www.newstream.com

63 "Coming Clean About Resource Efficient Clothes Washers: An Initial WashWise Program and Market Progress Report." Pacific Energy Associates. January 1998.

64 Lebot, B. et al. "Horizontal Access Domestic Clothes Washers: An Alternative Technology That Can Reduce Residential Energy and Water Use." Proceedings from the ACEEE's 1990 Summer Study on Energy Efficiency in Buildings. 1990. 1.148-1.155.

65 ENERGY STAR Program Requirements for Clothes Washers, found on the EnergyStar website (www.energystar.gov)

qualifying washers through incentive, educational and promotional programs. There are currently more than 50 participating utilities and energy organizations. Today, hundreds of different high efficiency models are available in leading retail outlets across the country. Every major domestic appliance manufacturer -- including Maytag, Frigidaire, Whirlpool and General Electric – has introduced at least one high-efficiency clothes washer to the market. In addition, DOE is sponsoring an ENERGY STAR® marketing and promotion program that awards an ENERGY STAR® label to washers that meet the CEE efficiency thresholds.

1.6.2 Market Barriers

All new washing machines must display EnergyGuide labels to help consumers compare energy efficiency. The EnergyGuide label for clothes washers is based on estimated energy use for 392 loads of laundry per year. This value does not take into account the variations in tub size and other factors. Top loading machines with smaller tubs may have a better rating, but might mean you have to run the machine more often. While high-efficiency washers have many benefits, there may be some limitations. First, most of the current high-efficiency units are front-loading machines. Consumers are used to top-loading machines and it is unclear what proportion of consumers will be averse to front-loaders. Second, some high-efficiency machines have longer cycle times than conventional machines. Third, high-efficiency machines currently sell at a significant cost premium (approximately $300) relative to conventional machines.[66] While prices are likely to come down in the future, the cost increment is likely to be significant (e.g. several knowledgeable industry experts have suggested a long-term incremental cost in mass production of approximately $175).

1.6.3 ENERGY STAR® Clothes Washers - Measure Data

Description – Clothes washers come in two main designs, horizontal-axis (often front-loading) and the conventional vertical axis model. Some new top-loading, horizontal-axis designs use much less water to clean clothes and numerous studies show they clean clothes better than vertical-axis models.

Measure savings – Energy savings for an ENERGY STAR® clothes washer for residential applications are between 29-286 kWh per year, depending on whether the water heater is gas or electric powered. Given the many different models, offering different features, the number will vary with the options needed or chosen. In addition, both machines save approximately 7056 gallons of water per year, while the gas-powered clothes washer adds 1.2 mmbtus in natural gas savings. All estimates are based on either 8 loads per week.[67]

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[66] Savings Calculator-Clothes Washers (.xls), found on the EnergyStar website (www.energystar.gov)

[67] ibid

Measure incremental cost – The incremental cost of this equipment is about $300.00.[68]

Measure useful life – The useful life of a high efficiency clothes washer is 11 years.[69]

Estimated baseline saturation in North Carolina - The current saturation of high efficiency clothes washers in North Carolina is approximately 09% of all clothes washers.[70]

Table A-11 - Market Penetration of High Efficiency Clothes Washers

New England	16%[71]
California	17.9%[72]
New York	21%[73]
Vermont	14%[74]
National Penetration Rate	10.5%[75]

Table A-12 - Summary of Data Sources for High Efficiency Clothes Washer Technology

Cost of high efficiency CW	EnergyStar website
Cost of standard CW	EnergyStar website
Energy use of high efficiency CW	EnergyStar website
Energy use of standard CW	EnergyStar website
Useful life of CW	EnergyStar website
Saturation of high efficiency CW	D&R International
Market barrier information	ACEEE, CEE
National and regional programs	NEEP, MEEA, NEEA

1.7 Dehumidifiers

1.7.1 Description of Measure - Dehumidifiers

Often used in the damp areas of a home, such as basements, dehumidifiers remove moisture from the air to maintain comfort and to limit the growth of mold and mildew. A standard efficiency dehumidifier can use as much electricity as a

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68 ibid

69 ibid

70 Email exchange with Bill McNary, D&R International. September 2006.

71 "Clothes Washer Market Assessment. TumbleWash Program Evaluation" October 1999. RLW Analytics.

72 "2005 California Statewide Residential Lighting and Appliance Efficiency Saturation Study" RLW Analytics. August 2005.

73 "NYSERDA Electricity and Peak Demand Savings Review for Residential Appliances & Lighting Program. 2001. (Non-public workpaper.)"

74 Email exchange with Bill McNary, D&R International. February 22, 2006.

75 "The Residential Clothes Washer Initiative: A Case Study of the Contributions of a Collaborative Effort to Transform a Market" Shel Feldman Management Consulting, Research Into Action Inc., XENERGY, Inc. June 2001.

conventional refrigerator, which consumes more energy than most other products in the home.[76] ENERGY STAR® qualified dehumidifiers provide the same features as conventional models— moisture removal, quiet operation, and durability— but they are more energy efficient. ENERGY STAR® qualified models have more efficient refrigeration coils, compressors, and fans than conventional models, which means they use less energy to remove moisture. ENERGY STAR® qualified dehumidifiers operate at least 10 percent more efficiently than conventional models. Depending on the size of the dehumidifier, consumers can save up to $300 on their electricity bills over the 12-year lifetime of an ENERGY STAR® qualified unit.[77]

1.7.2 Market Barriers

Among the market barriers in this market are a lack of consumer awareness of high efficiency equipment, a lack of information about this equipment, as well as product availability and model variety. Cost does not appear to be a market barrier for high efficiency dehumidifiers.

1.7.3 Dehumidifiers - Measure Data

Description – This analysis compared replacing a standard 40 pint dehumidifier with a 40 pint ENERGY STAR® dehumidifier that is used 6 months out of the year.

Measure savings – An ENERGY STAR® labeled dehumidifier saves an average of 173 kWh per year.[78]

Measure incremental cost – According to ENERGY STAR® there is no incremental cost between a standard and high efficiency dehumidifier.[79]

Measure useful life – According to ENERGY STAR®, the useful life of an ENERGY STAR® labeled dehumidifier is 12 years.[80]

Estimated baseline saturation in North Carolina – The saturation of ENERGY STAR® labeled dehumidifies in homes that operate dehumidifiers is estimated to be 10%.[81]

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76 Dehumidifiers. Northeast ENERGY STAR Lighting and Appliance Initiative website. April 2006. (www.myenergystar.com/Dehumidifiers.aspx)

77 Dehumidifiers. Northeast ENERGY STAR Lighting and Appliance Initiative website. April 2006. (www.myenergystar.com/Dehumidifiers.aspx)

78 Savings Calculator-Dehumidifiers (.xls), found on the EnergyStar website (www.energystar.gov).

79 ibid.

80 ibid.

81 GDS estimate.

Table A-13 - Summary of Data Sources for Dehumidifiers

Cost of high efficiency dehumidifier	ENERGY STAR
Cost of standard dehumidifier	ENERGY STAR
Energy use of high efficiency dehumidifier	ENERGY STAR
Energy use of standard dehumidifier	ENERGY STAR
Useful life of high efficiency dehumidifier	ENERGY STAR
Saturation of high efficiency dehumidifier	GDS estimate
Market barrier information	ACEEE, CEE
National and regional programs	NEEP, EPA

1.8 Standby Power

1.8.1 Description of Measure – Standby Power

In homes and offices, electrical equipment consumes some electricity when placed on standby mode or even when switched off. For example, telephone chargers left plugged into a wall socket will continue to draw electricity even after the equipment is fully charged and is not in use, and televisions also continue to draw power after the user switches them off with the remote control. Equipment responsible for standby power waste is present in all sectors: household, services and industry. However, in the household sector, equipment is more generic and easier to target.[82]

In 1999, the International Energy Agency (IEA) proposed that all countries enact energy policies to reduce standby power use to no more than one watt per device by 2010. To date, several countries (including Australia and Korea) have formally adopted the '1-Watt Plan' and other countries (notably Japan and China) have also undertaken strong measures to reduce standby power. In July 2001, President Bush issued an executive order requiring the federal government to purchase products with low standby, with the eventual goal of one-watt or less.[83]

1.8.2 Market Barriers

Standby Power appliances are often replaced not upon burnout, but by changes in technology. Retrofitting solutions, then, are not cost-effective compared to low standby power solutions directly incorporated into the design of newer products. As a result, the introduction of newer and more efficient products are dependent upon technological advances more than the useful lives of appliances.

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82 "The 1 Watt-Standby Power Initiative. an International Action to Reduce Standby Power Waste of Electrical Equipment" IEA, 2002. (www.iea.org)

83 "Reducing Standby Power Waste to Less than 1 Watt: A Relevant Global Strategy That Delivers" IEA, 2002. (www.iea.org)

1.8.3 Standby Power - Measure Data

Description – Standby power is the electricity consumed by end-use electrical equipment that is switched off or not performing its main function. A wide variety of consumer electronics, small household appliances, and office equipment use standby power. The most common sources of standby power consumption include products with remote controls, low-voltage power supplies, rechargeable devices, and continuous digital displays.[84] A typical North American home often contains fifteen to twenty devices constantly drawing standby power.[85]

Measure savings – Although the amount of standby power consumed by an individual product is relatively small, typically ranging from 0.5 to 30 Watts, the cumulative total is significant given the large number of products involved: an estimated 50 to 70 Watts per household, or 5% of average residential electricity consumption (EIA 2003b; Meier 2002).[86] The savings that can be acquired by replacing 15 devices with models consuming 1-watt or less of standby power is 265 kWh/year.[87]

Measure incremental cost – The incremental cost to consumers of consumer electronics and other small home appliances with standby power use of 1W or less is about $30.[88]

Measure useful life – The useful life of consumer electronics using standby power is about 7 years.[89]

Estimated baseline saturation in North Carolina – Approximately 15% of all homes in the US have at least one product with 1-watt standby.[90]

Table A-14 - Summary of Data Sources for Standby Power

Cost of Standby Power Devices	ACEEE
Energy use of 1-Watt Standby Device	ACEEE
Energy use of standard Device	ACEEE
Useful life of 1-Watt Standby Device	ACEEE
Saturation of 1-Watt Standby Device	ACEEE
Market barrier information	IEA
National programs	IEA

84 Emerging Technologies & Practices. ACEEE 2004. Chapter 6: Measures, Page 40.

85 "The 1 Watt-Standby Power Initiative: an International Action to Reduce Standby Power Waste of Electrical Equipment" IEA, 2002. (www.iea.org)

86 Emerging Technologies & Practices. ACEEE 2004. Chapter 6: Measures, Page 40.

87 ibid

88 ibid

89 ibid

90 Email from Jennifer Thorne Amann of ACEEE on March 9, 2006.

1.9 Pool Pump & Motor

1.9.1 Description of Measure – Pool Pump & Motor

With regard to pool filtration, quicker is not necessarily better. While large, single speed pool pumps filter pools quickly, they use substantially more energy than multi-speed or small single speed pool pumps and motors. The energy used to operate the cleaning and filtering equipment for a typical pool for one swimming season can equal the energy used to power the average home for the same period of time.[91] Programs offer rebates for high efficiency pool filtration pump and motors as part of a new swimming pool installation or a replacement of the standard single-speed filtration pump and motor in an existing swimming pool. Generally, the new pump and motor must be the primary filtration pump and motor assembly of a residential in-ground swimming pool. Above ground pool pumps, booster pumps or spa pumps, do not qualify.[92]

Energy efficient pool pump motors use copper and better magnetic materials to reduce electrical and mechanical losses. As a result, they are longer lasting and more efficient than standard pool pumps. Additionally, high efficiency pumps are much quieter at low speed than standard pumps. High efficiency pumps will also circulate water for a longer period of time, increasing the efficiency of most filter types, automatic chemical dispensers and chlorinators, as well as increasing filter efficiency by decreasing particle impact on most filter types.[93,94]

1.9.2 Market Barriers

High efficiency pool pump and motors may not be compatible with all pool equipment such as roof mounted solar heating systems and some pool sweeps. Efficient equipment may not provide adequate circulation if a system utilizes roof mounted solar water heating units, and pressure and suction side pool sweeps may not receive sufficient water flow. Another potential market barrier is the useful life of pool pump and motors in areas where pump and motor use is not year-round. Replacement opportunities are fewer in areas where residential pool use is seasonal compared to areas where pool pump and motor burnout is more frequent due to continued daily operation.

1.9.3 Pool Pump & Motor - Measure Data

Description – This analysis compared replacing a standard efficiency pool pump and motor utilized for pool filtration and circulation with a high efficiency pool pump and motor.

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91 Pool Pumps and Motors Factsheet SMUD. April 2006. (www.smud.org)
92 Pool Pumps and Motors Factsheet. SMUD. April 2006. (www.smud.org)
93 Multi-Speed Pool Pump Factsheet. PG&E. April 2006 (www.pge.com)
94 Pool Pumps and Motors Factsheet. SMUD. April 2006. (www.smud.org)

Measure savings – A high efficiency pool pump and motor saves an average of 635 kWh per year.[95]

Measure incremental cost – The incremental cost of an efficient pool pump and motor is estimated at $313.[96]

Measure useful life – The useful life of a high efficiency pool pump and motor is 15 years.[97]

Estimated baseline saturation in North Carolina – The saturation of homes in North Carolina with residential outdoor swimming pools is 9%.[98] Of these, approximately 10% is estimated to be operating high efficiency pool pump and motors.[99]

Table A-15 - Summary of Data Sources for Pool Pump & Motor

Cost of high efficiency pool pump & motor	Connecticut Study (GDS)
Cost of standard pool pump & motor	Connecticut Study (GDS)
Energy use of high efficiency pool pump & motor	Connecticut Study (GDS)
Energy use of standard pool pump & motor	Connecticut Study (GDS)
Useful life of high efficiency pool pump & motor	Connecticut Study (GDS)
Percent of homes in North Carolina with a swimming pool	EIA
Saturation of high efficiency pool pump & motor	GDS estimate
Market barrier information	SMUD, PG&E
National and regional programs	SMUD, PG&E, SDG&E

1.10 Programmable Thermostats

1.10.1 Description of Measure – Programmable Thermostats

Programmable thermostats automatically adjust the home's temperature setting on a set schedule, allowing for daily energy conservation during periods when normal cooling and heating is unnecessary (i.e. when the house in unoccupied or at night). Programmable thermostats can store and repeat multiple daily settings (six or more temperature settings a day) that you can manually override without affecting the rest of the daily or weekly program. However, programmable thermostats have to be set and used properly to deliver the advertised energy

95 "Independent Assessment of Conservation and Energy Efficiency Potential for Connecticut and the Southwest Connecticut Region, Appendix B." June, 2004, by GDS Associates
96 ibid
97 ibid
98 Residential Energy Consumption Survey 2001. Energy Information Administration. Table D-5.
99 GDS estimate

savings. Routine deviation from the programmed default settings and schedules can significantly lower actual energy savings.

1.10.2 Market Barriers

Among the market barriers in this market are lack of consumer awareness of high efficiency equipment, a high incremental cost and lack of information about this equipment. In addition, energy savings are highly dependent on consumer usage of product and actual savings are sometimes negligible, creating concerns about the measure's efficacy.

1.10.3 Programmable Thermostats - Measure Data

Description – Programmable thermostats are ENERGY STAR® qualified in 3 different models. The 7 day model provides the most flexibility, allowing several different daily temperature settings for each day of the week. The 5 + 2 model uses the same temperature control setting for each weekday, and another for the weekends. Finally, the 5-1-1 models are similar to the previous models; wit the exception of allowing different schedules for each weekend day.

Measure savings – An ENERGY STAR labeled programmable thermostat saves an average of 628 kWh per year based on climate data specific to North Carolina.[100]

Measure incremental cost – The comparison between a programmable thermostat unit and a conventional unit yields about a $30 incremental cost.[101]

Measure useful life – For this analysis, the useful life of a programmable thermostat is 10 years.[102] The useful life of a programmable thermostat can vary, however, and ENERGY STAR lists the useful life at 15 years.

Estimated baseline saturation in North Carolina – The saturation of programmable thermostats is estimated to be 17% in North Carolina.[103]

[100] Savings Calculator-Central Air Conditioner (.xls), found on the EnergyStar website (www.energystar.gov)

[101] Home Depot website. Sept. 2006. (www.homedepot.com)

[102] Richard Spellman phone call with Honeywell. 2001

[103] Residential Energy Consumption Survey 2001. Energy Information Administration. Table HC6-11a.

Table A-16 - Summary of Data Sources for Programmable Thermostats

Cost of Programmable Thermostat	Home Depot
Cost of standard Thermostat	Home Depot
Energy use of Programmable Thermostat	ENERGY STAR
Energy use of standard Thermostat	ENERGY STAR
Useful life of Programmable Thermostat	Honeywell
Saturation of Programmable Thermostat	EIA
Market barrier information	ACEEE, CEE
National and regional programs	NEEP, MEEA, NEEA

1.11 High Efficiency Central Air Conditioners

1.11.1 Description of Measure – High Efficiency Central Air Conditioners

While 81 percent of homes in North Carolina have central air conditioning,[104] about one-sixth of all the electricity generated in the US is used to air condition buildings. Central air conditioners are more efficient than room air conditioners. In addition, they are out of the way, quiet, and convenient to operate. Today's best air conditioners use 30%–50% less energy to produce the same amount of cooling as air conditioners made in the mid 1970s. Even if an air conditioner is only 10 years old, one may save 20%–40% of cooling energy costs by replacing it with a newer, more efficient model.

The installation of oversized air conditioning units in an effort to avoid problems involving inadequate cooling capacity is common. Oversized units have also been utilized as a method of compensating for potential distribution problems such as un-insulated or leaky ductwork. However, these oversized units also create increased costs and reduced efficiency levels.

A central A/C unit that is too big will cycle on and off much more often spending a greater proportion of time running in an inefficient start-up mode. This results in "blasts" of cold air, reducing efficiency, and increasing stress on components. In addition, moisture removal and interior air mixing are also reduced during short run times.[105] Consequently, oversized air conditioning units can do poor job of lowering the humidity, which is also an important component to comfort. Often, a slightly undersized air conditioner is just as comfortable, if not more, than an oversized air conditioner.

Central air conditioners are rated according to their seasonal energy efficiency ratio (SEER). SEER indicates the relative amount of energy needed to provide a specific cooling output. New residential central air conditioner standards went

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104 Residential Energy Consumption Survey 2001. Energy Information Administration. Table D-5.

105 "How Contractors Really Size Air Conditioning Systems." Presented at the 1996 ACEEE Summer Study on Energy Efficiency in Buildings. American Council for an Energy-Efficient Economy. Washington, D.C.

into effect in January 2006. Air conditioners manufactured after January 2006 must achieve a Seasonal Energy Efficiency Ratio (SEER) of 13 or higher. SEER 13 is 30% more efficient than the current minimum SEER of 10. The standard applies only to appliances manufactured after January 23, 2006. Equipment with a rating less than SEER 13 manufactured before this date may still be sold and installed.

1.11.2 Market Barriers

Among the market barriers in this market are lack of consumer awareness of high efficiency equipment, a high incremental cost and lack of information about this equipment. In addition, lengthy useful life, and high initial product costs largely prevent retrofitting before replacement is necessary.

1.11.3 ENERGY STAR® Central Air Conditioners - Measure Data

Description – Central air conditioners circulate cool air through a system of supply and return ducts. Supply ducts and registers (i.e., openings in the walls, floors, or ceilings covered by grills) carry cooled air from the air conditioner to the home. This cooled air becomes warmer as it circulates through the home; then it flows back to the central air conditioner through return ducts and registers. This analysis compared savings between the current minimum standard (SEER=13) for operating units and a more efficient commercially available air conditioning unit (SEER=15).

Measure savings – An ENERGY STAR® labeled central A/C Unit saves an average of 524 kWh per year based on climate data specific to North Carolina.[106]

Measure incremental cost – The comparison between a very high efficiency central air conditioning unit and a conventional unit yields about a $379 incremental cost.[107]

Measure useful life – The useful life of a central A/C is 14 years.[108]

Estimated baseline saturation in North Carolina – 81% of homes in North Carolina have central a/c.[109] The saturation of efficient central air conditioners is estimated to be 10% of homes with central a/c.[110]

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106 Savings Calculator-Central Air Conditioner (.xls), found on the EnergyStar website (www.energystar.gov)

107 Efficiency Vermont Technical Reference User Manual No. 2005-37. Page 368.

108 Savings Calculator-Central Air Conditioner (.xls), found on the EnergyStar website (www.energystar.gov)

109 Residential Energy Consumption Survey 2001. Energy Information Administration. Table D-5

110 GDS assumption

Table A-17 - Summary of Data Sources for Central AC Technology

Cost of high efficiency Central AC	ENERGY STAR
Cost of standard efficiency Central AC	ENERGY STAR
Energy use of high efficiency Central AC	ENERY STAR
Energy use of standard efficiency Central AC	ENERGY STAR
Useful life of Central AC	ENERGY STAR
Saturation of efficient residential Central ACs	GDS estimate
Market barrier information	ACEEE, CEE
National and regional programs	NEEP, MEEA, NEEA

1.12 Residential Lighting - Fluorescent Technologies

1.12.1 Description of Measure

Residential fluorescent bulbs and fixtures present a significant opportunity for energy and maintenance savings. On a per lamp basis, compact fluorescent lamps are generally 70 percent more efficient than incandescent lamps and last up to ten times longer. Poor quality, selection, appearance and reliability of residential fluorescent fixtures have in the past contributed to consumer aversion to fluorescent lighting. Additionally, the lack of brand loyalty among consumers coupled with the large number of manufacturers (500 including foreign companies) led to a proliferation of inferior fluorescent fixtures in the 1990's. According to Calwell et al., the existing stock of residential fixtures in 1996 was approximately 15 percent fluorescent and 85 incandescent,[111] More recent data shows that approximately 20% of existing lighting is fluorescent, suggesting that fluorescent share is increasing, but considerable technical potential for energy savings remains.[112]

In considering possible energy efficiency or market transformation initiatives, the fixture market can and should be separated into two end-use categories: hard-wired and portable units, which differ in both the supply chain and in consumer purchasing patterns. Hard-wired fixtures are most frequently purchased for new construction and major renovations, whereas portable fixtures are most often a retrofit, replacement or remodeling purchase. During recent years, national chain stores such as Home Depot and Lowe's have featured displays of compact fluorescent bulbs and have increased the market share of this technology in homes across the U.S.

Installing hard-wired fluorescent fixtures reduces the likelihood of reversion to incandescent lamps. Consequently, hard-wired fixtures (indoor and outdoor) that are characterized by energy efficiency, quality and safety present a significant

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[111] Calwell, Chris, Chris Granda, Charlie Stephens and My Ton. 1996. *Energy Efficient Residential Luminaires: Technologies and Strategies for Market Transformation*. Final Report. Submitted to the U.S.E.P.A., Office of Air and Radiation, ENERGY STAR Programs, under grant #CX824685. San Francisco, CA: Natural Resources Defense Council.

[112] "Energy Efficiency Lighting In the Residential Market." Brad Kates and Steve Bonnano. Powerpoint Presentation, April 2005.

opportunity to reduce energy consumption. Since the point-of-sale for hard-wired fixtures is relatively concentrated (and generally limited to showrooms, contractors and distributors), a fixture initiative can target these markets more effectively than lamp suppliers for which sales locations are more diffuse.

In contrast, portable fixtures represent less of an opportunity for market transformation because the target market is diffuse, and influencing purchasing decisions may take considerably more resources. However, new developments in torchiere lamps provide a unique market transformation opportunity. The 40 million halogen torchieres in American homes, dorms and offices consume up to 600 watts of power each, and often account for 30 to 50 percent of lighting retailers' sales.[113] The typical compact fluorescent alternative to halogen torchieres consumes 55 to 100 watts of power, representing an efficiency improvement of 6 times the halogen at full light output. Incandescent torchieres are becoming more popular as well, with consumption rates of 100 to 150 watts. In addition, some non-torchiere portable fixtures that use only compact fluorescent lamps are now available.

The costs of residential fluorescent fixtures vary widely. For this analysis of fluorescent and incandescent technologies, a Home Depot store has been used as the primary source of up-to-date cost and wattage data with the price impacts of light bulb multi-packs taken into account.

1.12.2 Market Barriers – Fluorescent Lighting Technologies

The primary market barriers to the penetration of fluorescent fixtures include product availability, quality of residential grade fixtures, consumer aversion to fluorescent lighting, and the first cost (purchase price) for high quality fixtures and bulbs. For hard-wired fixtures, specifier and commercial grade units are of better quality than residential fixtures. Consequently, making these fixture grades available to homeowners at a reasonable cost is an important market transformation strategy.

Market transformation programs for lighting fixtures exist nationally and regionally. Launched in March of 1997, the ENERGY STAR® Fixture program promotes the adoption of high quality, efficient fixtures through its labeling program. Two regional fixture initiatives sponsored by the Northeast Energy Efficiency Partnerships (NEEP) and the Northwest Energy Efficiency Alliance (NEEA) have recently been adopted and several states also fund their own residential lighting programs. Most of these initiatives coordinate with the ENERGY STAR® program, targeting both hard-wired and portable fixtures, and encourage active retail promotions and consumer education. Similarly, a coalition of California utilities, coordinating with the Northwest, selected the ENERGY STAR® Fixtures specification as the basis of a regional lighting fixture program

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[113] Calwell, Chris, Chris Granda, Charlie Stephens and My Ton. 1996. *Energy Efficient Residential Luminaires: Technologies and Strategies for Market Transformation.* Final Report. Submitted to the U.S.E.P.A., Office of Air and Radiation, ENERGY STAR Programs, under grant #CX824685. San Francisco, CA: Natural Resources Defense Council

and plans to offer performance-based incentives to fixture manufacturers, wholesalers, and large and small retailers. In addition to the above market transformation initiatives, another force advancing lighting efficiency is the banning of halogen torchieres by a number of universities due to the fire hazard they pose.[114]

1.12.3 Compact Fluorescent Bulb Measure Data

Description – The purchase price of compact fluorescent bulbs (CFLs) most commonly purchased for residential applications is now in the range of $3-$5 per bulb. These bulbs can be found in hardware stores as well as in chain stores such as Home Depot and Lowe's. CFL bulbs range in size and shape, and their appearance can be a spiral shaped fluorescent tube, or they can appear as a standard shape such as the R-30 floodlight for use in recessed cans.

Measure savings – Energy savings for a CFL are approximately 75% as compared to a standard incandescent light bulb (for example, a 19 watt compact fluorescent can replace a 75 watt incandescent bulb). For this report, GDS has calculated an average annual energy savings based on different wattages and 986 hours of annual operation. The average annual kilowatt-hour savings associated with installing more CFL bulbs in a home using partial compact fluorescent lighting is approximately 24 kWh (per bulb) per year. GDS assumed homes with partial CFL installation had previously installed the efficient bulbs in their most commonly used fixtures. The remaining fixtures, then, are used less frequently and fewer annual hours. Consequently, homes with no prior CFL installation would be able to install efficient lighting in their most commonly used fixtures and would realize greater average savings. Homes with no CFL bulbs presently installed would save an average of 28.8 kWh (per bulb) per year.[115]

Measure incremental cost – The purchase price of a single CFL at Home Depot/Lowe's in 2006 ranges from $4.71 to $12.02, though these prices decrease significantly when purchasing multi-pack bulbs. Because lower wattage CFL bulbs are purchased at a greater frequency than higher wattage CFL bulbs (with higher associated incremental costs) a weighted average incremental cost was calculated. The weighted average incremental cost of a CFL bulb (after an estimate effect of multi-pack price savings) used in this analysis is $5.00.[116]

Measure useful life – The useful life of a CFL bulb is approximately 7,500 hours, or 7.6 years when in use 986 hours annually.[117]

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114 Chris Calwell, "Big Lamp on Campus: An Energy and Environmental Curriculum Module for Colleges Concerned about Halogen Lamp Use," submitted by Ecos Consulting to the US Environmental Protection Agency, Office of Air and Radiation, ENERGY STAR Programs, under Grant # CX820578-01-0 to the Natural Resources Defense Council, April 15, 1997.

115 Impact Evaluation of the Massachusetts, Rhode Island, and Vermont 2003 Residential Lighting Programs. Nexus Market Research. Oct. 2004.

116 Home Depot (March 2006)

117 Manufacturer data

Estimated baseline saturation in North Carolina – Based on recent market assessment data collected in Vermont, homes with efficient lighting have an average of 6 CFL bulbs (out of 30 CFL-compatible sockets), or an estimated saturation of 20%. Homes without compact fluorescent lighting have an estimated saturation of 0% for this efficiency measure.[118]

Table A-18 - Summary of Data Sources for CFL Technology

Cost of CFL bulb	Home Depot store
Cost of incandescent bulb	Home Depot store
Energy use of CFL bulb	GDS Calculation
Energy use of incandescent bulb	GDS Calculation
Useful life of CFL bulb	Manufacturer data on product package
Useful life of incandescent bulb	Manufacturer data on product package
Saturation of CFL bulbs	KEMA, Inc., December 2005 Market Assessment Report
Market barrier information	ACEEE, CEE
National and regional programs	ACEEE, CEE, NEEP, NEEA, MEEA

1.13 High Efficiency Water Heaters & Water Heater Efficiency Options

1.13.1 Measure Description

The average standard efficiency stand alone electric water heater sold today has an Energy Factor (EF) of approximately 0.87. Higher efficiency models are available with thicker insulation (up to 3 inches thick) and with heat traps, which limit heat losses through inlet and outlet pipes. These models most commonly have an EF of 0.93. These efficiency values particularly apply to the 50 to 55 gallon size class, which represents a majority of all electric water heater sales. Energy savings with high efficiency water tanks are essentially all in reduced standby losses.

In addition to the traditional stand alone storage tank water heaters, heat pump water heaters are also commercially available. Heat pumps, commonly used for space heating purposes, can also apply the principle of transferring heat from surrounding air and deliver it to water. Some models comes as a complete package including tank and back-up resistance heating elements while others work as an accessory to a conventional water heater.

As this unit extracts heat from the surrounding air (indoor, exhaust, or outdoor air), a heat pump water heater delivers about twice the heat for the same electricity costs as a conventional stand alone water heater.[119] In addition, the transfer of heat from neighboring air also serves to cool and dehumidify a space,

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[118] "Phase 2 Evaluation of the Efficiency Vermont Residential Programs." KEMA, Inc. December 2005, Pages 1-23.

[119] "Heat Pump Water Heaters-Residential" Energy Efficiency Factsheet, Washington State University Energy Program. Accessed April 2006. (www.energy.wsu.edu)

creating additional benefits during the cooling season, but drawbacks during the heating season. In recent years, the market for heat pump water heating systems has been stagnant due to competition with gas waters heaters enjoying favorable gas prices and the failure of electric rates to rise as fast as initially projected in many areas.[120]

While most water heater systems are stand-alone systems, they can also be integrated with the boiler used to heat the home. There are two styles of integrated systems: Tankless Coil and Indirect. Tankless Coil systems heat water as it is needed just as a demand system, the only difference being that the boiler is used to heat the water. Indirect systems also heat water in the boiler, but the water is then stored in a tank. The advantage of a tankless coil system is the avoided cost of purchasing a separate water heating system. The disadvantage is that during the non-heating season water heating is inefficient since the heating system must operate solely for heating water.

Indirect systems have the added cost of a tank, but since the hot water is stored in an insulated tank, the boiler or furnace does not have to turn on and off as frequently, improving its fuel economy. This increased efficiency generally offsets the cost of a tank. According to ACEEE, when used in combination with new, high efficiency boilers or furnaces, indirect water heaters are generally the least expensive way to provide hot water.[121] Gas, oil, and propane-fired systems are available.

Although ENERGY STAR does not include water heaters in their label program, utilities in the Northwest, for example, have been promoting high efficiency electric water heaters for many years. The typical program pays incentives of $25 to $60 for water heaters with an EF of 0.93 or more. Participation rates of 40 to 60 percent of water heater sales have been achieved.

In lieu of replacing a water heater with a more efficient model, there are several alternative measures that can be used to help in the conservation of water and energy loss within the residential sector. The installation of water heater blankets, pipe wrap, low flow shower heads, and faucet aerators are all energy efficient measures that will save energy and money on an existing water heating system. Other techniques for increasing water heater efficiency is the addition of a solar water heating system as well as fuel-switching, or eliminating electric water heating systems for more efficient non-electric systems.

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120 "Heat Pump Water Heaters-Residential" Energy Efficiency Factsheet, Washington State University Energy Program. Accessed April 2006. (www.energy.wsu.edu)

121 "Consumer Guide to Home Energy Savings, 8th edition." ACEEEE. pg. 100

1.13.2 Market Barriers

Among the market barriers in this market are lack of consumer awareness of high efficiency equipment, a long measure useful life, and lack of information about this equipment and the efficiency options.

1.13.3 Water Heater Blanket - Measure Data

Description – Water heater jackets are designed to wrap around an existing water heater tank to improve insulation, prevent heat loss and save energy. Installing an insulating blanket will reduce standby heat loss - heat lost through the walls of the tank- by 25-40%.[122]

Measure savings – Water heater insulation blankets save approximately 315 kWh per year.[123]

Measure incremental cost – The incremental cost to consumers of water heater insulation blankets is $10.[124]

Measure useful life – The useful life of a water heater blanket is 6 years.[125]

Estimated baseline saturation in North Carolina – Approximately 10% of all homes with electric water heaters have installed an insulation blanket around their water heater.[126]

Table A-19 - Summary of Data Sources for Water Heater Blanket

Retail price of a water heater blanket	Home Depot
Labor Cost for installing WH blanket	Efficiency Vermont
Energy use of WH with blanket	Efficiency Vermont
Energy use of standard WH without blanket	Efficiency Vermont
Useful life of WH blanket	Efficiency Vermont
Saturation of WH blanket	GDS Estimate

1.13.4 Low Flow Shower Head - Measure Data

Description – Low flow showerheads are another measure that is low-cost, and in addition to faucet aerators can reduce home water consumption by as much as 50%.[127]

122 "Consumer Guide to Home Energy Savings." 8th ed. ACEEE. 2003. Page 112.
123 Efficiency Vermont Technical Reference User Manual No. 2005-37 Page 320.
124 Home Depot website (www.homedepot.com)
125 ibid.
126 GDS estimate
127 "Low-Flow Aerators" (www.eartheasy.com)

Measure savings – Low flow shower heads can save approximately 340 kWh and 3,441 gallons of water per year.[128]

Measure incremental cost – The incremental cost to consumers of low flow shower heads is around $15.[129]

Measure useful life – The useful life of a low flow shower head is 9 years.[130]

Estimated baseline saturation in North Carolina – Approximately 10% of all homes with electric water heaters have installed a low flow shower head in their home.[131]

Table A-20 - Summary of Data Sources for Low-Flow Shower Head

Cost of Low-Flow Shower Head	Efficiency Vermont
Energy use of Low-Flow Shower Head	Efficiency Vermont
Energy use of standard Shower Head	Efficiency Vermont
Useful life of Low-Flow Shower Head	Efficiency Vermont
Saturation of Low-Flow Shower Head	GDS Assumption

1.13.5 Pipe Wrap - Measure Data

Description – Insulating hot water pipes will reduce losses as the hot water is flowing to the faucet and, more importantly, it will reduce standby losses when the tap is turned off and then back on within an hour or so. Pipe wrap will conserve energy and water that would normally be lost waiting for the hot water to reach the tap. Energy loss still occurs after pipe wrap has been installed, though to a smaller degree than the losses observed in non-insulated pipes.

Measure savings – Pipe wrapping can save approximately 33 kWh per year.[132]

Measure incremental cost – The incremental cost to consumers of water heater pipe-wrap is $15.[133]

Measure useful life – The useful life of a pipe wrap is 13 years.[134]

Estimated baseline saturation in North Carolina – Approximately 10% of all electric water heaters have installed insulation wrap around their hot water pipes.[135]

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128 Efficiency Vermont Technical Reference User Manual No. 2005-37. Page 326.
129 Efficiency Vermont Technical Reference User Manual No. 2005-37. Page 327
130 ibid.
131 GDS estimate
132 Efficiency Vermont Technical Reference User Manual No. 2005-37. Page 322.
133 Efficiency Vermont Technical Reference User Manual No. 2005-37. Page 323.
134 ibid.

Table A-21 - Summary of Data Sources for Water Heater Pipe Wrap

Cost of Pipe Wrap	Efficiency Vermont
Energy use of WH w/ Pipe Wrap	Efficiency Vermont
Energy use of standard WH	Efficiency Vermont
Useful life of Pipe Wrap	Efficiency Vermont
Saturation of Pipe Wrap	GDS Assumption

1.13.6 Faucet Aerators - Measure Data

Description – Faucet aerators are attachments used to increase spray velocity, reduce splash and save water and energy. There are many variations of aerators yet they all should have a water usage of 2.75 gallons or less. These different models include swiveling, dual spray, vandal proof (requires a key to remove) and a one touch on/off tap saver. This model is equipped with a control lever to temporarily reduce the water flow without disturbing the temperature setting. This feature allows you to reduce the flow of water while shaving, brushing teeth, or washing dishes to save water.[136]

Measure savings – Faucet aerators can save approximately 57 kWh per year.[137]

Measure incremental cost – The incremental cost to consumers of a faucet aerator is $6.[138]

Measure useful life – The useful life of a faucet aerator is 9 years.[139]

Estimated baseline saturation in North Carolina – Approximately 10% of homes in North Carolina with electric water heaters have installed faucet aerator to conserve energy.[140]

Table A-22 - Summary of Data Sources for Faucet Aerators

Cost of Faucet Aerator	Efficiency Vermont
Energy use of Faucet Aerator	Efficiency Vermont
Energy use of home without FA	Efficiency Vermont
Useful life of Faucet Aerator	Efficiency Vermont
Saturation of Faucet Aerators	GDS estimate

135 GDS estimate
136 Faucet Aerators, AM Conservation Group, Inc (www.amconservationgroup.com)
137 Efficiency Vermont Technical Reference User Manual No 2005-37. Page 328.
138 Efficiency Vermont Technical Reference User Manual No 2005-37. Page 329.
139 ibid.
140 GDS estimate

1.13.7 Solar Water Heaters - Measure Data

Description – Solar water heaters are designed to serve as pre-heaters for conventional storage or demand water heaters. As the solar system preheats the water, the extra temperature boost required by the storage or demand water heater is relatively low, and high flow rate can be achieved. Although less common than they were two to three decades ago, solar water heating units are considerably less expensive and more reliable.[141] Solar water heaters can be particularly effective if they are designed for three-season use, with a home's heating system providing hot water during the winter months.

Measure savings – Solar water heating units save approximately 3442 kWh per year.[142]

Measure incremental cost – The incremental cost per home to consumers of a solar water heating system is $2,500.[143]

Measure useful life – The useful life of a solar water heater is 20 years.[144]

Estimated baseline saturation in North Carolina – Approximately 10% of all electric water heaters in North Carolina are pre-heated with solar power.[145]

Table A-23 - Summary of Data Sources for Solar Water Heater Technology

Cost of Solar WH	ACEEE
Cost of standard WH	ACEEE
Energy use of Solar WH	ACEEE
Energy use of standard WH	ACEEE
Useful life of Solar WH	ACEEE
Baseline saturation of Solar WH	GDS estimate

1.13.8 High Efficiency Water Heaters - Measure Data

Description – Ranging in size from 20 to 80 gallons (75.7 to 302.8 liters), storage water heaters remain the most popular type for residential heating needs in the United States. A storage heater operates by releasing hot water from the top of the tank when the hot water tap is turned on. To replace that hot water, cold water enters the bottom of the tank, ensuring that the tank is always full.[146]

141 "Consumer Guide to Home Energy Savings" 8th ed. ACEEE. 2003. Page 101.
142 ibid.
143 ibid
144 ibid
145 GDS estimate
146 U.S. Department of Energy website http://www.eren.doe.gov/erec/factsheets/watheath.html

Measure savings -- Based on the DOE test procedure, energy savings associated with the switch from 0.90 EF to a 0.95 EF tank are approximately 363 kWh annually per high efficiency electric water heater installed.[147]

Measure incremental cost – The incremental cost to consumers of high efficiency electric water heaters is $90.[148]

Measure useful life – The useful life of an electric water heater is 13 years.[149]

Estimated baseline saturation in North Carolina – Roughly 66% of all homes in North Carolina have electric water heaters.[150] Approximately 10% of all electric water heaters in North Carolina can currently be classified as energy efficient.[151]

Table A-24 - Summary of Data Sources for High Efficiency Water Heater Technology

Cost of high efficiency WH	ACEEE
Cost of standard WH	ACEEE
Energy use of high efficiency WH	ACEEE
Energy use of standard WH	ACEEE
Useful life of WH	ACEEE
Saturation of high efficiency WH	GDS estimate
Market barrier information	ACEEE, CEE
National and regional programs	NEEP, MEEA, NEEA

1.14 Efficient Furnace Fan Motors

1.14.1 Description of Measure – Efficient Furnace Fan Motors

In general, a forced-air furnace is a relatively simple device, similar to a gas oven that's hooked up to a fan. First, natural gas is piped to a burner inside a combustion chamber where the gas is mixed with air and ignited by a pilot light, a spark or a related device at the request of a thermostat. Next, a blower in the furnace pulls cool air in from rooms through air ducts, passes it through a metal "heat exchanger" where it's heated by the burner, and blows the warm air back into rooms through ductwork. Finally, exhaust gasses from the burners are vented outside through a flue.[152]

147 "Consumer Guide to Home Energy Savings" 8th ed. Table 6-6 ACEEE. 2003
148 ibid.
149 ibid.
150 Residential Energy Consumption Survey 2001, Energy Information Administration. Table HC5-11a.
151 GDS Assumption
152 "High Efficiency Furnaces: A Buying & Care Guide." High Efficiency Furnaces & Forced Air Heating. (www.hometips.com)

Over the past several years, manufacturers have used several new technologies to boost efficiency. One advancement was the move from the standing pilot light -- which burns gas even when the furnace is dormant -- to electronic spark ignition that fires the furnace on demand. Yet another step forward is "hot surface ignition," a method said to be more reliable than the electronic spark. Rather than using a spark plug that can corrode, it ignites the gas mixture with a coil that glows white hot.

Many gas-fired, high-efficiency furnaces also save on the electricity required to power the fan. They can do this by coupling a sophisticated, programmable thermostat to a variable-speed motor. Unlike a conventional system, where the furnace goes on, blows hot air into the house at full force for a few minutes, then shuts off, a variable-speed or "variable capacity" system runs the blower for longer periods at lower speeds. It provides more even, quiet, comfortable heat than a conventional furnace and doesn't consume electricity unnecessarily because it rarely runs at full speed.[153] These high efficiency fans systems are referred to as electronically commutated motors, or "ECMs".

1.14.2 Market Barriers

Furnace fan energy use, which is disclosed in public databases, is not regulated so little attention is generally paid to it. As a result, although attention to efficiency can save consumers money in life cycle costs, few have a firm understanding of the benefits. Additionally, in a retrofit market, dealer training and experience, stocking practices and availability, and related factors have limited the willingness of many dealers to recommend the higher price but more efficient products.

1.14.3 Efficient Furnace Fan Motor - Measure Data

Description – This measure examines the installation of high efficiency brushless permanent magnet fan motor in a qualified natural gas, propane, or fuel-oil fired furnace.

Measure savings – An efficient furnace fan motor can create an annual savings of 510 kWh. Additionally, although efficient furnace fan motors are often installed on high efficiency furnaces, an efficient furnace fan motor installed on a standard furnace will create incremental gas use in heating season to replace electricity no longer dissipated as heat. Increased gas usage can be as much as approximately 2.20 mmbtus.[154]

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[153] "High Efficiency Furnaces: A Buying & Care Guide." High Efficiency Furnaces & Forced Air Heating. (www.hometips.com)

[154] Emerging Energy-Saving Technologies and Practices for the building sector as of 2004. Report# AO42. Oct. 2004. Pg. 59.

Measure incremental cost – The incremental cost of a high efficiency furnace fan motor is approximately $80.[155]

Measure useful life – The useful life of an efficient furnace fan motor is 15 years.[156]

Estimated baseline saturation in North Carolina – The saturation of efficient furnace fans in homes that operate central forced air gas-fired furnaces is estimated to be 10%.[157]

Table A-25 - Summary of Data Sources for Efficient Furnace Fan Motors

Cost of high efficiency furnace fan motor	ACEEE
Cost of standard furnace fan motor	ACEEE
Energy use of high efficiency furnace fan motor	ACEEE
Energy use of standard furnace fan motor	ACEEE
Useful life of high efficiency furnace fan motor	ACEEE
Saturation of high efficiency furnace fan motor	GDS estimate
Market barrier information	ACEEE
National and regional programs	ACEEE

1.15 High Efficiency ENERGY STAR Windows

1.15.1 Description of Measure

Typical residential windows in existing residential construction have aluminum or wood frames, high U-values, and are single or double-glazed. U-value is a measure of energy transmittance, the inverse of R-value, so more efficient windows have lower U-values. However, in many areas of the country, heat gains through windows are a major contributor to building cooling load in the summer, and heat loss in the winter contributes to space heating costs. An additional measure of window performance is its Solar Heat Gain Coefficient (SHGC), which considers heat gains that affect cooling energy. SHGC depends primarily on a window's ability to block infrared wavelengths of light through tints and selective coatings. More efficient windows have lower SHGC values.

To be eligible for the ENERGY STAR®, products must be rated, certified, and labeled for both U-Factor and Solar Heat Gain Coefficient (SHGC) in accordance with the procedures of the National Fenestration Rating Council at levels which meet ENERGY STAR® qualification criteria in one or more Climate Zone.

155 ibid.
156 ibid.
157 GDS estimate

1.15.2 Market Barriers

High costs are the primary market barrier to customers purchasing or adopting efficient windows in new homes or existing homes. In a recent study, both manufacturers and retailers were uniform in their opinion that price is the overriding barrier to ENERGY STAR® windows adoption, and that new home builders will often take tradeoff approaches to meet code so they can save money on materials. A perceived uncertainty amongst consumers about potential savings generated by ENERGY STAR® windows is another remaining market barrier. Research and development aimed at reducing manufacturing costs, as well as increased education efforts may be helpful. Regional approaches, in particular, appear to be productive.

Two recent activities that address market barriers to increased window efficiency include DOE's ENERGY STAR® labeling program (labels are expected to be found in stores in mid-1998) and the formation of the Efficient Windows Collaborative (EWC). The EWC is a coalition of manufacturers, researchers, and government agencies that aims to expand the market for high efficiency fenestration products. To achieve its goals, the EWC:

- Provides consumer education
- Offers training and education to company sales forces and trade ally audiences
- Develops demonstration projects for regional marketing and education opportunities;
- Works to strengthen national and state building codes to incorporate efficient window standards; and
- Communicates information on market trends, technical information, training opportunities and demonstration results to a broad audience.

In addition, the EWC can offer both technical and logistical support to utility planning efforts, emphasizing information on the energy and peak demand performance of windows, as well as liaison with on-going national activities, such as the NFRC rating and labeling procedures, or the ENERGY STAR® Window and ENERGY STAR Builder programs.

Regional groups and utilities can take advantage of these national efforts. PG&E, for example, plans to work collaboratively with NFRC, and the ENERGY STAR® program to promote high efficiency windows (particularly spectrally selective glazing products) for new and existing homes. The EWC project includes a comprehensive awareness campaign, sales training for manufacturers, and technical assistance for builders. As market share for efficient windows increases, incorporating more aggressive efficiency requirements for windows into building codes will become a viable approach to sustaining the market.

1.15.3 High Efficiency Windows - Measure Data

Description – In a typical house, over 40% of the annual energy budget is consumed by heating and cooling. Proper selection of windows, doors and skylights can significantly effect how much money is spent or saved every year on keeping homes bright and comfortable. In North Carolina, ENERGY STAR® qualified windows have a U-value of less than .40. Regarding required SHGC values, North Carolina falls in between the north/central region (SHG of less than or equal to .55) and the south/central region (SHG of less than or equal to .40).[158] Specifically, for this analysis, GDS assumed window construction to increase from a single pane window to a double-pane low-e window.

Measure savings – The annual electric energy savings derived from the installation of ten ENERGY STAR® qualified windows in a single family home in North Carolina with electric heating is approximately 3,880 kWh.[159] The savings due to installation of ten ENERGY STAR® qualified windows in a multi family home with electric heating is approximately 1,940 kWh per year.[160]

Measure incremental cost – The incremental cost of ENERGY STAR® qualified windows in a household is $1,223 for a single family home and $633 for a multi family home.[161]

Measure useful life – The useful life of a high efficiency window is 35 years.[162]

Estimated baseline saturation in North Carolina – ENERGY STAR® qualified windows are currently installed in approximately 10% of electric heated households in North Carolina.[163]

Table A-26 - Summary of Data Sources for High Efficiency Window Technology

Incremental cost information	Energy10 Model
Annual Energy savings information	Energy10 Model
Useful life of high efficiency window	ACEEE
Saturation of HE window	GDS estimate
Market barrier information	ACEEE, CEE
National and regional programs	NEEP, MEEA, NEEA, EPA

158 ENERGY STAR website. (www.energystar.gov/products/windows)

159 Energy10 Model Simulations. Completed in 2005 by GDS for the development of an Integrated Resource Plan for the Big Rivers Electric Cooperative in Kentucky. The measure savings have been adjusted for interactive effects.

160 ibid.

161 ibid.

162 "Selecting Targets for Market Transformation Programs, A National Analysis", ACEEE Report. August 1998, page 60.

163 GDS Assumption

1.16 Weatherization Technologies

1.16.1 Description of Measure – Residential Weatherization Technologies

Weatherization measures address the reduction of thermal transfer through the "shell" between the interior and exterior of a heated/cooled structure. These measures can appear in the form of air-sealing to prevent air infiltration and heat loss through gaps in the building shell, or in the form of insulation to reduce the amount of heat flow between conditioned and unconditioned spaces.

Heat moves from warmer spaces to cooler spaces. In a typical home heat moves directly from heated living spaces to adjacent unheated spaces such as attics, basements and crawl spaces. The degree to which this heat transfer takes place depends upon the R-value of various building shell components such as ceilings, walls and floors. The R-value represents a material's resistance to *thermal* conductance or heat flow and depends upon three factors: the material's type, density, and thickness.

Recommended R-values are suggested from two different points of view: those R-values recommended for maximum comfort and those recommended for maximum energy efficiency. Most R-values established by local building codes are set based on comfort, while those proposed by the U.S. Department of Energy focus on energy efficiency. For this reason, even newer homes can receive added insulated and produce a payback within a few years. Recommended R-values for a particular home are dependent upon the building shell component being considered, the climactic zone and the heat fuel type.

Air infiltration accounts for one of the largest contributions to excess energy usage in existing residential structures. Air infiltration is typically measured by either the number of air changes per hour (ACH) or cubic feet per minute (CFM). These quantities are usually expressed at an assumed pressure (50 pascals).[164]

Factors affecting the air infiltration include the following:

- the temperature differential between the indoor and outdoor air temps,
- wind speed,
- terrain, and
- the degree to which air moves through the building shell.

Of these factors, the latter is the one most commonly addressed with DSM measures.

To ascertain the leakiness of a structure, a blower door test can be performed. While the blower door has the home depressurized a technician will seek out

[164] Suozzo, Margaret and Steven Nadel, "Selecting Targets for Market Transformation programs A National Analysis", ACEEE, 1998

points of air infiltration using a smoke puffer. Once areas of air infiltration are located they are addressed using caulking, sealants and weather stripping. Typical points of air infiltration include areas around windows and doors, and areas where plumbing and electrical infrastructure penetrate the buildings shell between heated and unheated spaces.

1.16.2 Market Barriers – Weatherization

Market barriers for weatherization in residential settings may include the following:[165]

High First Cost – The cost of installing weather stripping is not expensive. However, to insulate large attic spaces and walls can be more costly. Often areas needing additional insulation are not accessible and require additional light construction expense for creating access to certain areas. Also, usually the installation of loose fill insulation requires hiring a professional insulation company with specialized equipment.

Information or research costs - The costs of researching and identifying energy efficient products or services. This includes the value of the time spent locating a product or service or the cost of hiring someone to do this research.

Performance uncertainties – The uncertainty that energy efficiency investment will actually return stated savings.

Transaction Costs -- This refers to the indirect cost and hassle of hiring contractors or purchasing energy efficient equipment.

In addition, a large segment of the residential market is within rental housing where if the tenant pays for the heat and electricity there is little incentive for the property owner to invest in their property without foreseeing a direct return on investment. Similarly, in cases where units are master metered and therefore individual household consumption is not monitored, there is little incentive for tenants to alter their behavior to save energy.

1.16.3 Weatherization/Insulation

Description – Inadequate insulation and air leakage are leading causes of energy waste in most homes. Properly installed weatherization measures can reduce a home's energy expenses by over 30 percent.[166] The following measures are typical components in an insulation and weatherization program: attic insulation, wall insulation, and air sealing.

165 New York Energy $mart[SM] Program Evaluation and Status Report, Interim Report, 9/2000.
166 "Energy Savers: Insulation and Sealing Air Leaks" DOE Energy Efficiency and Renewable Energy. March 2006. (www.eere.energy.gov)

Low-Income Homes were also included in this analysis. Low-Income homes receive 100% incentive for the cost of the measures, and qualify based on income. Eligible households must meet federal poverty level guidelines.

Table A-27 –Sample R-value upgrades for Weatherization/Insulation Program Measures

Base Home	Upgraded Home
Attic insulation R-19	Attic insulation to R-38
Wall insulation R-0	Wall insulation to R-13
Floor insulation R-0	Floor insulation to R-19
Air infiltration to .75 ACH	Reduced air infiltration to .50 ACH

Measure savings – Energy savings for the addition of insulation will depend upon change in R-Value between the insulation that already exists and what is being added. Savings are calculated based upon this change in R-value, the heating-degree-days (HDD) at the project's location and the square footage of the area to be insulated. In a typical house in North Carolina, the weatherization/ insulation program would save an average of 7,500 kWh annually in single-family houses, and 3,750 kWh annually in multi-family houses.[167] Low income housing would also benefit from insulation/weatherization measures. A low income single family house would save an average of 3431kWh per year.[168]

Measure incremental cost – The incremental cost of all measures combined for non low income weatherization measures is approximately $1,558 for single family homes and $779 for multi family homes.[169] Additionally, it is approximately $1,430 for low income home weatherization assistance.[170]

Measure useful life – The useful life of building shell measures are typically 20 years.[171]

Estimated baseline saturation in North Carolina – Approximately 50% of non low-income homes in North Carolina with electric heating have been properly insulated and weatherized.[172] Nearly 50% of low-income homes have also been

[167] Energy10 Model Simulations. Completed in 2005 by GDS for the development of an Integrated Resource Plan for the Big Rivers Electric Cooperative in Kentucky. The measure savings have been adjusted for interactive effects.

[168] "Meeting the Challenge. The Prospect of Achieving 30% Energy Savings Through the Weatherization Assistance Program. ORNL 2002. Table 8.

[169] Energy10 Model Simulations. Completed in 2005 by GDS for the development of an Integrated Resource Plan for the Big Rivers Electric Cooperative in Kentucky. The measure savings have been.

[170] "Meeting the Challenge: The Prospect of Achieving 30% Energy Savings Through the Weatherization Assistance Program. ORNL 2002. Table 8.

[171] GDS calculation based on useful life of insulation/weatherization individual measures.

[172] GDS estimate

properly weatherized and insulated with the help of a weatherization assistance program.[173]

Table A-28 - Summary of Data Sources for Weatherization/Insulation Technology

Incremental cost information	Energy10 Model ; ORNL
Annual Energy savings information	Energy10 Model; ORNL
Useful life of weatherization	GDS
Saturation of weatherized homes	GDS estimate
Market barrier information	ACEEE, CEE
National and regional programs	DOE, EPA

1.17 Residential New Construction

1.17.1 Description of Measure – Residential New Construction

ENERGY STAR® qualified new homes are new residential construction projects that have been independently verified to be at least 30% more energy efficient than homes built to the 1993 national Model Energy Code or 15% more efficient than state energy code, whichever is more rigorous. Only recently, have newer standards and a new Home Energy Rating System (HERS) come into effect. These new guidelines and new HERS rating system must be used to qualify homes for the ENERGY STAR® label that are not enrolled in a state or utility program before December 31, 2005 or permitted before July 1, 2006.

The new system evaluates the energy efficiency of a home compared to a computer-simulated reference house of identical size and shape as the rated home that meets minimum requirements of the 2004 International Energy Conservation Code (IECC). The HERS rating results in a HERS Index score between 0 and 100, with the reference house assigned a score of 100 and a zero energy house assigned a score of 0. Each 1 percent reduction in energy usage (compared to the reference house) results in a one point decrease in the HERS score. Thus, an ENERGY STAR® Qualified Home, required to be approximately 15 percent more energy efficient than 2004 IECC in the south requires a HERS Index of 85; and an ENERGY STAR® Qualified Home, required to be approximately 20 percent more energy efficient than 2004 IECC in the north requires a HERS Index of 80.[174]

Savings are based on heating, cooling, and hot water energy use and typically achieved through a combination of: high performance windows, controlled air infiltration, upgraded heating and conditioning systems, tight duct systems, high efficiency water-heating equipment, and high efficiency building envelope standards. These features contribute to improved home quality and homeowner comfort, and to lower energy demand and reduced air pollution. ENERGY

[173] GDS estimate

[174] "September 2005 Update. EPA Releases Final New Guidelines for ENERGY STAR Qualified Homes." (www energystar gov)

STAR® also encourages the use of energy-efficient lighting and appliances, as well as features designed to improve indoor air quality.

Any single-family or multi-family residential home that is three stories or less in height can qualify to receive the ENERGY STAR® label. This includes traditional site-constructed homes as well as modular, systems-built (e.g., insulated concrete forms, structurally insulated panels), and HUD-code manufactured homes.

1.17.2 Market Barriers

An evaluation of the Efficiency Vermont Residential New Construction Program by KEMA, Inc. found that most builders and customers were confused regarding program benefits and procedures. This confusion may have been due to frequent changes in the program name and features between 1999 and 2003. Targeted mail and phone call campaigns to builders statewide, as well as outreach to municipal officials and builders of manufactured homes are some of the efforts that are underway to educate and increase interest in the ENERGY STAR® new homes program. Increasing builder awareness of non-energy benefits of energy efficient equipment (including increased comfort and lower equipment maintenance costs) is also important to the success of program.

1.17.3 North Carolina ENERGY STAR® Homes- Measure Data

Description – To earn the ENERGY STAR label, homes are tested by a third-party inspector to ensure they meet the DOE's criteria. Generally speaking, a home must be at least 30 percent more efficient than the national Model Energy Code for homes or 15 percent more efficient than the state energy code, whichever is more rigorous. Typical characteristics of an ENERGY STAR home include: effective insulation, high-performance windows, tight construction and tight ducts, energy-efficient HVAC equipment and independent testing provided by third-party inspectors.

Measure savings – An electric-heated ENERGY STAR® qualified home in North Carolina is estimated to save an average of 2678 kWh per year.[175] Non-electric heated ENERGY STAR® qualified home saves an average of 1910 kWh per year and 56 mmbtu of gas and water savings.[176]

Measure incremental cost – The incremental cost of building a new home to meet the ENERGY STAR® Homes criteria is approximately $3,000.[177]

Measure useful life – The useful life of an ENERGY STAR® qualified home is 35 years.[178]

175 2004 Georgia Power IRP
176 ibid.
177 ibid.