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

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Report for the North Carolina Utilities Commission

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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

[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.

[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 UO51.

[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.

[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%

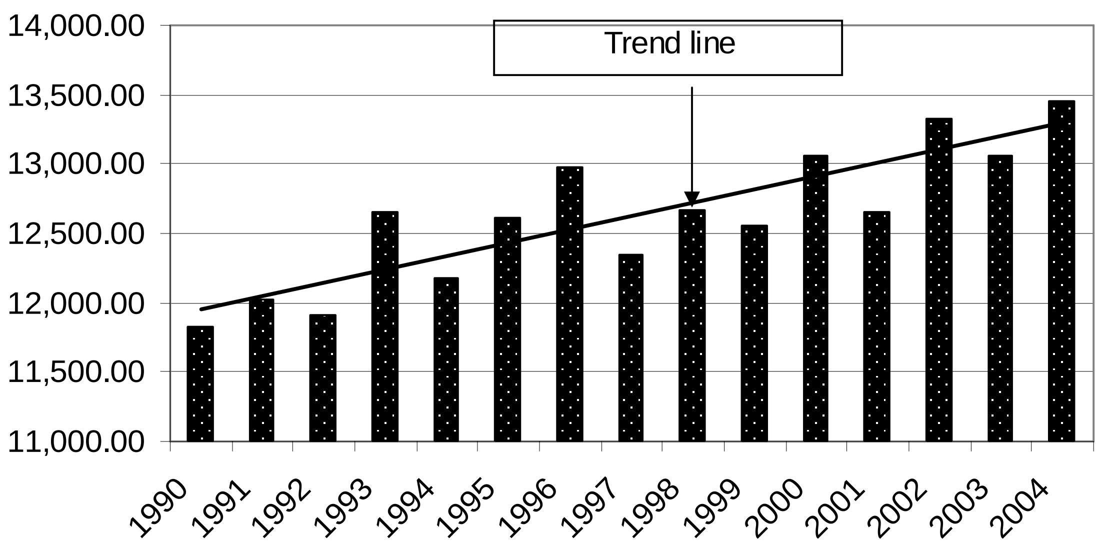
13 This historical kWh sales data for North Carolina is taken directly from the Energy Information Administration, Electric Power Annual 2004 – State Data Tables. (www.eia.doe.gov/cneaf/electricity/epa/epa_sprdshts.html)

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

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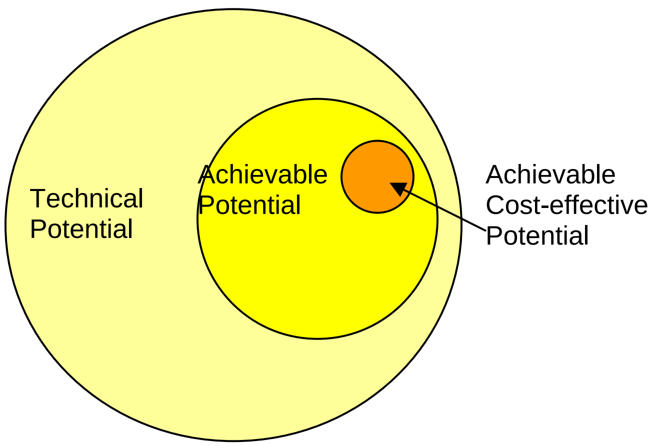
15 A Venn diagram is a graph that employs circles to represent logical relations between sets and subsets.

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.

[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.

[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				

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

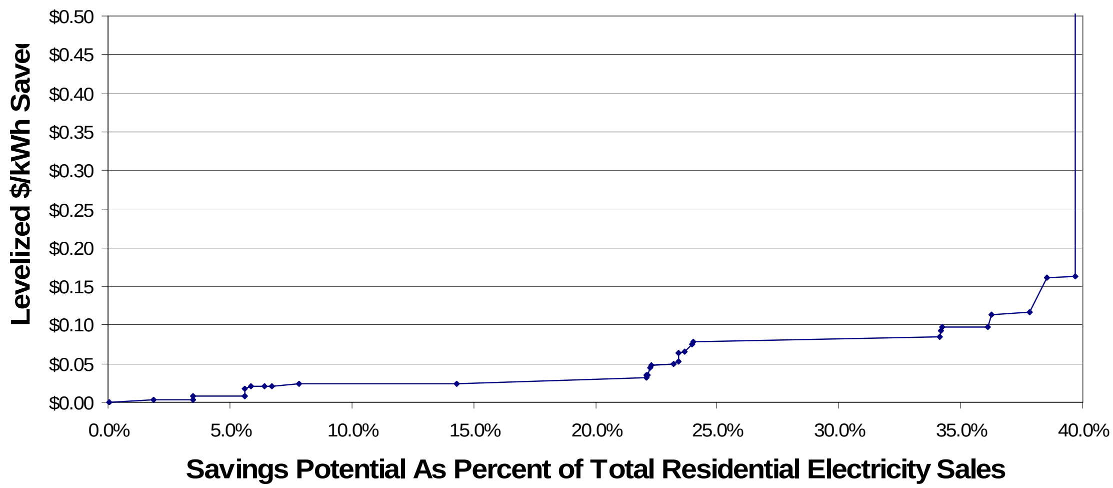
Table 5-4: Total Annual Achievable Cost-Effective Potential kWh Savings for Electric Energy Efficiency In North Carolina By 2017

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

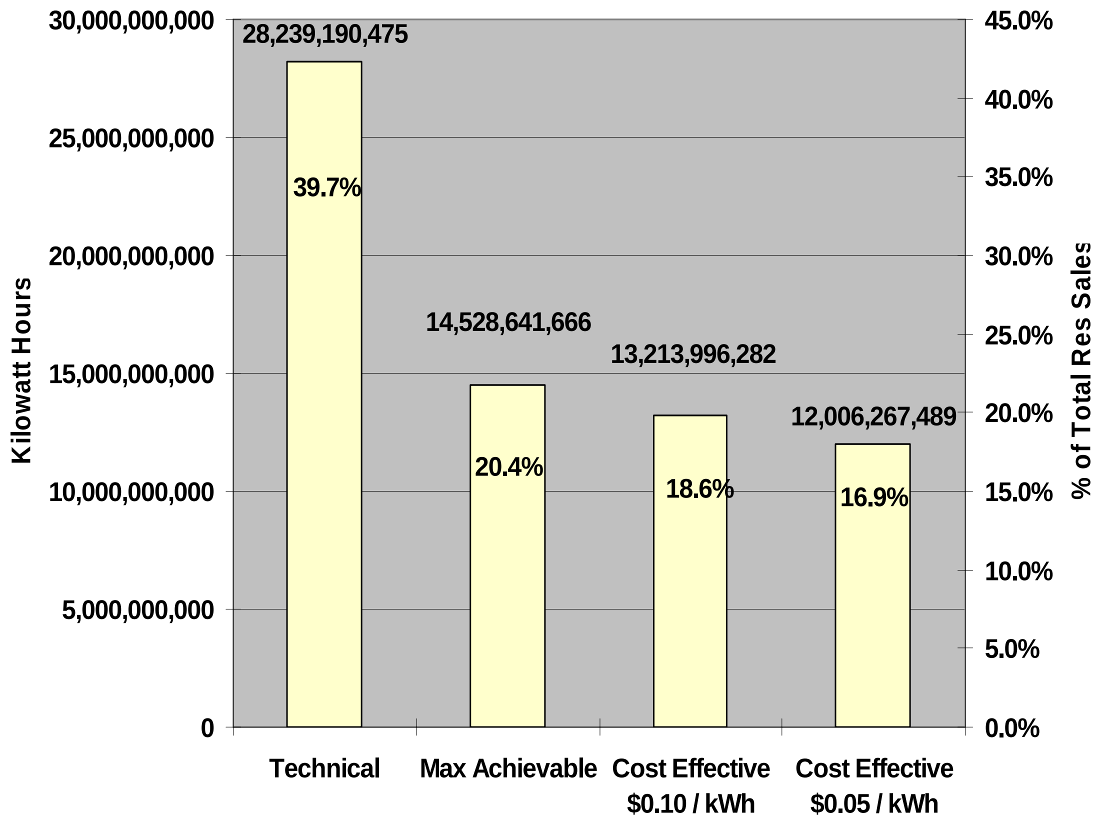


Figure 5-3 Residential Sector Technical Potential Savings By Measure Type - Kilowatt Hours

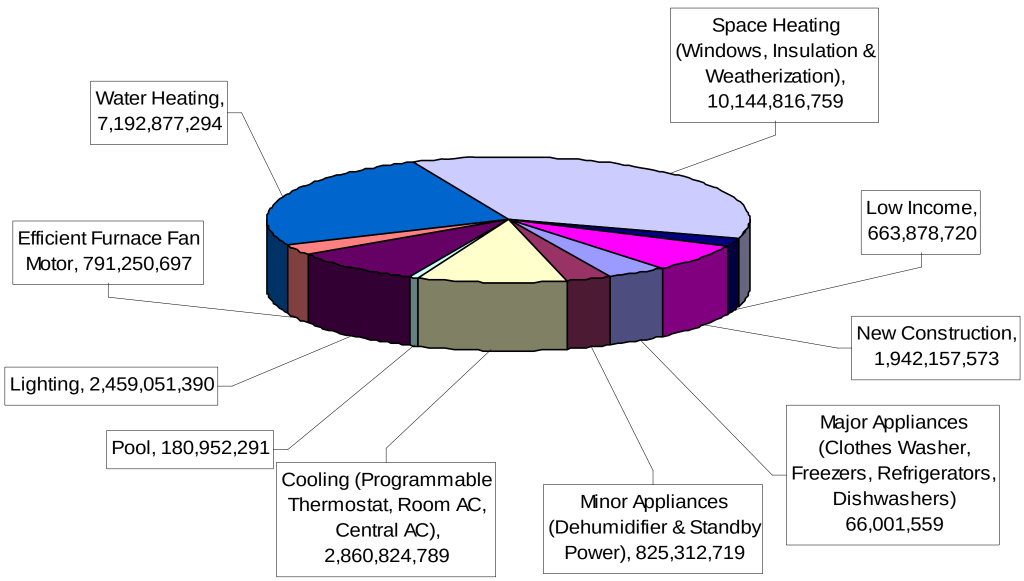


Figure 5-4 Residential Sector Technical Potential Savings By Measure Type - Percent of Total Savings

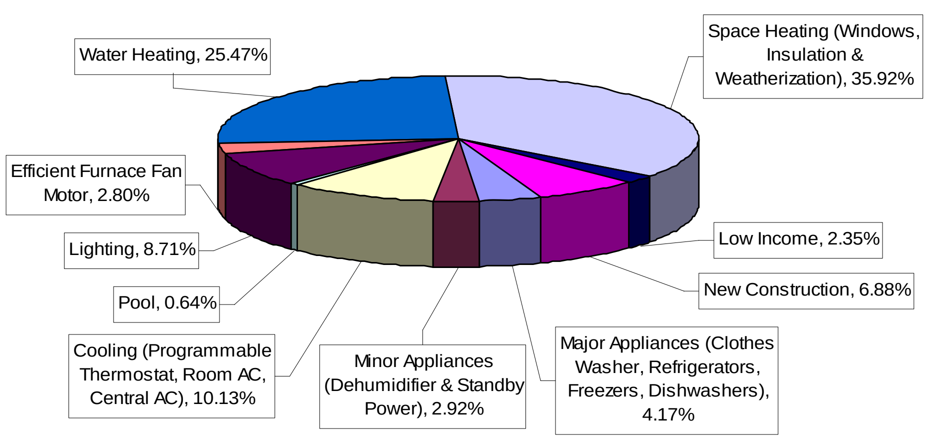


Figure 5-5 Residential Sector Achievable Savings By Measure Type - Kilowatt Hours

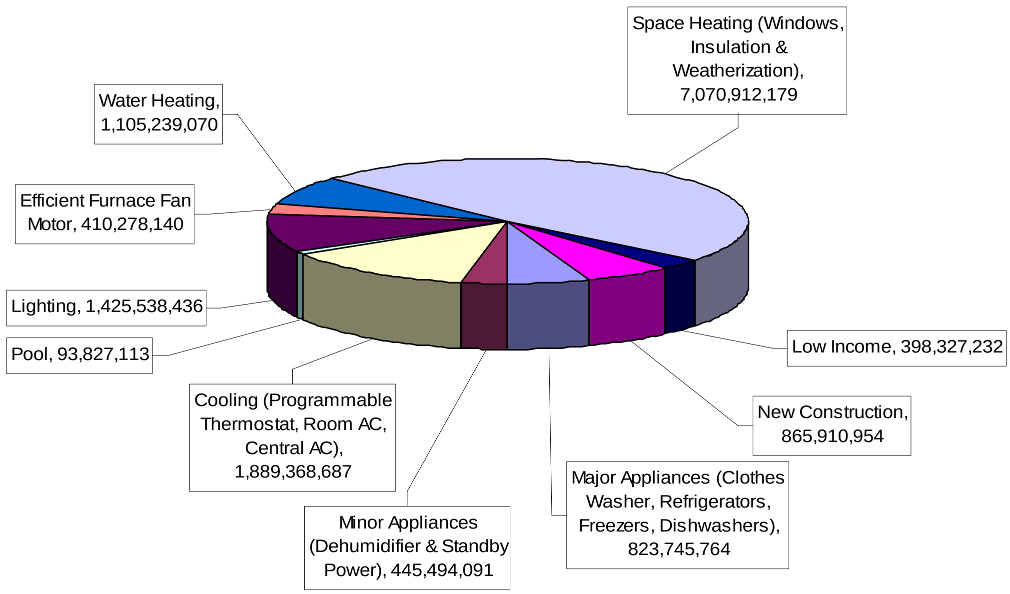


Figure 5-6 Residential Sector Achievable Savings by Measure Type - Percent of Total Savings

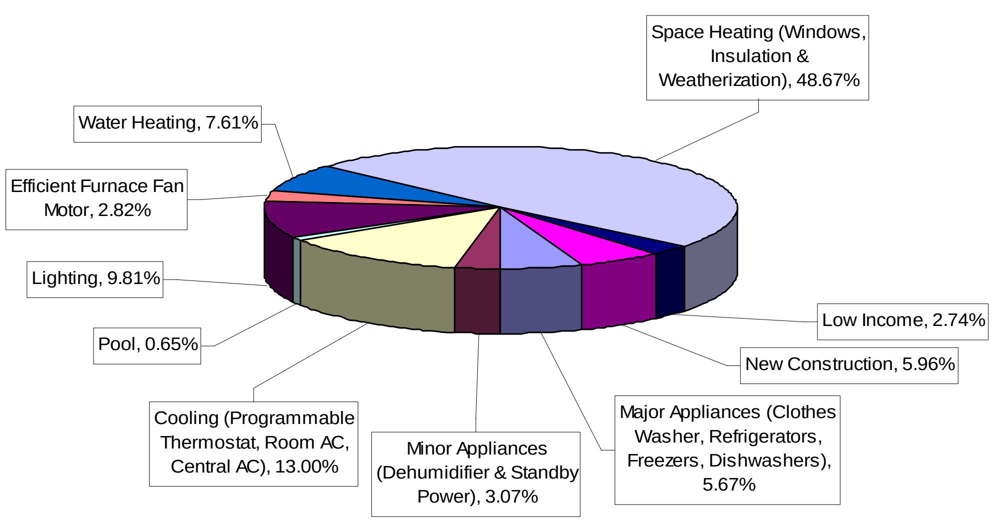


FIgure 5-7 Residential Sector Achievable Cost Effective Savings (based on screened at $0.05 per kWh saved) by Measure Type - Kilowatt Hours

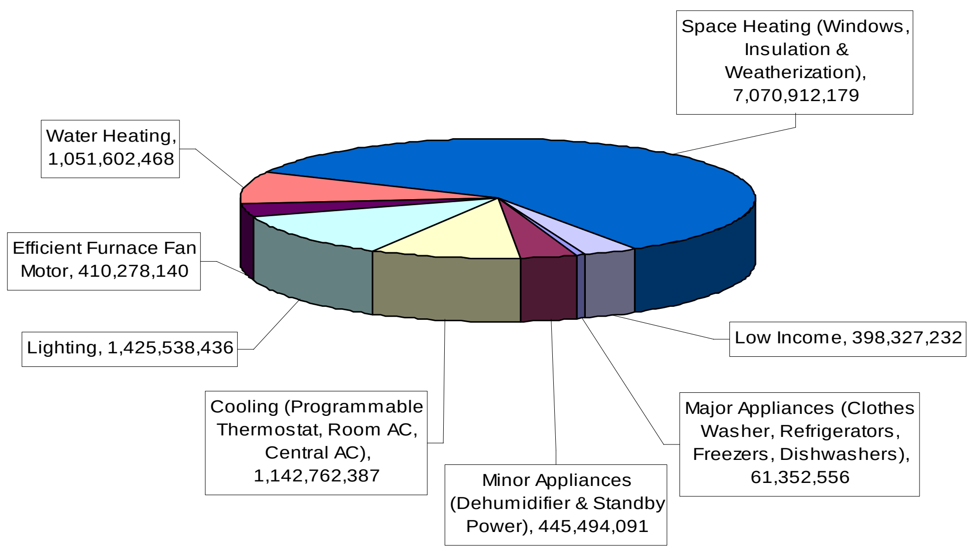


Figure 5-8 Residential Sector Achievable Cost Effective Savings (based on screening at $0.05 per kWh saved) by Measure Type - Percent of Total Savings

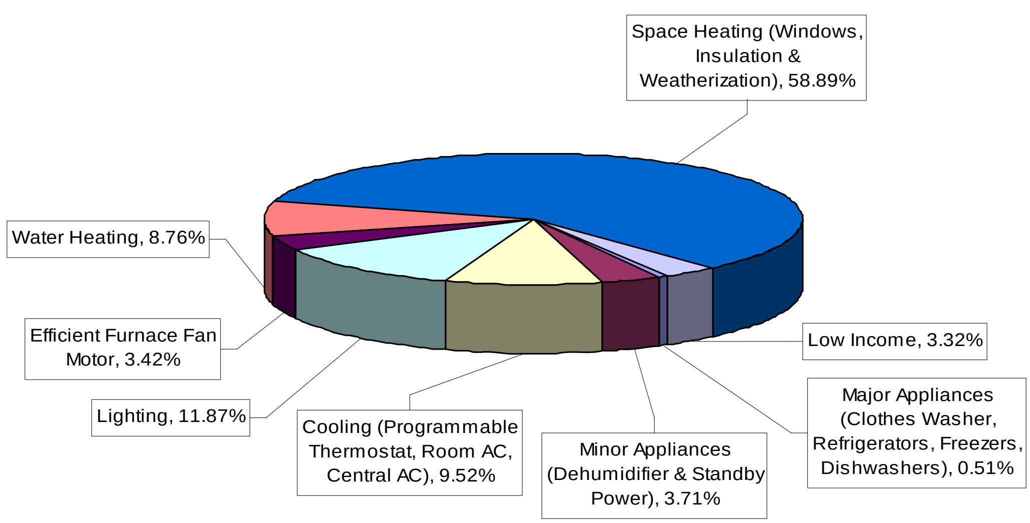
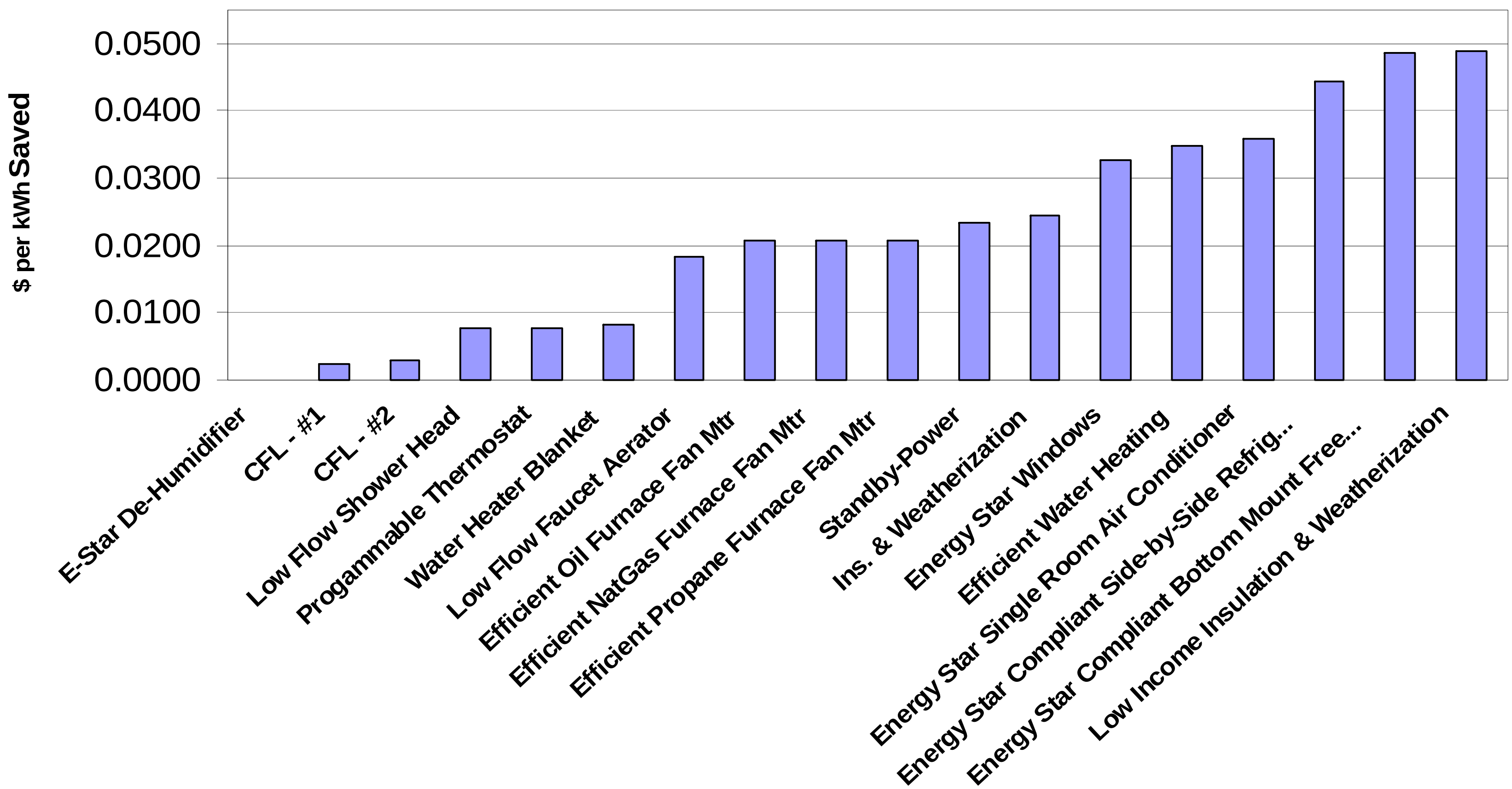


Figure 5-9: Cost Effective Residential Electric Energy Efficiency Measures (Measures under $.05 Per Lifetime kWh Saved)



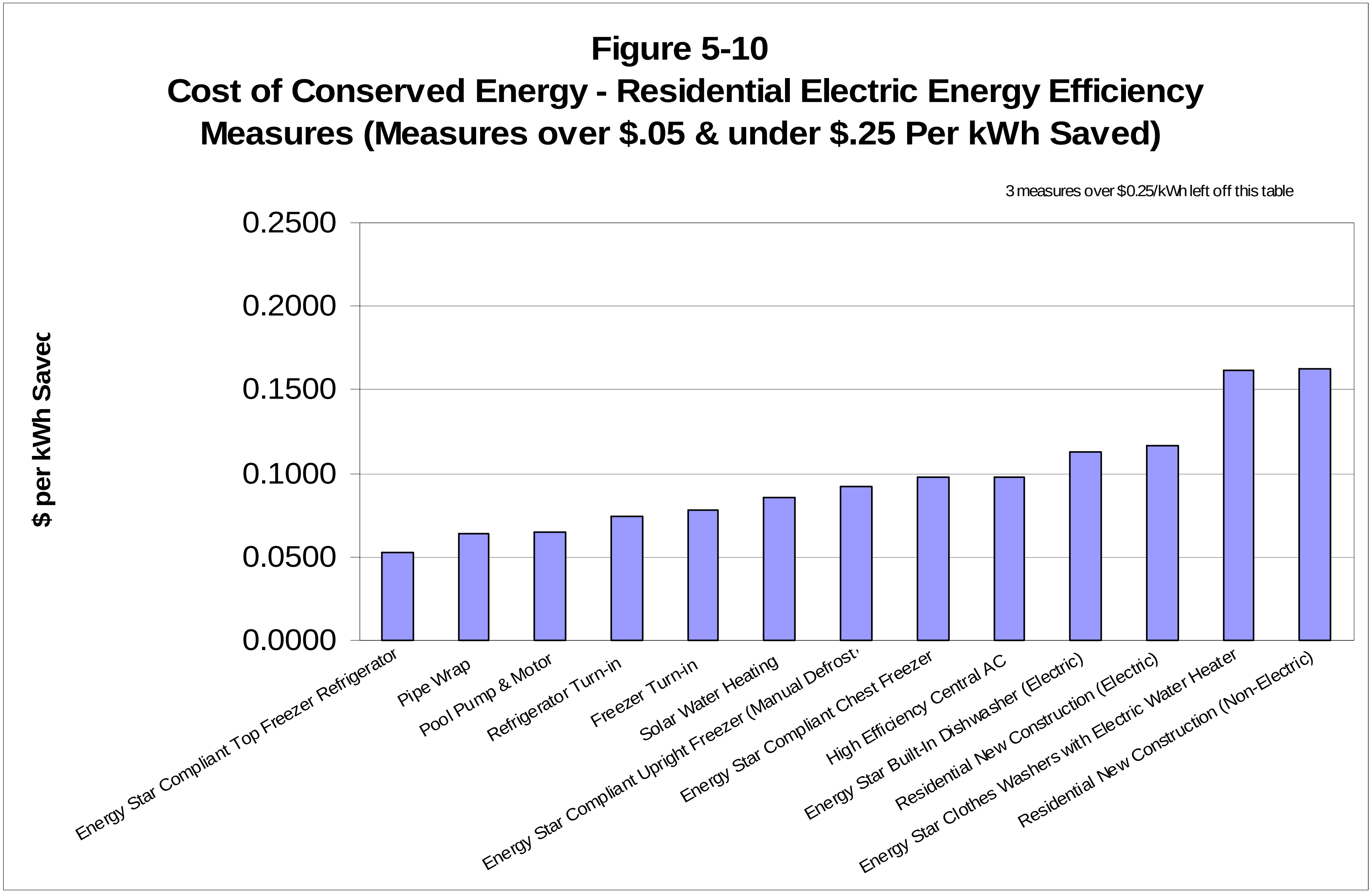


Figure 5-10
Cost of Conserved Energy - Residential Electric Energy Efficiency Measures (Measures over $.05 & under $.25 Per kWh Saved)
3 measures over $0.25/kWh left off this table
$ per kWh Savec
0.2500
0.2000
0.1500
0.1000
0.0500
0.0000
Energy Star Compliant Top Freezer Refrigerator
Pipe Wrap
Pool Pump & Motor
Refrigerator Turn-in
Freezer Turn-in
Solar Water Heating
Energy Star Compliant Upright Freezer (Manual Defrost)
Energy Star Compliant Chest Freezer
High Efficiency Central AC
Energy Star Built-In Dishwasher (Electric)
Residential New Construction (Electric)
Energy Star Clothes Washers with Electric Water Heater
Residential New Construction (Non-Electric)

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]

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

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

[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]

[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

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.

[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

[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]

[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

[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,

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.

[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]

[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]

[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.

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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

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[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.

Estimated baseline saturation in North Carolina – 1.3% of newly constructed homes in North Carolina already participate in the ENERGY STAR® Homes program.[179]

Table A-29 - Summary of Data Sources for ENERGY STAR® Homes program

Cost of ENERGY STAR® qualified home	GPC IRP
Cost of standard new home	GPC IRP
Energy use of ENERGY STAR® qualified home	GPC IRP
Energy use of standard new home	GPC IRP
Useful life of ENERGY STAR® qualified home	GPC IRP
Saturation of ENERGY STAR® qualified home	ENERGY STAR Homes Prog.
Market barrier information	KEMA
National and regional programs	EPA

1.18 Emerging Technologies

1.18.1 Emerging Technologies – LED Lighting

Highly efficient light-emitting diodes (LED's) are a relatively old technology (1970's) and currently dominate the exit sign market as well as being adopted in many cities for replacement of incandescent lamps in traffic signals. In the residential market the white light LED has opened the eyes of many lighting experts; however, they currently do not produce enough lumen output to enable them to be on a competitive level with many general light sources.

By 2020, solid-state lighting devices such as LED's could cut electricity used for illumination by 50 percent, according to a US Department of Energy study and with continued studies and analyses on this technology, commercial availability should increase to a substantial level within the near future.[180]

1.18.2 Emerging Technologies – Residential Cogeneration Systems

Cogeneration systems in the residential sector have the ability to produce both useful thermal energy and electricity from a single source of fuel such as oil or natural gas. This means that the efficiency of energy conversion to useful heat and power is potentially significant greater than by using the traditional alternatives of boilers or furnaces and conventional fossil fuel fired central electricity generation systems.[181] In one testing case, a collaborative effort between American Honda Motor Company and Massachusetts-based Climate

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178 ibid.

179 Email from Brian Ng, ENERGY STAR Homes, Sept. 2006.

180 "LED There Be Light" David Pescovitz. Berkeley Engineering Lab Notes. Vol. 2(8): 2002.

181 Residential Cogeneration Systems: A Review of Current Technologies. International Energy Agency. April 2005.

Energy, LLC has resulting in the residential installation of a micro-sized combined heat and power system combined with a furnace or boiler. This complete system results in more than 85% efficiency in converting fuel energy into useful heat and electric power. The unit quietly generates up to three kilowatts of thermal output per hour and one kilowatt of electricity.[182] However, as residential scale cogeneration technologies are still in their infancy, the actual potential for residential cogeneration energy and emissions savings is yet to be firmly established.

1.18.3 Emerging Technologies – Drainwater Heat Recovery Systems

The Gravity Film Heat Exchanger (GFX) is an energy efficiency system designed to capture the heat in the warm drainwater that falls down a vertical section of copper drainpipe. Heat transfer, which occurs because the water tends to cling to the inside of the vertical pipe like a film, can be transferred to cold water circulating around the outside of the drainpipe. If the drainwater is produced at the same time as the incoming water (such as the constant flow that occurs from a shower), the GFX can capture more than half the drainwater energy.[183] This saves energy otherwise used to generate hot water and effectively extends the recovery performance of the water heater itself, saving money and increasing shower capacity in the process.

Drainwater Heat Recovery Systems will be most effective in multi-family applications to quantify the energy savings and enhanced performance. Although the technology is suited for single family homes too, the greater throughput of drainwater from multifamily dwellings is expected to save more energy and improve the economics of introducing this technology into this sector.[184]

Preliminary findings from a field test utilizing the efficiency measure in one triplex housing unit determined the drain recovery system would save between 25%-30% of the total energy needed for hot water production based on the measured efficiency of the resistance water heater in the triplex. Over the year of this experiment, the system saved the equivalent of 2800 kWh of electricity.[185]

1.18.4 Emerging Technologies – Cool Roofs

Cool Roofs are roofs consisting of materials that effectively reflect the sun's energy from the roof surface. Cool materials for low-slope roofs are mainly bright white in color, although non-white colors are becoming available for sloped roof applications. Cool Roofs must also have high emissivity, allowing them to emit

[182] "Honda and Climate Energy Provide Innovative and Energy Efficient Heating Solution. " Published March 2006. Accessed April 2006. (www.hondanews.com)

[183] "Emerging Technologies. Building Technologies Program." DOE Energy Efficiency and Renewable Energy. April 2006. (www.eere.energy.gov)

[184] ibid.

[185] "Preliminary Findings of the GFX Drainwater Recovery System. (Memo)" Prepared by ORNL. Submitted to DOE. Aug. 2000. (www.eere.doe.org)

infrared energy. Unfortunately bare metals and metallic coatings tend to have low emissivity and are not considered cool materials.

Cool roofs reduce the roof surface temperature by up to 100 degrees Fahrenheit, thereby reducing the heat transferred into the building below.[186] This helps to reduce energy costs (by keeping attics and ducts cooler), improve occupant comfort, cut maintenance costs, increase the life cycle of the roof, and reduce urban heat islands along with associated smog.

Products for sloped roofs, usually found on residences, are currently available in clay, or concrete tiles. These products stay cooler by the use of special pigments that reflect the sun's infrared heat. Lower priced shingles or coated metal roofing products are not yet available in “cool” versions.

186 “Cool Roofs.” Consumer Energy Center. Accessed April 2006. (www.consumerenergycenter.org)

Attachment B

Descriptions of Commercial Sector Energy Efficiency Measures for North Carolina

1.0 Introduction to Commercial Measures

This technical appendix describes a broad range of commercial sector energy efficiency measures and programs where GDS has assessed the achievable potential for electric energy savings in North Carolina. The purpose of this technical appendix is to describe these commercial sector energy efficiency measures and to provide data on their costs, energy savings and useful lives. Table 1 shows a list of every measure and its levelized cost per kWh saved.

Table 1: 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

Table 1-2 presents a comparison of the commercial results of 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 24 percent in Massachusetts by 2007. We estimate the achievable cost-effective potential for North Carolina to be 12.1% which is an average of all eight studies shown in the table below.

Table 1-2: 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 Efficiency In 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. August 2006
*Wisconsin reported combined results for commercial and industrial sectors as C&I.

1.1 Space Heating

Two commercial space heating energy efficiency measures are covered in this section: high efficiency heat pumps and ground source heat pumps. Listed below are the basic assumptions used in this study for these technologies (annual kWh savings, demand savings, useful life, and incremental cost). Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
High Efficiency Heat Pump	1,254	0.1	15	$48
Ground Source Heat Pump - Heating	12,685	11.7	15	$33,000

1.1.1 High Efficiency Heat Pump[187]

Electric air-source heat pumps, often used in moderate climates, use the difference between outdoor air temperatures and indoor air temperatures to cool and heat buildings. ENERGY STAR qualified heat pumps have a higher seasonal efficiency rating (SEER) and heating seasonal performance factor (HSPF) than standard models, which makes them about 20% percent more efficient than standard new models and 20-50% more efficient then existing equipment in buildings.

1.1.2 Ground Source Heat Pump[188]

Unitary ground-source heat pump systems for commercial buildings can be installed in a variety of configurations. The oldest and, until recently, most widely used approach was the groundwater system. In this design, groundwater from a well or wells is delivered to a heat exchanger installed in the heat pump loop. After passing through the heat exchanger (where it absorbs heat from or delivers heat to the loop), the groundwater is disposed of on the surface or in an injection well. The use of an injection well is desirable in order to conserve the groundwater resource.

A second and increasingly popular design is the ground-coupled heat pump system. In this approach a closed loop of buried piping is connected to the building loop. For larger commercial applications, the buried piping is installed in a grid of vertical boreholes 100 to 300 ft deep. Heat pump loop water is circulated through the buried piping network absorbing heat from or delivering heat to the soil. The quantity of buried piping varies with climate, soil properties and building characteristics, but is generally in the range of 150 to 250 ft (of borehole) per ton of system capacity. Borehole length requirements are almost always dictated by heat rejection (cooling mode) duty for commercial buildings.

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[187] ENERGY STAR website, www.energystart.gov

[188] A CAPITAL COST COMPARISON OF COMMERCIAL GROUND-SOURCE HEAT PUMP SYSTEMS. Geo-Heat Center, Oregon Institute of Technology

A third design for ground-source systems in commercial buildings is the "hybrid" system. This approach may also be considered a variation of the ground-coupled design. Due to the high cost associated with installing a ground loop to meet the peak cooling load, the hybrid system includes a cooling tower. The use of the tower allows the designer to size the ground loop for the heating load and use it in combination with the tower to meet the peak cooling load. The tower preserves some of the energy efficiency of the system, but reduces the capital cost associated with the ground loop installation.

In addition to the three designs discussed above, ground source systems can also be installed using lake water, standing column wells and horizontal ground coupled approaches.

1.2 Water Heating

Water heating energy efficiency measures are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Heat Pump Water Heater	14,155	6.1	14	$4,067.01
Booster Water Heater	625	0.3	10	$951.37
Point of Use Water Heater	345	0.1	10	$106.88
Solar Water Heating System	62,500	26.9	15	$11,500.00
Solar Pool Heating	68,445	29.5	10	$33,750.00

1.2.1 Heat Pump Water Heater[189]

Heat pump water heaters are more efficient than electric resistance models because the electricity is used for moving heat from one place to another rather than for generating the heat directly. The heat source is the outside air or air in the basement where the unit is located. Refrigerant fluid and compressors are used to transfer heat into an insulated storage tank. Heat pump water heaters are available with built-in water tanks called integral units, or as add-ons to existing hot water tanks. A heat pump water heater uses one-third to one-half as much electricity as a conventional electric resistance water heater. In warm climates they may do even better, but there are few sources for these products.

[189] Consumer Guide to Home Energy Savings: Condensed Online Version, ACEEE, September 2006

1.2.2 Booster Water Heater[190]
A booster water heater is an instantaneous water heater designed and intended to raise the temperature of hot water to a higher temperature for a specific purpose, such as for the sanitizing rinse on a high temperature automatic dishwasher.

1.2.3 Point of Use Water Heater[191]
A tankless water heater, also known as point of use water heater or on demand units, turns on when you open a hot water faucet and turns off when you close the faucet, so the energy that is consumed is only for the hot water that is being used at that instant in time. Since there is no storage of hot water and thus no constant heating and re-heating of stored hot water, there is no energy being wasted to unnecessarily heat water. This energy savings translates to dollar savings and reduced impact on our environment. Furthermore, since a tankless water heater heats the water when in use, an endless supply of hot water is available, provided the unit is sized appropriately. Tankless water heaters are also designed to last for 20 years and are smaller than tank units.

1.2.4 Solar Water Heater
Solar water heaters use energy from the sun to heat water. Solar water heaters are designed to serve as pre-heaters for conventional storage or demand water heaters. While the initial cost of a solar water heater is high, it can save a lot of money over the long term. Solar water heaters are much less common than they were during the 1970s and early 1980s when they were supported by tax credits, but the units available today tend to be considerably less expensive and more reliable. At today’s prices, solar water heaters compete very well with electric and propane water heaters on a life-cycle cost basis, though they are still usually more expensive than natural gas. [192] Tax credits are available for qualified solar water heating and photovoltaic systems. The credits are available for systems “placed in service” in 2006 and 2007. The tax credit is for 30 percent of the cost of the system, up to $2,000.

1.2.5 Solar Pool Heating[193]
Solar heating systems are designed to heat swimming pools using free heat from the sun. Solar collectors can be mounted on roofs or any area near the pool that provides the proper exposure, orientation and tilt toward the sun. The system should be in operation during the daytime when solar radiation can be absorbed. A system equipped with an automatic controller turns on and off effortlessly

[190] GUIDELINES FOR SIZING WATER HEATERS, California Conference of Directors of Environmental Health, September, 1995

[191] Tankless Water Heaters: On Demand Oil, Electric, Propane or Gas Hot Water Heaters, http://www.tanklesswaterheatersdirect.com/

[192] Consumer Guide to Home Energy Savings: Condensed Online Version, ACEEE, September 2006

[193] Solar Pool Heating, Engineered for Life, Heliocol FAQ Section, http://www.heliocol.com/

whenever there is sufficient solar energy. Solar pool heating is the most economical way to heat your pool. There are zero operating costs and virtually no maintenance.

1.3 Envelope

High efficiency windows are covered in this section. Listed below are the basic assumptions used in this study for this measure. These assumptions include annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Double Pane Low Emissivity Windows	7	0.0	30	$0.51

1.3.1 Double Pane Low Emissivity Windows[194]

Double- or triple-pane windows have insulating air- or gas-filled spaces between each pane. Each layer of glass and the air spaces resist heat flow. The width of the air spaces between the panes is important, because air spaces that are too wide (more than 5/8 inch or 1.6 centimeters) or too narrow (less than 1/2 inch or 1.3 centimeters) have lower R-values (i.e., they allow too much heat transfer). Advanced, multi-pane windows are now manufactured with inert gases (argon or krypton) in the spaces between the panes because these gases transfer less heat than does air. Low-emissivity (low-e) glass has a special surface coating to reduce heat transfer back through the window. These coatings reflect from 40% to 70% of the heat that is normally transmitted through clear glass, while allowing the full amount of light to pass through.

1.4 Space Cooling

Space cooling energy efficiency measures are covered in this section. Listed below are the basic assumptions used in this study for measure annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Centrifugal Chiller, 0.51 kW/ton, 300 tons	34,803	23.5	25	$16,200
Centrifugal Chiller, 0.51 kW/ton, 500 tons	58,005	39.1	25	$27,000
Centrifugal Chiller, Optimal Design, 0.4 kW/ton, 500 tons (may be new construction only)	128,900	86.9	25	$60,000

[194] Energy Guide Website. www.energyguide.com

1.4.1 Centrifugal Chillers[195]

A centrifugal chiller utilizes the vapor compression cycle to chill water and reject the heat collected from the chilled water plus the heat from the compressor to a second water loop cooled by a cooling tower.

1.4.2 DX Packaged System[196]

Unitary or "packaged" equipment (i.e., air- or water-cooled direct expansion [DX] systems) are the most widely used air conditioning and heat pump equipment in the United States. These systems are often roof-mounted. Packaged air conditioners provide cooling by a means similar to that employed in the common household refrigerator-the refrigerant vapor-compression cycle. The vapor-compression cycle converts a liquid refrigerant to a gas, and back again, and in the process provides cooling and produces waste heat. (Packaged heat pump units reverse the process in the heating mode to provide space heating).

This equipment includes all the components required to deliver heating and/or cooling to a space or building in a single package. It includes a fan for moving air, an indoor cooling coil (the evaporator), a heating coil or furnace, air filters, dampers for regulating air flow, refrigeration compressor(s), an outdoor or condensing coil for rejecting heat, and controls for automatically regulating space temperature. Smaller packaged units closely resemble residential air conditioners in using a single, fixed-output compressor. Multiple compressors become common in sizes of about 10 tons of cooling capacity (120,000 Btuh) and above. Multiple compressors give stepped output, particularly when the compressors are of different capacities. As a hypothetical example, a unit with both a 4-ton and 6-ton compressor would have output capacities of 4, 6, or 10 tons, which is very valuable under part-load conditions. At part loads, these units will be very efficient, since the heat exchangers are effectively oversized, but humidity control may suffer with some designs. Roof-top units may include a non-condensing (lower efficiency) gas furnace section. The combinations are called "year-round" units. Larger roof-top units may have very sophisticated controls, and some are designed for multi-zone variable air volume applications much like those typical of chiller-based systems.

[195] Centrifugal Chiller Fundamentals. Application Guide. http://www.mcquay.com/mcquaybiz/literature/lit_corporate/AppGuide/AG_31_002.pdf

[196] Online Guide to Commercial Energy Efficiency Equipment. www.aceee.org/ogeece/ch1_index.htm

1.5 Space Cooling – Packaged AC

Packaged air conditioning systems are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
DX Packaged system EER = 10.9, 10 tons	2,996	1.9	15	$607
DX Packaged System, CEE Tier 2, <20 Tons	4,494	3.0	15	$612
DX Packaged System, CEE Tier 2, >20 Tons	8,988	6.1	15	$1,813
Packaged AC - 3 tons, Tier 2	929	0.6	15	$345
Packaged AC - 7.5 tons, Tier 2	2,110	1.3	15	$683
Packaged AC - 15 tons, Tier 2	4,824	2.9	15	$1,485
Ground Source Heat Pump - Cooling	16,755	4.1	15	$33,000

1.5.1 Packaged Air Conditioners

Commercial unitary air conditioners and heat pumps refer to package air-cooled air conditioning and air-source heat pump units with rated cooling capacities of <65,000 Btu/h up to 240,000 Btu/h. This category does not include water-cooled equipment, evaporative coolers, or water-source heat pumps. Unitary package air conditioning units represent the heating, ventilating, and air conditioning (HVAC) equipment class with the greatest energy use in the commercial building sector in the United States. Equipment covered under the current rulemaking accounts for the majority of the total shipped tonnage of unitary HVAC equipment for commercial building applications. Commercial unitary air conditioners and heat pumps are used in 17.2 billion square feet of U.S. commercial floor space, which is close to half of the cooled floor space in that sector. This equipment uses more energy than any other class of commercial space-conditioning equipment in the United States.[197]

North Carolina uses a state-developed code based on the 2003 IECC and references the ASHRAE 90.1-2004. Standard 90.1-2004 lists minimum efficiencies for air conditioners as shown in the following table.

[197] Energy Efficiency Standards. Commercial A/C & Heat Pumps, Lawrence Berkley Labs.

Standard ASHRAE 90.1-2004		
Equipment Type	Size Category	Minimum Efficiency
Air Conditioners, Water and Evaporatively Cooled	<65,000 Btu/h	12.1 EER
	>=65,000 Btu/h and <135,000 Btu/h	11.5 EER
	>=135,000 Btu/h and <240,000 Btu/h	11.3 EER

1.6 Space Cooling – Maintenance

The following measures are covered in this section, below are the basic assumptions used in this study which include annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Chiller Tune Up/Diagnostics - 300 ton	24,491	16.5	10	$5,100
Chiller Tune Up/Diagnostics - 500 ton	41,248	27.8	10	$8,500
DX Tune Up/ Advanced Diagnostics	1,934	1.3	2	$340

1.6.1 Chiller Tune-Up/Diagnostics[198]

Chilled Water And Condenser Water Temperature Reset - A chiller's operating efficiency can be increased by raising the chilled water temperature and/or by decreasing the temperature of the condenser water. Chilled water reset is the practice of modifying the chilled water temperature and/or condenser water temperature in order to reduce chiller energy consumption. If one decides to undertake chilled water reset, one must be careful that all of the considerations are taken into account. Although raising the chilled water will reduce chiller energy consumption, it may increase supply fan energy consumption. Reducing the condenser water temperature may increase the cooling tower fan energy consumption as well.

Chiller Tube Cleaning And Water Treatment - Optimum heat transfer relies on clean surfaces on both the refrigerant and water side of the chiller tubes. Typically, the water side of the condenser needs the most attention because evaporative cooling towers have an open loop and new water is introduced continuously. Thus, water treatment is needed to keep surfaces clean and reduce biological films and mineral scale. Similar treatments may be needed for the chilled water loop. As part of the tune-up, clean the condenser and evaporator tubes to remove any scale or buildup of biological film. To do this, the

[198] ENERGY STAR Buildings Manual – Aspen Systems Document EPA–430–B–98–004B.

surfaces usually have to be physically scrubbed and sometimes treated with chemicals.

Reciprocating Compressor Unloading - Reciprocating compressors are typically used for smaller chillers. Many of these compressors utilize multiple stages (that is, more than one piston for the compressor) of cooling to allow for more efficient part-load performance and reduced cycling of the compressor motor. At part-load performance, one or more of the stages are unloaded. If the controls of the system fail to unload the cooling stage, then the system may cycle unnecessarily during low cooling loads. Because starting and stopping is inherently inefficient, cycling decreases the efficiency of the cooling system. Additionally, increased cycling can lead to compressor and/or electrical failures (E SOURCE, *Space Cooling Atlas*, p. 9.11.4). Consult manufacturer's maintenance information to check for proper cooling stage unloading. Unloading may be controlled by a pressure sensor that is set for a specific evaporator pressure. This sensor, and the controls dependent upon it, can fall out of calibration or fail.

1.7 HVAC Controls

HVAC controls are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Retrocommissioning	1.2	0.0	7	$0.09
Programmable Thermostats	1,934	1.3	5	$28
EMS install	0.50	0.0	10	0.29
EMS Optimization	0.05	0.0	5	0.06

1.7.1 Retrocommissioning[199]

On start-up, many new commercial buildings do not perform as designed. Additionally, commercial building performance tends to degrade over time, unless there are active programs and knowledgeable personnel to operate and maintain equipment and controls. When buildings operate poorly, operators face rising equipment repair costs, rising utility bills, deteriorating indoor air quality, and tenant dissatisfaction. Retrocommissioning (RCx) involves a systematic step-by-step process of identifying and correcting problems and ensuring system functionality (Haasl and Sharp 1999). RCx focuses on steps for optimizing the building through O&M tune-up activities and diagnostic testing, though capital improvements may also be recommended. The best candidates for retrocommissioning are those buildings over 100,000 ft^2, with newer HVAC systems, and a functioning building control system. By conducting RCx, building

[199] ACEEE Report: Emerging Energy-Saving Technologies and Practices for the Buildings Sector as of 2004. October 2004, Report Number A042.

managers can diagnose problems in mechanical systems, controls, and lighting, and improve the overall performance of the building. Improving the functionality of individual mechanical and electrical components, as well as their combined performance as a system, reduces energy consumption, operating costs, and occupant discomfort.

1.7.2 Programmable Thermostats[200]

Savings can be gained from programmable thermostats in two ways. The most common savings is associated with setting back the temperature at night or when leaving for extended periods of time through a programming feature. The other savings comes from newer, digital thermostats having a tighter band on the set point temperature so there is less cycling of the heating unit.

1.7.3 Energy Management Systems - Install/Optimization[201]

An Energy Management System (EMS) is a combination of software, data acquisition hardware, and communication systems to collect, analyze and display building information to aid commercial building energy managers, facility managers, financial managers and electric utilities in reducing energy use and costs in buildings. This technology helps perform key energy management functions such as organizing energy use data, identifying energy consumption anomalies, managing energy costs, and automating demand response strategies. Compared to other data archive and visualization systems, EMS is more tied-in to business enterprise information such as; facilitating energy benchmarking, optimizing utility procurement, and managing overall energy costs.

The main intent of the EMS installation is to identify opportunities for increasing the effectiveness and energy efficiency, while reducing the operating costs of the monitored systems. Once the energy saving and/or cost saving potential in the operation of a system is identified and quantified, plant personnel can take specific actions with confidence in the outcome. The ability to visually represent both the impact of current practice and the potential for improvement is a major asset in obtaining management approval for system improvements. The EMS can be built out incrementally over time to include measurement and analysis of other systems within the plant. Multiple facilities can also be connected into a corporate network via multi-site EMS installations.

[200] PHA Measure Descriptions, GDS Associates, September 2006

[201] Enterprise Energy Management System Installation Case Study at a Food Processing Plant, Lawrence Berkeley National Laboratory, 2006, http://industrial-energy.lbl.gov/node/362

1.8 Ventilation

Ventilation measures are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Dual Enthalpy Economizer - from Fixed Damper	3,400	0.8	10	$800
Dual Enthalpy Economizer - from Dry Bulb	2,500	0.6	10	$400
Heat Recovery	7	0.0	23	$14
Fan Motor, 40hp, 1800rpm, 94.1%	2,354	0.4	12	$286
Fan Motor, 15hp, 1800rpm, 92.4%	1,053	0.2	12	$46
Fan Motor, 5hp, 1800rpm, 89.5%	393	0.1	12	$34
Variable Speed Drive Control, 15 HP	12,000	1.9	20	$3,465
Variable Speed Drive Control, 5 HP	4,000	0.6	20	$1,925
Variable Speed Drive Control, 40 HP	32,000	5.0	20	$6,280

1.8.1 Dual Enthalpy Economizer[202]

Dual enthalpy economizers regulate the amount of outside air introduced into the ventilation system based on the relative temperature and humidity of the outside and return air. If the enthalpy (latent and sensible heat) of the outside air is less than that of the return air when space cooling is required, then outside air is allowed in to reduce or eliminate the cooling requirement of the air conditioning equipment.

This is a prescriptive measure included on the regional Cool Choice application form. Customers are eligible for a Cool Choice incentive only with the purchase of an efficient HVAC unit that also qualifies for an incentive. Custom incentives are available for other cost-effective dual enthalpy economizers for both retrofit and replacement/new construction units.

1.8.2 **Heat Recovery**[203]

There are many areas in such buildings as hospitals, manufacturing facilities requiring clean rooms, and laboratories that must be zoned as “once-through” systems in which the air that heats, cools, and ventilates is used only once. However, much of this HVAC energy can be recovered before it exits the building by installing heat-recovery coils in the exhaust air handlers. This heat can then be used to precondition the outside air coming into the building. Energy can be recovered without risk of contamination.

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[202] Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.

[203] Energy Efficiency Guide for Utah Businesses. Energy Efficient Measures – Heat Recovery. http://www.utahefficiencyguide.com/measures/commercial/heat_recovery.htm

Waste heat recovery on boiler stacks can be used to preheat boiler makeup water, thereby improving overall energy efficiency quite substantially. Heat recovery from stacks in heat treating furnaces is frequently used to preheat combustion air, thereby achieving savings of well over 50%.

Water-to-water heat exchangers are quite useful in a range of applications, from dyeing operations (where energy from a depleted batch of hot dye water is used to pre-heat the next batch) to various operations in chemical plants.

Heat exchangers allow for the transfer of heat from one fluid to another (including air) without the contents of one stream polluting those of the other. When the requirement for ensuring that absolutely no transfer of contents is high (e.g., exhaust air from hospitals), double-wall heat exchangers are used.

Heat exchangers are frequently employed in industry to save energy and enhance the performance of both batch and continuous processes. For example, a plant that uses large quantities of steam to heat batches of dye can install a heat exchanger to preheat the water for fresh batches of dye by using the waste water from an old batch. This both increases the speed of heating the new water and lowers energy requirements precipitously, while retaining good quality control over colors. When water or steam is involved in such heat transfer functions, “counter flow” shell-and-tube or plate-type heat exchangers are routinely employed. These result in good heat transfer coefficients at minimal risk of cross contamination.

Air-to-air heat exchangers are widely employed in processes which require heating materials to high temperatures over long periods of time, such as in ceramics or heat treating applications. Instead of allowing the hot combustion air to be vented directly to exhaust stacks, heat exchangers recover as much as 80% or more of the heat from the exhaust stream and use it to pre-heat combustion air. This can save well over half of the primary energy used in such facilities.

Other examples of the use of heat exchangers include:

- Condensing steam from a boiler to produce hot water for service hot water or other processes;
- Isolating two systems which operate at different pressures while extracting heat from the higher temperature system;
- Moving heat or cool in various refrigerator cycles that may include changing of state from liquids to gases in the heat exchanger; and
- Moving heat into and out of thermal storage containers.

1.8.3 Fan Motors[204]

Packaged refrigeration equipment is estimated to account for more than half of the electricity used by refrigeration systems in the commercial sector. In the U.S., the ENERGY STAR-labeled commercial refrigerators and freezers are generally at least 25% more efficient than some products in the market. However, the existing stock of packaged refrigeration equipment is considered very inefficient due to the focus by most purchasers on first cost and the lack of effort from manufacturers to differentiate equipment on the basis of energy efficiency (Nadel 2002).

Fan and fan motors used in the condensers and evaporators account for 20% of the annual energy use and operate at overall efficiencies as low as 7 to 15%. These low efficiencies are due to both inefficient fans and low cost shaded pole (SP) motors with low efficiencies (TIAX 2002).

New axial fan designs enable improved fan performance and advanced electric motors such as brushless DC or electronically commutated motors (ECM) offer motor performance solutions.

It appears that the majority of currently installed evaporator and condenser fan-motor sets can be replaced with advanced units that can achieve energy savings as high as 70% of the fan-motor energy. The input fan power of an evaporator and condenser in a typical 48 ft^3 two-door reach-in commercial refrigerator can be reduced from 70W (35W per component) to 20W (10W per component) with use of the energy-efficient fans and motors (TIAX 2002). Incremental costs range from a low of approximately $20 for a better fan with a brushless DC motor to $50 for an ECM motor. The total incremental cost for a commercial fridge would be in the range of $40 to $100 (Nadel 2002; TIAX 2002).

1.8.4 Variable Speed Drive Controls[205]

These controls are electronic circuits that receive feedback information from the driven motor and adjusts the output voltage or frequency to the selected values. Usually the output voltage is regulated to produce a constant ratio of voltage to frequency (V/Hz). Controllers may incorporate many complex control functions.

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[204] Efficient Fan Motor Options for Commercial Refrigeration, Emerging Technologies & Practices, ACEEE, 2004 http://www.aceee.org/pubs/a042_r3.pdf#search=%22fan%20motors%20measure%20description%22

[205] Natural Resources Canada – Energy Efficiency Office. http://oee.nrcan.gc.ca/industrial/equipment/vfd/vfd.cfm?attr=24

1.9 Motors

High efficiency motors are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Efficient Motors	1,540	0.3	20	$201
Variable Frequency Drives (VFD)	4,833	4.6	15	$3,600

1.9.1 Efficient Motors

Electric motors consume more than half of the electricity in the U.S. and almost 70 percent of manufacturing sector electricity. For most motor types, a range of efficiencies is available and even small efficiency improvements can make economic sense for equipment that is operated for thousands of hours per year. Therefore, the overall opportunity for energy savings from more efficient motors remains large.

Typically, the annual operating cost of a motor far outstrips the initial purchase price. For example, a typical 75 horsepower motor running at full load for 8,000 hours per year would consume about $24,000 worth of electricity at $0.05 per kWh.

In August of 2001, the National Electrical Manufacturers Association (NEMA) implemented a new NEMA Premium Energy Efficiency Motor Standard. Under this voluntary program, a motor may be marketed as a NEMA Premium motor if it meets or exceeds a set of NEMA minimum full-load efficiency levels. These levels are higher than the minimum full-load efficiency standards for energy-efficient motors under the Energy Policy Act of 1992 (EPAct).[206]

The following tables list the nominal energy efficiency levels that the products must meet in order to be considered a NEMA Premium Motor.

[206] Energy Tips: Motor Systems. September 2005. DOE – Energy Efficiency and Renewable Energy.

Nominal Efficiencies For "NEMA Premium™" Induction Motors Rated 600 Volts Or Less (Random Wound)						
HP	Open Drip Proof			Totally Enclosed Fan Cooled		
	6-pole	**4-pole**	**2-pole**	**6-pole**	**4-pole**	**2-pole**
1	82.5	85.5	77.0*	82.5	85.5	77
1.5	86.5	86.5	84	87.5	86.5	84
2	87.5	86.5	85.5	88.5	86.5	85.5
3	88.5	89.5	85.5	89.5	89.5	86.5
5	89.5	89.5	86.5	89.5	89.5	88.5
7.5	90.2	91	88.5	91	91.7	89.5
10	91.7	91.7	89.5	91	91.7	90.2
15	91.7	93	90.2	91.7	92.4	91
20	92.4	93	91	91.7	93	91
25	93	93.6	91.7	93	93.6	91.7
30	93.6	94.1	91.7	93	93.6	91.7
40	94.1	94.1	92.4	94.1	94.1	92.4
50	94.1	94.5	93	94.1	94.5	93
60	94.5	95	93.6	94.5	95	93.6
75	94.5	95	93.6	94.5	95.4	93.6
100	95	95.4	93.6	95	95.4	94.1
125	95	95.4	94.1	95	95.4	95
150	95.4	95.8	94.1	95.8	95.8	95
200	95.4	95.8	95	95.8	96.2	95.4
250	95.4	95.8	95	95.8	96.2	95.8
300	95.4	95.8	95.4	95.8	96.2	95.8
350	95.4	95.8	95.4	95.8	96.2	95.8
400	95.8	95.8	95.8	95.8	96.2	95.8
450	96.2	96.2	95.8	95.8	96.2	95.8
500	96.2	96.2	95.8	95.8	96.2	95.8

Nominal Efficiencies For "NEMA Premium™" Induction Motors Rated Medium Volts 5kV or Less (Form Wound)						
HP	Open Drip Proof			Totally Enclosed Fan Cooled		
	6 Pole	**4 Pole**	**2 Pole**	**6 Pole**	**4 Pole**	**2 Pole**
250	95	95	94.5	95	95	95
300	95	95	94.5	95	95	95
350	95	95	94.5	95	95	95
400	95	95	94.5	95	95	95
450	95	95	94.5	95	95	95
500	95	95	94.5	95	95	95

1.9.2 Variable Frequency Drives (VFD)

Controlling motor speed to correspond to load requirements provides many benefits, including increased energy efficiency and improved power factor. Adding adjustable speed capability can significantly improve the productivity of many manufacturing processes by reducing scrap, enabling quality manufacturing during transition times, and allowing more control over startup and shutdown.

By controlling the speed of a motor, the output of the motor/load system can be matched exactly to the requirements of the process. When this happens, the control valves, dampers, or other throttling mechanisms can be removed, thereby dramatically improving energy efficiency. With an adjustable speed drive (ASD) driven induction motor, precise process controls possible throughout the speed range. Most induction motor/ASD systems will provide nearly perfect phase power factor, but with some added harmonics. Improved power factor can result in energy savings in the cables and transformers supplying the motor. Other benefits from installing ASDs include: improved tool life, increased production and flexibility, faster response, extended operating range, etc.

1.10 Lighting

Lighting energy efficiency measures are covered in this section, Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Super T8 Fixture - from 34W T12	173	0.0	15	$65
Super T8 Fixture - from standard T8	77	0.0	15	$25
T5 Fluorescent High-Bay Fixtures	418	0.1	15	$100
T5 Troffer/Wrap	92	0.0	15	$40
T5 Industrial Strip	84	0.0	15	$40
T5 Indirect	92	0.0	15	$40
CFL Fixture	100,487	0.1	15	$35
Exterior HID	100,140	0.0	15	$30
LED Exit Sign	175,200	0.0	10	$25
Lighting Controls	151,140	0.1	10	$55
LED Traffic / Pedestrian Signals	674,520	0.1	10	$140
Electronic HID Fixture Upgrade	385	0.1	15	$100
Halogen Infra-Red Bulb	52	0.0	1.3	$6
Integrated Ballast MH 25W	223	0.1	3.4	$40
Induction Fluorescent 23W	230	0.1	4.9	$22
CFL Screw-in	2,800	0.1	3.4	$1
Metal Halide Track	360	0.1	15	$150

1.10.1 Super T8 Fixture[207]

"High-Performance" or "Super" T8 lamp/ballast systems have higher lumens per watt than standard T8 systems. This results in lamp/ballast systems that produce equal or greater light than standard T8 systems, while using fewer watts. When used in a high-bay application, high-performance T8 fixtures can provide equal light to HID High-Bay fixtures, while using fewer watts. Eligible fixtures include new, replacement, or retrofit.

1.10.2 T5 Fluorescent High-Bay Fixtures[208]

A T5 high-bay fixture has a fixture efficiency of over 91%, while a metal-halide fixture has a fixture efficiency of ~70%. By using a more efficient fixture, a space can be lit with fewer watts or fixtures. Typically, a 4-lamp F54T5HO system using 240 watts will provide as much light on a target surface as a standard 400 watt metal-halide fixture using 455 watts.

1.10.3 T5 Fixtures and Lamp/Ballast Systems[209]

T5 lamp/ballast systems have higher lumens per watt than a typical T8 system. In addition, the smaller lamp diameter allows for better optical systems, and more precise control of light. The combination of these characteristics results in light fixtures that produce equal or greater light than T8 fixtures, while using fewer watts. When used in a high-bay application, T5 fixtures can provide equal light to HID High-Bay fixtures, while using fewer watts. Eligible fixtures include new and replacement.

1.10.4 CFL Fixture

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 commercial 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. (1996), 23 percent of new fixture sales are fluorescent while 76 percent are incandescent. The existing stock of residential fixtures is approximately 15 percent fluorescent and 85 incandescent, suggesting that fluorescent share is increasing, but considerable technical potential for energy savings remain.

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 opportunity to reduce energy consumption. Since the point-of-sale for hard-wired fixtures is relatively concentrated (and generally limited to showrooms,

[207] Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.
[208] Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006
[209] ibid

contractors and distributors), a fixture initiative can target these markets more effectively than lamp suppliers for which sales locations are more diffuse.

1.10.5 LED Exit Sign

Several exit sign technologies exist that can significantly improve energy efficiency, including light-emitting diodes (LEDs), reduced wattage incandescent lamps, compact fluorescent lamps (CFLs), electroluminescent assemblies, and tritium assemblies. LEDs and CFLs are the two most prevalent and cost-effective means of upgrading exit signs. LEDs are the most promising of all technologies because of their low power consumption, long life, numerous designs, and excellent luminescence. E Source (1994) indicates that approximately 45 percent of exit signs are incandescent, followed by 40 percent CFLs, and 15 percent LED and electroluminescent. However, LEDs are estimated to comprise 50 percent of new sales (Conway 1998).

1.10.6 LED Traffic / Pedestrian Signals

Instead of a single incandescent light bulb, the LED lights feature a number of smaller lights assembled in one unit. Together, the numerous pinpoints of light from an LED lamp are brighter than a comparable incandescent lamp, and as much as 80 percent more energy efficient. While traditional incandescent traffic lamps use between 69 and 150 watts each, LED lights use between 10 and 25 watts, depending on size, color and type.

LEDs provide other cost benefits as well. When an incandescent traffic signal lamp fails, it burns out all at once, and incandescents typically need to be replaced every two years. The numerous pinpoints of light in an LED lamp, on the other hand, don't all burn out at the same time, and LED lamps can have a lifespan of up to ten years. Fewer burned out traffic signals means safer intersections, an important improvement in public safety. Agencies that have installed LEDs have discovered additional savings in traffic signal maintenance and lamp replacement costs because highway crews need to replace burned-out traffic signals less frequently. As an additional safety feature, brighter LED lights are more visible in foggy conditions.

The California Energy Commission reports that, through its program offering loans and grants to local agencies, over 236,780 old incandescent red, green and amber traffic signals, along with pedestrian walk and don't-walk signals, have been replaced with new lamps that use light emitting diodes (LEDs). The new LED lights reduce the State's need for electricity by nearly 10 megawatts Ñ enough electricity to power nearly 10,000 typical California homes. That reduced electricity demand should save the 80 public agencies participating in the Energy

Commission's LED traffic signal replacement program an estimated $7.9 million every year on their electricity costs.[210]

LED traffic signals are a good candidate for what could be a relatively easy market transformation effort. And in fact, a transformation to red signals appears to be occurring in the absence of significant intervention. For red and green signals to be more attractive to jurisdictions, the cost of green LEDs will have to come down and/or the additional maintenance benefits from two-color change outs highlighted. Movement to three-color LED signals is proceeding more slowly.[211]

Key opportunities to accelerate the transformation for red, green, and yellow LED traffic signals include: (1) developing and disseminating case studies, particularly where maintenance savings can be documented; (2) supporting targeted demonstrations to educate traffic engineers, where they are unaware, as well as local officials about benefits; (3) improving access to and availability of financing; (4) influencing and speeding the development of a national specification, by working with ITE or supporting outside research to supplement that being conducted currently by the NCHRP; and (5) supporting development and broader demonstration of three-color LED traffic signals (Suozzo 1998).[212]

1.10.7 Electronic HID Fixture Upgrade

High-intensity discharge (HID) lighting sources are the primary alternative to high-wattage incandescent lamps in the commercial sector wherever an intense point source of light is required. HID lamps can provide very high efficacy, offering energy savings of 50-90 percent when replacing incandescent sources. Efficiency upgrades within the HID family can provide smaller but significant savings of about 10- 50 percent, i.e., replacements of mercury vapor lamps.

There are several possibilities for retrofitting existing inefficient lighting technology to efficient HID sources. The key to HID retrofits is to carefully consider the light distribution of the new fixtures, as the new lamps will usually have much higher light output. New fixtures can be installed, complete with new ballasts. Replacing the ballast provides more control over the wattage and light output of the new source. Ballasts-and-lamp only retrofits are also possible, but may invalidate the UL listing of the old fixture.

Metal halide lamps can be used in many situations. Columbia University replaced wall sconces that contained 250W halogen lamps with 70W metal halide lamps and fixtures in their cafeteria. The new lamps and fixtures provided more light,

[210] California 'Green Lights' Energy Savings With New Traffic Signals. News Release, California Energy Commission, March 2002.
[211] ACEEE Selecting Targets for Market Transformation Program: A National Analysis, August 1998, Pg 171
[212] ACEEE Selecting Targets for Market Transformation Program: A National Analysis, August 1998, Pg 172

higher color rendition and less lumen depreciation, making it a far better choice overall. The new lamps and ballasts have been operating since 1991.

1.10.8 Halogen Infra-Red Bulb[213]

A new development in halogen technology is the advent of Infra-Red bulbs. Available only in PAR30, PAR38, and MR16 type bulbs, it is used for spot-lighting, often in museums, retail establishments, and restaurants. The technology generally offers around 20% energy-savings, and longer lamp life.

1.10.9 Integrated Ballast MH 25W and Induction Fluorescent 23W

Integrated ballast 25W Par 38 metal halide lamps are three times more efficient than the Par 38 halogen lamps that they replace. Light output is comparable and the 10,500 hour life of the metal halide lamps is up to three times longer than standard halogens. Very good color rendering of 87 and a crisp white light (3000K) make this a good replacement lamp for general, ambient or accent lighting. The integrated ballast allows for an easy upgrade from a halogen Par 38. Due to the high pressure and operating temperature of metal halide lamps, there are some safety considerations concerning these efficient lamps.

Specialty Products refers to new, cutting-edge niche technologies that save energy. They are often only available from a single manufacturer. The current products listed include an Induction Fluorescent R30, and an Integrated-Ballast PAR38.[214]

Inductive fluorescent lamps are white light sources with very good color rendering and color temperature properties. These lamps are energy efficient and offer extremely long life (over 100,000 hours), good lumen maintenance characteristics, and instant-on capability. The lamp enclosure is called a "vessel" and (shapes vary) coated on the inside with phosphor. Dimming is already available in Europe and will be available in the near future in the United States. They are powered by a small generator (about the size of a fluorescent ballast) attached to the lamp via a short fixed-length cable. The generator induces a current in the lamp which causes it to glow—there are no electrodes to wear out. The larger, diffuse nature of these sources makes them excellent for lighting larger volumes and surfaces. They are often used in place of low- to medium-wattage high intensity discharge sources because of the instant-on capability and reduced maintenance associated with the longer lamp life. This lamp source has promising application for indoor and outdoor lighting applications.[215]

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213 Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.

214 Philips Lighting Company. Product literature on the Philips MasterColor Integrated 25W PAR 38 Ceramic Metal Halide Lamp, Product # 14477-4. www.philips.com

215 WBDG: Energy Efficient Lighting, David Nelson, AIA, David Nelson & Associates, February 2006, http://www.wbdg.org/design/efficientlighting.php

1.10.10 CFL Screw-in

Compact fluorescent lamps (CFL) have become an icon of energy efficiency and are commonly used as simple substitutes for incandescent lamps due to their significantly longer life and better energy efficiency. CFLs use approximately ¼ of the electricity as compared to a similar incandescent lamp and CFLs last between 8 and 10 times longer than a typical incandescent lamp. Dimmable CFL lamps are available. Much of the original concern over the performance of CFLs has been addressed through instant-start lamps (no flicker) and the use of electronic ballasts that function at much higher frequencies than their magnetic counterparts (no noticeable strobe effect).

1.10.11 Metal Halide Track[216]

A metal-halide track head produces equal or more light as compared to halogen track head(s), while using fewer watts. Typically, a 39 watt PAR20 metal-halide track head using 43 watts can be used in place of (3) 50 watt halogen PAR20 track heads.

1.11 Lighting Controls

Lighting control measures are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Bi-Level Switching	83	0.0	10	$40
Occupancy Sensors	302	0.1	10	$55
Daylight Dimming	353	0.1	10	$181
Daylight Dimming - New Construction	252	0.1	10	$181
5% More Efficient Design	9,000	2.1	20	$4,000
10% More Efficient Design	18,000	4.1	20	$8,000
15% More Efficient Design - New Construction	27,000	6.2	20	$4,000
30% More Efficient Design - New Construction	54,000	12.3	20	$8,000

216 Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.

1.11.1 Bi-Level Switching[217]

With bi-level switching, each office occupant is provided with two wall switches near the doorway to control their lights. In a typical installation, one switch would control 1/3 of the fluorescent lamps in the ceiling lighting system, while the other switch would control the remaining 2/3 of the lamps. This allows four possible light levels: OFF, 1/3, 2/3 and FULL lighting.

1.11.2 Occupancy Sensors

Occupancy sensors save energy by automatically turning off lights in spaces that are unoccupied. Most occupancy sensors have adjustable settings for both sensitivity and time delay. Occupancy sensors are available in both ceiling-mounted and wall-mounted versions. Two motion-sensing technologies are commonly used in occupancy sensors: passive infrared and ultrasonic. Passive infrared are the most common and best suited for a 15-foot range, since there are potential “dead spots” that increase with distance and since this technology depends upon the heat intensity of the moving subject. Ultrasonic sensors are able to cover larger areas, since they emit rather than receive a signal. However, these sensors are more prone to false triggering. Some manufacturers combine these two technologies into one product called a hybrid or a dual technology sensor.

1.11.3 Daylight Dimming

Dimming controls reduce the output of light sources. Compared to on-off controls, dimming saves energy, allows better alignment between lighting service and human needs, and can also extend lamp life.[218]

For the most part, day lighting applications are best suited for new construction projects where a systems approach is taken, although some retrofit applications (generally large projects in suitable buildings) can be economic. The commercial energy savings potential from day lighting is small relative to other lighting measures, since applications are limited to areas that receive sunlight. Measures such as T8 lamping, electronic ballast upgrades and on-off switching should be implemented before daylight-dimming measures are pursued.[219]

Most lighting designers do not incorporate day lighting systems into new building designs or extensive renovation or remodeling projects. Increased training and education activities by professional organizations (e.g., IES), utilities, states and others can help lower designer reluctance to incorporate day lighting systems and teach them how to properly specify systems. Similarly, installer training may

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[217] The Usefulness of Bi-Level Switching. August 1999. Building Technologies Department, Lawrence Berkley Lab.

[218] E-Source Technology Access Series 1998 CD, Lighting Atlas, Chapter 5 Daylighting - Pages 256

[219] ACEEE Selecting Targets for Market Transformation Program: A National Analysis, August 1998, Pg 123

be necessary to ensure that well-specified systems are installed properly. Increased specification and installation of day lighting systems will also help to drive down the cost of dimmable ballasts as well as the costs of installation (as installers gain experience). Computer lighting software and other design tools can also facilitate the use of day lighting systems.[220]

1.11.4 Efficient Lighting Design[221]

Energy-efficient lighting design focuses on methods and materials that improve both quality and efficiency of lighting. Energy-efficient lighting design principles include the following:

- Keep in mind that more light is not necessarily better. Human visual performance depends on light quality as well as quantity.
- Match the amount and quality of light to the performed function.
- Install task lights where needed and reduce ambient light elsewhere.
- Use energy-efficient lighting components, controls, and systems.
- Maximize the use of daylighting.

1.12 Refrigeration

Refrigeration energy efficiency measures are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

[220] ACEEE Selecting Targets for Market Transformation Program: A National Analysis, August 1998, Pg 124

[221] Efficient Lighting Strategies. Office of Building Technologies Program. Energy Efficiency and Renewable Energy. US DOE. http://www.toolbase.org/PDF/DesignGuides/doe_energyefficientlighting.pdf

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Vending Miser for Soft Drink Vending Machines	1,635	0.2	15	$160
Refrigerated Case Covers	2,900	0.3	4	$90
Refrigeration Economizer	600	0.2	15	$2,558
Commercial Reach-In Refrigerators	800	0.1	9	$100
Commercial Reach-In Freezer	700	0.1	9	$100
Commercial Ice-makers	300	0.1	9	$45
Evaporator Fan Motor Controls	2,600	0.3	15	$1,050
Permanent Split Capacitor Motor	550	0.1	15	$235
Zero-Energy Doors	800	0.1	10	$800
Door Heater Controls	3,500	0.7	10	$250
Discus and Scroll Compressors	1,500	0.3	13	$650
Floating Head Pressure Control	2,000	0.3	10	$734
Anti-sweat (humidistat) controls (refrigerator)	190	0.0	12	$6,500
Anti-sweat (humidistat) controls (freezer)	375	0.1	12	$6,500

1.12.1 VendingMiser for Soft Drink Vending Machines[222]

The VendingMiser is an energy control device for refrigerated vending machines. Using an occupancy sensor, during times of inactivity the VendingMiser turns off the machine's lights and duty cycles the compressor based on the ambient air temperature. The VendingMiser is applicable for conditioned indoor installations.

1.12.2 Refrigerated Case Covers[223]

By covering refrigerated cases the heat gain due to the spilling of refrigerated air and convective mixing with room air is reduced at the case opening. Strip curtains can be deployed continuously and allow the customer to reach through the curtain to select the product. Continuous curtains can be pulled down overnight while the store is closed. Strip curtains are not used for low temperature, multi-deck applications. Glass door retrofits are a better choice for these applications.

1.12.3 Refrigeration Economizer[224]

Economizers save energy in walk-in coolers by bringing in outside air when it is sufficiently cool, rather than operating the compressor.

222 Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.
223 ibid
224 ibid

1.12.4 Commercial Reach-In Refrigerators[225]

The measure described here is a high-efficiency packaged commercial reach-in refrigerator with solid doors, typically used by foodservice establishments. This includes one, two and three solid door reach-in, roll-in/through and pass-through commercial refrigerators. Beverage merchandisers – a special type of reach-in refrigerator with glass doors – are not included in this characterization.

1.12.5 Commercial Reach-In Freezer[226]

The measure described here is a high-efficiency packaged commercial reach-in freezer with solid doors, typically used by foodservice establishments. This includes one, two and three solid door reach-in, roll-in/through and pass-through commercial freezers.

1.12.6 Commercial Ice-makers[227]

A typical ice-maker consists of a case, insulation, refrigeration system, and a water supply system. They are used in hospitals, hotels, food service, and food preservation. Energy-savings for ice-makers can be obtained by using high-efficiency compressors and fan motors, thicker insulation, and other measures. CEE has developed 2 efficiency thresholds – Tiers 1 and 2. Tier 2 units are not currently available, but more efficient models have been developed that are expected to be on the market soon.

1.12.7 Evaporator Fan Motor Controls[228]

Walk-in cooler evaporator fans typically run all the time; 24 hrs/day, 365 days/yr. This is because they must run constantly to provide cooling when the compressor is running, and to provide air circulation when the compressor is not running. However, evaporator fans are a very inefficient method of providing air circulation. Each of these fans uses more than 100 watts. Installing an evaporator fan control system will turn off evaporator fans while the compressor is not running, and instead turn on an energy-efficient 35 watt fan to provide air circulation, resulting in significant energy savings.

1.12.8 Permanent Split Capacitor Motor[229]

Cooler or freezer evaporator fan boxes typically contain two to six evaporator fans that run nearly 24 hours each day, 365 days each year. Not only do these fans use electricity, but the heat that each fan generates must also be removed by the refrigeration system to keep the product cold, adding more to the annual electricity costs. If the cooler or freezer has single-phase power, the electricity usage can be reduced by choosing permanent split capacitor (PSC) or brushless DC motors instead of conventional, shaded-pole motors. Brushless DC motors

[225] ibid
[226] ibid
[227] ibid
[228] Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.
[229] ibid

are also sometimes known by the copyrighted trade name ECM (electronically commutated motor).

1.12.9 Zero-Energy Doors[230]

Cooler or freezer reach-ins with glass doors typically have electric resistance heaters installed within the door frames. Refrigerator door manufacturers include these resistance heaters to prevent condensation from forming on the glass, blocking the customer’s view, and to prevent frost formation on door frames. Zero-energy doors may be chosen in place of standard cooler and freezer doors. These doors consist of two or three panes of glass and include a low-conductivity filler gas (e.g., Argon) and low-emissivity glass coatings. This system keeps the outer glass warm and prevents external condensation. Manufacturers can provide information on how well these systems work with “respiring” products.

1.12.10 Door Heater Controls[231]

Another option to zero-energy doors – that is also effective on existing reach-in cooler or freezer doors – is “on-off” control of the operation of the door heaters. Because relative humidity levels differ greatly across the United States, a door heater in Vermont needs to operate for a much shorter season than a door heater in Florida. By installing a control device to turn off door heaters when there is little or no risk of condensation, one can realize energy and cost savings.

There are two strategies for this control, based on either (1) the relative humidity of the air in the store or (2) the “conductivity” of the door (which drops when condensation appears). In the first strategy, the system activates your door heaters when the relative humidity in your store rises above a specific setpoint, and turns them off when the relative humidity falls below that setpoint. In the second strategy, the sensor activates the door heaters when the door conductivity falls below a certain setpoint, and turns them off when the conductivity rises above that setpoint.

1.12.11 Discus and Scroll Compressors[232]

Discus Technology involves using effective gas and oil flow management through valving that provides the best operating efficiency in the range of the compressor load. This eliminates capillary tubes typically used for lubrication, and also offers maximum compressor protection as well as environmental integrity. Discus retainers inside the cylinder also improve efficiency and lower sound levels. Reducing discharge pulsation levels by 20% over older reed models accomplishes this. The discus action is similar to a piston in the car engine. There is a moving reed action in the top part of the piston, which decreases lost gas from escaping. This leads to the effective gas utilization mentioned above. Because of the close tolerance maintained by this discus retainer to the top of the compressor structure, the fluid loss is minimized and

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[230] ibid

[231] ibid

[232] Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.

adds to efficiency, however this same tight tolerance requires completely particle free fluid to pass through it.

The discus compressor offers a rated compressor efficiency rating, expressed in EER, which is significantly higher than the standard reciprocating type compressor, therefore leading to significant annual energy savings.

Scroll Technology involves using two identical, concentric scrolls, one inserted within the other. One scroll remains stationary as the other orbits around it. This movement draws gas into the compression chamber and moves it through successively smaller pockets formed by the scroll's rotation, until it reaches maximum pressure at the center of the chamber. At this point, the required discharge pressure has been achieved. There, it is released through a discharge port in the fixed scroll. During each orbit, several pockets are compressed simultaneously, making the operation continuous.

Scroll compressors generally have slightly lower efficiency ratings than do discus compressors, particularly in lower temperature applications, but are nevertheless significantly more efficient than standard reciprocating compressors.

1.12.12 Floating Head Pressure Control[233]

Installers conventionally design a refrigeration system to condense at a set pressure-temperature setpoint, typically 90 degrees. By installing a "floating head pressure control" condenser system, the refrigeration system can change condensing temperatures in response to different outdoor temperatures. This means that as the outdoor temperature drops, the compressor will not have to work as hard to reject heat from the cooler or freezer.

1.12.13 Anti-Sweat Controls[234]

Due to basic laws of physics involving humidity, air temperature and dew point, when warm, humid air from a store's interior meets the cold air of a refrigerated display case, condensation occurs. This can lead to ice build-up on door gaskets and to the fogging and "sweating" of the doors, which can not only damage equipment but prevent customers from seeing the products inside the refrigerated case.

To prevent this condensation and "sweating," the refrigerated display case doors and frames are heated (hence the name, "anti-sweat heaters"). In essence, the heater dries up any warm, humid air that may have gotten trapped inside the display cases during customers' opening and closing of the doors. Anti-sweat heater controls, in turn, are used to ensure that the doors and frames are heated only when necessary.

[233] Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.
[234] Anti-Sweat Heater Controls: Technical Data Sheet, Focus On Energy, 2004 www.focusonenergy.com/data/common/pageBuilderFiles/AntiSweatTDS3429.pdf

Most anti-sweat heaters operate non-stop 24 hours a day, 365 days a year, even though condensation is a serious problem in Wisconsin only during warm, humid summer days. (Warm air can hold more moisture, which is one reason why humidity tends to be higher in the summer.)

An anti-sweat heater needs to run continuously only when a store's relative humidity reaches 55 percent and condensation is likely. Yet approximately 80 percent of grocery stores run their anti-sweat heaters continuously, regardless of humidity levels, according to a survey by Focus on Energy.

1.12.14 High Efficiency Ice Maker[235]

A typical ice-maker consists of a case, insulation, refrigeration system, and a water supply system. They are used in hospitals, hotels, food service, and food preservation. Energy-savings for ice-makers can be obtained by using high-efficiency compressors and fan motors, thicker insulation, and other measures. CEE has developed 2 efficiency thresholds – Tiers 1 and 2. Tier 2 units are not currently available, but more efficient models have been developed that are expected to be on the market soon.

A high efficiency ice-maker can fall into one of two tiers: Tier 1 – those approximately meeting the Federal Energy Management Program (FEMP) specifications, or Tier 2 – those 20% more efficient than Tier 1. Refer to the specification table in the Reference Tables section for the precise specification.

1.13 Compressed Air

Compressed air energy efficiency measures are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Compressed Air – Non-Controls	13,473	1.5	7	$1,347
Compressed Air – Controls	37,781,880	1.1	7	$4,313

1.13.1 Compressed Air – Controls and Non-Controls[236]

Controls that reduce compressed air system energy requirements. This measure applies to new construction, equipment replacement and retrofit. Non – controls refers to measures other than controls that reduce compressed air system energy requirements.

235 Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.
236 ibid

1.14 Monitor Power Management

Monitor power management energy efficiency measures are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
EZ Save Monitor Power Management Software	30	0.1	2	$26

1.14.1 EZ Save Monitor Power Management Software[237]

This measure describes the energy savings associated with office computer monitor power management (MPM) EZ Save software that enables a computer monitor to automatically power-down (i.e., sleep mode feature for the monitor after a period of inactivity).[238] EZ Save software is appropriate for organizations with a computer network and an in-house network administrator knowledgeable about network software installations. Energy savings are estimated in this characterization on a per computer basis and aggregated based on the indicated number of computers to be activated on the software download form. EZ Save is installed on the local server without the need to go to the separate computer stations connected to the network. The energy savings estimated in this characterization are applicable to computers used on average 45 hours per week. Given that not all downloads of EZ Save MPM software will be installed due to the two-step process required by network administrators, we discount total kWh savings by an in-service rate (ISR) factor.

1.15 Water/Wastewater Treatment

The following water and waste water treatment energy efficiency measures are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
Improved equipment and controls	158,000	18.0	17	$75,200

[237] Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.
[238] EVT implementation of this measure will identify intended computer type through the website registration and download requirements.

1.15.1 Improved equipment and controls[239]

Multiple Point Control Systems (MPCS) are control systems using multiple points of control to improve energy efficiency for building systems such as cooling, heating, lighting, ventilation, and/or other end uses. MPCS may control only a single system or may provide integrated control of several different building systems. Examples include chiller staging controls and integrated building Energy Management Systems (EMS). The description is not intended to include simple setpoint control systems, nor does it apply to any control system specifically described elsewhere in the Technical Reference Manual (e.g., demand controlled ventilation, lighting controls, refrigeration floating head pressure controls, variable frequency drives, etc.). This measure applies to new construction, equipment replacement and retrofit.

1.16 Transformers

High efficiency power transformers measures are covered in this section. Listed below are the basic assumptions used in this study for annual kWh savings, demand savings, useful life, and incremental cost. Sources for this data can be found in Appendix B1: Commercial Measure Assumptions.

Measure Name	Annual kWh Savings	KW Demand Savings	Measure Useful Life	Incremental Cost
ENERGY STAR Transformers	7,498,560	0.6	30	$856

1.16.1 ENERGY STAR Transformers[240]

Low-voltage, 3-phase, dry-type transformers where the primary voltage is 480/277 Volt, and the secondary voltage is 208/120V. Utility-owned transformers are not eligible. All transformers must include an ENERGY STAR® label (TP-1).

[239] Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.

[240] Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.

Appendix B1

Data for Commercial Sector Energy Efficiency Measures

Appendix B1: Data for Commercial Sector Energy Efficiency Measures

Measure Name	Cost Type: 1=Full 2=Inc.	End Use	Annual kWh Savings	kWh Savings Source	kWh Savings Source Notes	kW demand savings	kW demand source	kW Demand Source Notes	Annual MMBtu savings	MMBtu savings source	Incremental Cost	Cost Source	Source Notes
Space Heating													
High Efficiency Heat Pump	2	Space Heating	1,254	32		0.1	21				$48	21	
Ground Source Heat Pump - Heating	2	Space Heating	12,685	31		11.7	26				$33,000	9	
Water Heating End Use													
Heat Pump Water Heater	2	Water Heating	14,155	21		6.1	26				$4,067.01	21	
Booster Water Heater	2	Water Heating	625	21		0.3	26				$951.37	21	
Point of Use Water Heater	1	Water Heating	345	21		0.1	26				$106.88	21	
Solar Water Heating System	1	Water Heating	62,500	14		26.9	26				$11,500.00	14	
Solar Pool Heating	1	Water Heating	68,445	33		29.5	34				$33,750.00	14	
Envelope													
Double Pane Low Emissivity Windows	2	Space Heating	7	21		0.0	26		0.0	1	$0.51	21	
Space Cooling - Chillers													
Centrifugal Chiller, 0.51 kW/ton, 300 tons	*2*	Space Cooling - Chillers	34,803	30		23.5	5		0.0		$16,200	5	
Centrifugal Chiller, 0.51 kW/ton, 500 tons	*2*	Space Cooling - Chillers	58,005	30		39.1	5		0.0		$27,000	5	
Centrifugal Chiller, Optimal Design, 0.4 kW/ton, 500 ton	*2*	Space Cooling - Chillers	128,900	30		86.9	5		0.0		$60,000	5	
Space Cooling - Packaged AC													
DX Packaged system EER = 10.9, 10 tons	*2*	Space Cooling - Packaged	2,996	30		1.9	5		0.0		$607		
DX Packaged System, CEE Tier 2, <20 Tons	*2*	Space Cooling - Packaged	4,494	30		3.0	5		0.0		$612		
DX Packaged System, CEE Tier 2, >20 Tons	*2*	Space Cooling - Packaged	8,988	30		6.1	5		0.0		$1,813		
Packaged AC - 3 tons, Tier 2	*2*	Space Cooling - Packaged	792	30		0.5	5		0.0		$345	18	TRM - $115/ton
Packaged AC - 7.5 tons, Tier 2	*2*	Space Cooling - Packaged	1,797	30		1.2	5		0.0		$683	18	TRM - $91/ton
Packaged AC - 15 tons, Tier 2	*2*	Space Cooling - Packaged	4,108	30		2.8	5		0.0		$1,485	18	TRM - $99/ton
Ground Source Heat Pump - Cooling	*2*	Space Cooling - Packaged	16,755	31		4.1	26				$33,000	9	
Space Cooling - Maintenance													
Chiller Tune Up/Diagnostics - 300 ton	*1*	Space Cooling - Maint.	24,491	5		16.5	5		0.0		$5,100	5	
Chiller Tune Up/Diagnostics - 500 ton	*1*	Space Cooling - Maint.	41,248	5		27.8	5		0.0		$8,500	5	
DX Tune Up/ Advanced Diagnostics	*1*	Space Cooling - Maint.	1,934	5		1.3	5		0.0		$340	5	
HVAC Controls													
Retrocommissioning	*1*	HVAC Controls	1.2	1		0.0	26		0.0	1	$0.09	10	
Programmable Thermostats	*1*	HVAC Controls	1,934	5		1.3	5				$28	5	
EMS install	*1*	HVAC Controls	0.50	21		0.0	5	based on kW/kWh from CT	0.0	10	0.29	21	
EMS Optimization	*1*	HVAC Controls	0.05	9		0.0	26		0.0	10	0.06	9	
Ventilation													
Dual Enthalpy Economizer - from Fixed Damper	2	HVAC	3,400	18		0.8	18	Energy savings ÷ 4438 hr/yr (from TRM)			$800	18	
Dual Enthalpy Economizer - from Dry Bulb	2	HVAC	2,500	18		0.6	18	Energy savings ÷ 4438 hr/yr (from TRM)			$400	18	
Heat Recovery	2	HVAC	7	20		0.0	26				$14	20	
Fan Motor, 40hp, 1800rpm, 94.1%	2	HVAC	2,354	5		0.4	5				$286	5	
Fan Motor, 15hp, 1800rpm, 92.4%	2	HVAC	1,053	5		0.2	5				$46	5	
Fan Motor, 5hp, 1800rpm, 89.5%	2	HVAC	393	5		0.1	5				$34	5	
Variable Speed Drive Control, 15 HP	2	HVAC	12,000	5		1.9	5				$3,465	5	
Variable Speed Drive Control, 5 HP	2	HVAC	4,000	5		0.6	5				$1,925	5	
Variable Speed Drive Control, 40 HP	2	HVAC	32,000	5		5.0	5				$6,280	5	
Motors													
Efficient Motors	2	Motors	1,540	18		0.3	18	TRM: if hours are unknown, "use 4500 hours (E Source Technology Atlas Series Volume IV, Drivepower, p. 32)"			$201	18	TRM for 25-hp motor (which agrees with savings estimate)
Variable Frequency Drives (VFD)	2	Motors	4,833	18		4.6	18	TRM using DSVG factor and 27 avg hp			$3,600	18	From TRM for 30-hp VFD for environmental remediation

Appendix B1: Data for Commercial Sector Energy Efficiency Measures

Appendix B-1: Data for Commercial Energy Efficiency Measures - Page 2

Measure Name	Cost Type: 1=Full 2=Inc.	End Use	Annual kWh Savings	kWh Savings Source	kWh Savings Source Notes	kW demand savings	kW demand source	kW Demand Source Notes	Annual MMBtu savings	MMBtu savings source	Incremental Cost	Cost Source
Lighting End Use												
Super T8 Fixture - from 34W T12	2	Lighting - Flor	173	19		0.0	19	TRM update for 4-lamp measure	(0.0)	18	$65	19
Super T8 Fixture - from standard T8	2	Lighting - Flor	77	19		0.0	19	TRM update for 4-lamp measure	(0.0)	18	$25	19
T5 Fluorescent High-Bay Fixtures	2	Lighting - High Bay	418	18		0.1	18	g warehouse hours	(0.0)	18	$100	19
T5 Troffer/Wrap	2	Lighting - Flor	92	18		0.0	18	ming office hours of	(0.0)	18	$40	19
T5 Industrial Strip	2	Lighting - Flor	84	18		0.0	18	manufacturing hou	(0.0)	18	$40	19
T5 Indirect	2	Lighting - Flor	92	18		0.0	18	ming office hours of	(0.0)	18	$40	19
CFL Fixture	2	Lighting - Flor	197	18	TRM FOR OFFICE	0.1	18	TRM for 1 lamp >= 20 W total	(0.0)	18	$35	18
Exterior HID	2	Lighting	55	18		0.0	18			18	$30	18
LED Exit Sign	2	Lighting	88	18		0.0	18		(0.0)	18	$25	18
Lighting Controls	1	Lighting	291	18	TRM FOR OFFICE	0.1	18		(0.0)	18	$55	18
LED Traffic / Pedestrian Signals	2	Lighting	354	18	TRM FOR RED	0.1	18	TRM for Red ball		18	$140	18
Electronic HID Fixture Upgrade	2	Lighting - High Bay	385	19	TRM update (40	0.1	19	e using hours for ma	(0.0)	18	$100	19
Halogen Infra-Red Bulb	2	Lighting	52	19	TRM update (pa	0.0	19	pdate using hours fo	(0.0)	19	$6	19
Integrated Ballast MH 25W	2	Lighting	223	19		0.1	19	pdate using hours fo	(0.0)	19	$40	19
Induction Fluorescent 23W	2	Lighting	230	19		0.1	19	pdate using hours fo	(0.0)	19	$22	19
CFL Screw-in	2	Lighting	155	18		0.1	18		(0.0)	18	$1	29
Metal Halide Track	2	Lighting	360	18	TRM - 20 at 39	0.1	18	ming retail hours of	(0.0)	18	$150	18
Lighting Controls												
Bi-Level Switching	1	Lighting Controls	83	19		0.0	19		(0.0)	19	$40	19
Occupancy Sensors	1	Lighting Controls	302	5		0.1	5				$55	18
Daylight Dimming	1	Lighting Controls	353	5		0.1	5				$181	5
Daylight Dimming - New Construction	1	Lighting Controls	252	5		0.1	5				$181	5
5% More Efficient Design	2	Lighting Controls	9,000	5		2.1	5				$4,000	5
10% More Efficient Design	2	Lighting Controls	18,000	5		4.1	5				$8,000	5
15% More Efficient Design - New Construction	1	Lighting Controls	27,000	5		6.2	5				$4,000	5
30% More Efficient Design - New Construction	1	Lighting Controls	54,000	5		12.3	5				$8,000	5
Refrigeration End Use												
Vending Miser for Soft Drink Vending Machines	1	Refrigeration	1,635	18		0.2	18				$160	18
Refrigerated Case Covers	2	Refrigeration	2,900	18		0.3	18				$90	18
Refrigeration Economizer	1	Refrigeration	600	18		0.2	18				$2,558	18
Commercial Reach-In Refrigerators	1	Refrigeration	800	18		0.1	18				$100	18
Commercial Reach-In Freezer	1	Refrigeration	700	18		0.1	18				$100	18
Commercial Ice-makers	1	Refrigeration	300	18		0.1	18				$45	18
Evaporator Fan Motor Controls	2	Refrigeration	2,600	18		0.3	18				$1,050	18
Permanent Split Capacitor Motor	2	Refrigeration	550	18		0.1	18				$235	18
Zero-Energy Doors	2	Refrigeration	800	18		0.1	18				$800	18
Door Heater Controls	1	Refrigeration	3,500	18		0.7	18				$250	18
Discus and Scroll Compressors	2	Refrigeration	1,500	18		0.3	18				$650	18
Floating Head Pressure Control	1	Refrigeration	2,000	18		0.3	18				$734	18
Anti-sweat (humidistat) controls (refrigerator)	1	Refrigeration	190	5		0.0	5				$6,500	5
Anti-sweat (humidistat) controls (freezer)	1	Refrigeration	375	5		0.1	5				$6,500	5
High Efficiency Ice Maker	2	Refrigeration	437	18	n/a	0.1	18				$45	18
Compressed Air End Use												
Compressed Air – Non-Controls	2	C Air	13,473	22		1.5	23	Energy and demand savings indicate 24/7 operation			$1,347	23
Compressed Air – Controls	1	C Air	10,064	23	nd savings indic	1.1	18, 22	Ngrid experience indicates approx 28 hp average installation. TRM indicates 22% savings on average diversified kW load. GDS estimate that avg diversified load is about 25% of connected load.			$4,313	23
Monitor Power Management												
EZ Save Monitor Power Management Software	1	Monitors	30	18		0.1	18				$26	
Water/Wastewater Treatment												
Improved equipment and controls	1	Pumping and aeration	158,000	9	example from R	18.0	9				$75,200	9
Transformer End Use												
Energy Star Transformers	2	Transformer	4,853	18		0.6	18				$856	
Total Measures for Commercial Sector:			***45***									

Appendix B1: Data for Commercial Sector Energy Efficiency Measures

Measure Name	Cost/Unit Descriptor	Cost/Unit	Persistence Factor	Measure Life	Effective Measure Life	Measure Life Source	Measure Life Source Notes	Annualized cost	Levelized cost per kWh saved
Space Heating									
High Efficiency Heat Pump	$/Unit	$48	1	15	15	21		$6.26	$0.0050
Ground Source Heat Pump - Heating	$/Unit	$33,000	1	15	15			$4,338.63	$0.3420
Water Heating End Use						2			
Heat Pump Water Heater	$/Unit	$4,067.01	1	14	14	21		$552.08	$0.0390
Booster Water Heater	$/Unit	$951.37	1	10	10	21		$154.83	$0.2477
Point of Use Water Heater	$/Unit	$106.88	1	10	10	21		$17.39	$0.0504
Solar Water Heating System	$/unit	$11,500.00	1	15	15	14		$1,511.95	$0.0242
Solar Pool Heating	$/unit	$33,750.00	1	10	10	14		$5,492.66	$0.0802
Envelope									
Double Pane Low Emissivity Windows	$/sf-window	$0.51	1	30	30	21		$0.05	$0.0077
Space Cooling - Chillers									
Centrifugal Chiller, 0.51 kW/ton, 300 tons	$/unit	$16,200.00	1	25	25	18		$1,784.72	$0.0513
Centrifugal Chiller, 0.51 kW/ton, 500 tons	$/unit	$27,000.00	1	25	25	18		$2,974.54	$0.0513
Centrifugal Chiller, Optimal Design, 0.4 kW/ton, 500 ton	$/unit	$60,000.00	1	25	25	18		$6,610.08	$0.0513
Space Cooling - Packaged AC									
DX Packaged system EER = 10.9, 10 tons	$/unit	$607	1	15	15			$79.80	$0.0266
DX Packaged System, CEE Tier 2, <20 Tons	$/unit	$612	1	15	15			$80.46	$0.0179
DX Packaged System, CEE Tier 2, >20 Tons	$/unit	$1,813	1	15	15			$238.36	$0.0265
Packaged AC - 3 tons, Tier 2	$/unit	$345	1	15	15	18		$45.36	$0.0573
Packaged AC - 7.5 tons, Tier 2	$/unit	$683	1	15	15	18		$89.73	$0.0499
Packaged AC - 15 tons, Tier 2	$/unit	$1,485	1	15	15	18		$195.24	$0.0475
Ground Source Heat Pump - Cooling	$/unit	$33,000	1	15	15	21		$4,338.63	$0.2589
Space Cooling - Maintenance									
Chiller Tune Up/Diagnostics - 300 ton	$/unit	$5,100.00	1	10	10	5		$830.00	$0.0339
Chiller Tune Up/Diagnostics - 500 ton	$/unit	$8,500.00	1	10	10	5		$1,383.34	$0.0335
DX Tune Up/ Advanced Diagnostics	$/unit	$340.00	1	2	2	5		$195.90	$0.1013
HVAC Controls									
Retrocommissioning	$/sq ft	$0.09	1	7	7	10		$0.02	$0.0145
Programmable Thermostats	$/unit	$28	1	5	5	5		$7.25	$0.0038
EMS install	$/sq ft	$0.29	1	10	10	11		$0.05	$0.0951
EMS Optimization	$/sq ft	$0.06	1	5	5	3		$0.01	$0.2968
Ventilation									
Dual Enthalpy Economizer - from Fixed Damper	$/unit	$800	0.7	10	7	18		$164.32	$0.0483
Dual Enthalpy Economizer - from Dry Bulb	$/unit	$400	0.7	10	7	18		$82.16	$0.0329
Heat Recovery	$/sq ft	$14	1	23	23			$1.55	$0.2215
Fan Motor, 40hp, 1800rpm, 94.1%	$/unit	$286	1	12	12	5		$41.97	$0.0178
Fan Motor, 15hp, 1800rpm, 92.4%	$/unit	$46	1	12	12	5		$6.75	$0.0064
Fan Motor, 5hp, 1800rpm, 89.5%	$/unit	$34	1	12	12	5		$4.99	$0.0127
Variable Speed Drive Control, 15 HP	$/unit	$3,465	1	20	20	5		$407.00	$0.0339
Variable Speed Drive Control, 5 HP	$/unit	$1,925	1	20	20	5		$226.11	$0.0565
Variable Speed Drive Control, 40 HP	$/unit	$6,280	1	20	20	5		$737.65	$0.0231
Motors									
Efficient Motors	$/unit	$201	1	20	20	18		$23.61	$0.0153
Variable Frequency Drives (VFD)	$/unit	$3,600	1	15	15	18	TRM "15 years for non-process VFDs. 10 years for process."	$473.31	$0.0979

Appendix B1: Data for Commercial Sector Energy Efficiency Measures

Measure Name	Cost/Unit Descriptor	Cost/Unit	Persistence Factor	Measure Life	Effective Measure Life	Measure Life Source	Measure Life Source Notes	Annualized cost	Levelized cost per kWh saved
Lighting End Use									
Super T8 Fixture - from 34W T12	$/unit	$65	1	15	15	18		$8.55	$0.0494
Super T8 Fixture - from standard T8	$/unit	$25	1	15	15	18		$3.29	$0.0427
T5 Fluorescent High-Bay Fixtures	$/unit	$100	1	15	15	18		$13.15	$0.0315
T5 Troffer/Wrap	$/unit	$40	1	15	15	18		$5.26	$0.0570
T5 Industrial Strip	$/unit	$40	1	15	15	18		$5.26	$0.0626
T5 Indirect	$/unit	$40	1	15	15	18		$5.26	$0.0570
CFL Fixture	$/unit	$35	1	15	15	18		$4.60	$0.0234
Exterior HID	$/unit	$30	1	15	15	18		$3.94	$0.0716
LED Exit Sign	$/unit	$25	1	10	10	18		$4.07	$0.0461
Lighting Controls	$/unit	$55	1	10	10	18		$8.95	$0.0308
LED Traffic / Pedestrian Signals	$/unit	$140	1	10	10	18	TRM "100,000 hours divided by the life of the bulb; capped at 10 years" -- for red balls at 4818 hr/yr = 20 yr	$22.78	$0.0644
Electronic HID Fixture Upgrade	$/unit	$100	1	15	15	19		$13.15	$0.0341
Halogen Infra-Red Bulb	$/unit	$6	1	1.3	1.303781	19		$5.13	$0.0996
Integrated Ballast MH 25W	$/unit	$40	1	3.4	3.422425	19		$14.37	$0.0643
Induction Fluorescent 23W	$/unit	$22	1	4.9	4.8891786	19		$5.91	$0.0257
CFL Screw-in	$/unit	$1	1	3.4	3.4	18		$0.36	$0.0023
Metal Halide Track	$/unit	$150	1	15	15	18		$19.72	$0.0548
Lighting Controls									
Bi-Level Switching	$/unit	$40	1	10	10	18		$6.51	$0.0783
Occupancy Sensors	$/unit	$55	1	10	10	18		$8.95	$0.0296
Daylight Dimming	$/unit	$181	1	10	10	18		$29.46	$0.0834
Daylight Dimming - New Construction	$/unit	$181	1	10	10	18		$29.46	$0.1169
5% More Efficient Design	$/unit	$4,000	1	20	20	5		$469.84	$0.0522
10% More Efficient Design	$/unit	$8,000	1	20	20	5		$939.68	$0.0522
15% More Efficient Design - New Construction	$/unit	$4,000	1	20	20	5		$469.84	$0.0174
30% More Efficient Design - New Construction	$/unit	$8,000	1	20	20	5		$939.68	$0.0174
Refrigeration End Use									
Vending Miser for Soft Drink Vending Machines	$/unit	$160	0.7	15	10	18		$26.04	$0.0159
Refrigerated Case Covers	$/unit	$90	1	4	4	18		$28.39	$0.0098
Refrigeration Economizer	$/unit	$2,558	1	15	15	18		$336.31	$0.5605
Commercial Reach-In Refrigerators	$/unit	$100	1	9	9	18		$17.36	$0.0217
Commercial Reach-In Freezer	$/unit	$100	1	9	9	18		$17.36	$0.0248
Commercial Ice-makers	$/unit	$45	1	9	9	18		$7.81	$0.0260
Evaporator Fan Motor Controls	$/unit	$1,050	1	15	15	18		$138.05	$0.0531
Permanent Split Capacitor Motor	$/unit	$235	1	15	15	18		$30.90	$0.0562
Zero-Energy Doors	$/unit	$800	1	10	10	18		$130.20	$0.1627
Door Heater Controls	$/unit	$250	1	10	10	18		$40.69	$0.0116
Discus and Scroll Compressors	$/unit	$650	1	13	13	18		$91.51	$0.0610
Floating Head Pressure Control	$/unit	$734	1	10	10	18		$119.46	$0.0597
Anti-sweat (humidistat) controls (refrigerator)	$/unit	$6,500	1	12	12	19		$953.96	$5.0209
Anti-sweat (humidistat) controls (freezer)	$/unit	$6,500	1	12	12	19		$953.96	$2.5439
High Efficiency Ice Maker	$/unit	$45	1	9	9	18		$7.81	$0.0179
Compressed Air End Use									
Compressed Air – Non-Controls	$/unit	$1,347	1	7	7	*GDS estimate*		$276.68	$0.0205
Compressed Air – Controls	$/unit	$4,313	0.85	7	5.95	*GDS estimate*		$996.47	$0.0990
Monitor Power Management									
EZ Save Monitor Power Management Software	$/unit	$26	0.85	2	1.7	18		$17.65	$0.5883
Water/Wastewater Treatment									
Improved equipment and controls	$/unit	$75,200	1	17	17	17	Predominently lights, motors, and pumps	$9,374.74	$0.0593
Transformer End Use									
Energy Star Transformers	$/unit	$856	1	30	30	18		$90.80	$0.0187
Total Measures for Commercial Sector:									

Appendix B-1: Data for Commercial Energy Efficiency Measures

Sources for Data for Commercial Sector Energy Efficiency Measures

1 American Council for an Energy Efficient Economy (ACEEE), Selecting Targets for Market Transformation Programs: A National Analysis, 1998.
2 California Statewide Commercial Sector Energy Efficiency Potential Study, July, 2002, C.1-3.
3 CALIFORNIA STATEWIDE COMMERCIAL SECTOR NATURAL GAS ENERGY EFFICIENCY POTENTIAL STUDY, Study ID #SW061, Prepared for Pacific Gas & Electric Company, Prepared by Mike Rufo and Fred Coito KEMA-XENERGY Inc., May 14, 2003
4 California Urban Water Conservation Council, http://www.cuwcc.org/sprayvalves.lasso
5 Independent Assessment of Conservation and Energy Efficiency Potential for Connecticut and the Southwest Connecticut Region, GDS Associates, June 2004
6 Database for Energy Efficient Resources (DEER) 2001 Update, California Energy Commission, http://www.energy.ca.gov/deer/index.html
7 EIA - Technology Forecast Updates - Residential and Commercial Building Technologies - Reference Case, September 2004, Navigant Consulting, Reference No. 117943
8 Federal Energy Management Program (FEMP) brochure: "How to Buy an Energy-Efficient Family-Sized Commercial Clothes Washer", http://www.eere.energy.gov/femp/procurement/comm_clotheswashers.html#cost
9 GDS Associates Estimate/Calculation
10 The Maximum Achievable Cost Effective Potential for Natural Gas Energy Efficiency In the Service Territory of PNM, GDS Associates, May 2005
11 Keyspan Energy, 2004. Program data provided via email.
12 Maine Cost Effectiveness Model, March 2003.
13 National Grid, 2000 Energy Initiative Program Data, 2000 DSM Performance Measurement Report, Appendix 3, December 2001 15 hp motor (725 KWh per hp)
14 KeySpan Energy, 2005. Cost benefit analysis conducted for solar measures.
15 Northeast Utilities, Action Program C&I Persistence Study, Oct. 2001, p. 39
16 Quantum Consulting - Pilot program experience from Oakland CA per email communication from Mike Rufo on 2/3/04. and American Council for an Energy Efficient Economy (ACEEE), Selecting Targets for Market Transformation Programs: A National Analysis, 1998.
17 RS Means CostWorks 2005, construction cost estimating database for Albequerque
18 Efficiency Vermont Technical Reference User Manual (TRM) No. 2004-31
19 Efficiency Vermont Technical Reference User Manual (TRM) Update - Portfolio of New and Revised Measures - Portfolio Update No. 38
20 WI Focus on Energy Cost Data (VA Hospital)
21 Energy Efficiency and Renewable Energy Resource Development Potential in New York State - Final Report, Volume 5 Energy Efficiency Technical Appendices, August 2003.
22 National Grid, RFP LJR 05-07, Prescriptive Compressed Air Impcat Study p. 10
23 NYSERDA final report for Agreement number 5035, Turnkey Pump and Compressed Air System Efficiency Program, Final Report, November 2003, p.12
24 Draft Final Report: Phase 2 Evaluation of the Efficiency Vermont Business Programs, December 2005.
25 Dairy Farm Energy Audit Summary Report for FlexTech Services, NYSERDA, July 2003.
26 GDS Benefit Cost Model with Vermont Avoided Costs
27 Email from Efficiency Vermont on March 12, 2006 responding to GDS questions on market penetrations of efficient measures.
28 Energy Trust of Oregon - personal communication, noted that they expect 20-50% savings from water and wastewater project.
29 Home Depot website. www.homedepot.com
30 Independent Assessment of Conservation and Energy Efficiency Potential for Connecticut and the Southwest Connecticut Region, GDS Associates, June 2004 with revised cooling hours for North Carolina.
31 Vermont Electric Energy Efficiency Potential Study, GDS Associates, August 2006. With revised
32 EPA ENERGY STAR Air Source Heat Pump Calculator (http://www.energystar.gov/index.cfm?c=airsrc_heat.pr_as_heat_pumps) with Raleigh as the weather station
33 KeySpan Energy, 2005. Cost benefit analysis conducted for solar measures, adjusted for heating degree days in Raleigh, NC.
34 GDS Benefit Cost Model with Vermont Avoided Costs adjusted for heating degree days in Raleigh, NC.

Appendix C

Descriptions of Industrial Sector Energy Efficiency Measures for North Carolina

1. Introduction to Industrial Measures

This technical appendix describes a range of industrial sector energy efficiency measures suitable for North Carolina. GDS plans to add information to this section of the report based upon comments that will be received from the RPS Advisory Group. 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. Table 1-1, below, shows a list of measures considered for this sector, and the levelized cost per lifetime kWh saved for each measure.

Table 1-1: Industrial Measures – Levelized Cost per Lifetime kWh Saved

Measure	Levelized cost per kWh saved
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
Air Compressor System Management	$0.0015
Industrial Motor Management	$0.0013
Advanced Motor Designs	$0.0025
Motor System Optimization (including ASD)	$0.0025
Fan System Improvements	$0.0023
Transformers (NEMA Tier II)	$0.0050
Lighting End Use	
Efficient Industrial Lamps and Fixtures	$0.0114
Other Industrial Energy Efficiency Measures	$0.0100

1.1 Sensors and Controls

Industrial sensors and control refers to a variety of measures that can be implemented to optimize the energy use of motors, lighting, and other electric end uses.

1.2 Advanced Lubricants[241]

Industrial lubricants are oils, fluids, greases and other compounds designed to reduce friction, binding or wear and exclude moisture. Advanced lubricants are able to withstand high temperatures as well as reduce noise in many applications.

241 http://industrial-lubricants.globalspec.com/LearnMore/Materials_Chemicals_Adhesives/Industrial_Oils_Fluids/Industrial_Lubricants_Greases

1.3 Pump System Efficiency Improvements[242]

Existing pump system efficiency improvements involve changing the control system and/or the pump. New pump systems have far greater improvement opportunities because the piping itself can be selected to reduce energy costs.

1.4 Advanced Air Compressor Controls

Air compressor controls reduce compressed air system energy requirements. This measure applies to new construction, equipment replacement and retrofit. Non-controls refer to measures other than controls that also reduce compressed air system energy requirements.

1.5 Air Compressor System Management[243]

Intelligent air compressor management systems are designed to save energy and reduce operating costs. Most control kits can reduce energy consumption by up to 10% of industrial air compressor installation employing multiple compressors.

Heat recovery can be utilized for energy savings in a compressed air system because approximately 80-90% of the input energy to a compressor is applied to raise the temperature of the air. Ducting warm air to preheat or dry materials and ducting heat from an air-cooled compressor can be ducted inside the plant to reduce space heating costs as well as deflected outside during the summer months.

1.6 Industrial Motor Management

Even the most efficient motors may not save a significant amount of electricity if the motor system is not running in an optimal way. Since the motor is only a component of the larger motor system, optimizing the whole system provides the greatest opportunity for savings.

1.7 Advanced Motor Designs[244,245]

Advanced motors, or high efficiency motors, save energy and demand by delivering the same shaft power to the load using less energy than a standard efficiency motor. High efficiency motors generally have improved efficiency at full load and improved efficiency at reduced motor load. Because many industrial motors operate between 40 and 80 hours per week, even a small increase in efficiency can yield huge energy savings.

1.8 Motor System Optimization (including VSD)[246]

Motor system optimization starts with an in-depth analysis of motors and motor systems (including fans and pumps) to match motor output with end-use (load) requirements and to optimize the motor system's energy efficiency. The review of the motor system

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242 http://www.pumps.org/public/pump_resources/Pump_Systems_Matter/Why_Do_Pumps_Matter.pdf

243 http://www.pge.com/003_save_energy/003c_edu_train/pec/info_resource/pdf/COMPAIR.PDF

244 Engineering Methods for Estimating the Impacts of Demand-Side Management Programs, EPRI, 1993

245 http://www.cee1.org/resrc/facts/mot-sys-fx.php3

246 http://www.xcelenergy.com/docs/retail/busmrkts/EsourceMotorOptimization.pdf

begins with an evaluation of the duty cycles and load profiles for every motor at the facility. Potential improvements include replacing oversized motors with smaller, more efficient motors and installing variable speed drives (VSD) when the load varies significantly.

For systems in which the loads vary frequently, installing a VSD can be a good investment. A VSD is considerably more expensive than buying a smaller and more-efficient replacement motor, so if the load is consistently low (less than 40 to 50 percent of the rated output), then the motor-replacement option is the smarter choice.

1.9 Fan System Improvements[247,248]

Fan systems can be upgraded in a few ways to save energy and costs. The main source of energy savings comes from the combination of sizing the system correctly, and installing variable speed drives (VSD) to efficient fan motors. There are also ways to save through static pressure resets.

Variable air volume (VAV) systems are in general more energy efficient than constant volume systems because VAV systems reduce airflow in response to a demand decrease. Sizing the system correctly increases the lifetime of the air handler and decreases energy usage to begin with.

Installing a VSD on fans allows them to follow the actual energy load, which changes with time.

Static pressure reset is a method of controlling air handlers in VAV systems and is more efficient than methods based on static pressure, especially when operating at part-load conditions. The benefits that result include energy savings, high reliability and reduced noise. The speed of the supply fan on most VAV systems is controlled to maintain a constant static pressure in the supply duct. Energy is saved by controlling the fans to supply the minimum amount of air needed to allow the terminal boxes to remain in control. This reduces the supply static pressure, lowering the supply fan speed and power. Heating and cooling energy savings are also created.

1.10 Transformers[249,250]

Electricity in the industrial sector for the most part flows through distribution transformers. The Federal Energy Policy Act of 1992 calls on the Department of Energy to require minimum efficiency standards for distribution transformers. Because of this national regulation most of the transformers today convert more than 95% of the power input to output power. There is still room for improvement in energy and cost savings because of the constant flow of electricity through the transformers.

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247 http://www.energystar.gov/ia/business/FanSystems.pdf
248 http://208.57.108.243/pdfs/VAVSYSTEM.PDF
249 http://www.energystar.gov/index.cfm?c=ci_transformers.pr_ci_transformers
250 http://www.nema.org/stds/tp1.cfm

Energy efficient transformers are usually medium or low-voltage, 3-phase, dry-type transformers where the primary voltage is 480/277 Volts and the secondary voltage is 208/120V. Manufacturers have helped move the market to higher efficiencies on a voluntary basis with the NEMA standard TP-1. The transformers that follow the NEMA standard include an ENERGY STAR® label.

1.11 Efficient Industrial Lamps and Fixtures[251]

"High-Performance" or "Super" T8 lamp/ballast systems have higher lumens per watt than standard T8 systems. This results in lamp/ballast systems that produce equal or greater light than standard T8 systems, while using fewer watts. When used in a high-bay application, high-performance T8 fixtures can provide equal light to HID High-Bay fixtures, while using fewer watts. Eligible fixtures include new, replacement, or retrofit.

A T5 high-bay fixture has a fixture efficiency of over 91%, while a metal-halide fixture has a fixture efficiency of ~70%. By using a more efficient fixture, a space can be lit with fewer watts or fixtures. Typically, a 4-lamp F54T5HO system using 240 watts will provide as much light on a target surface as a standard 400 watt metal-halide fixture using 455 watts.

T5 lamp/ballast systems have higher lumens per watt than a typical T8 system. In addition, the smaller lamp diameter allows for better optical systems, and more precise control of light. The combination of these characteristics results in light fixtures that produce equal or greater light than T8 fixtures, while using fewer watts. When used in a high-bay application, T5 fixtures can provide equal light to HID High-Bay fixtures, while using fewer watts. Eligible fixtures include new and replacement.

[251] Technical Reference User Manual (TRM) No. 2006-41. Efficiency Vermont, June 2006.

Appendix D

kWh and kW Savings for the Achievable Cost-effective Potential Electricity Savings Base Case for North Carolina

Appendix D: kWh and kW Savings for the Achievable Cost-effective Potential Electricity Savings Base Case for North Carolina

Year	Residential Sector - Achievable Cost Effective Potential - Cumulative Annual kWh Savings - customer level	Residential Sector - Achievable Cost Effective Potential - Cumulative Annual kWh Savings - generation level	Residential Sector - Achievable Cost Effective Potential - Cumulative Annual kW Savings - generation level	Commercial Sector - Achievable Cost Effective Potential - Cumulative Annual kWh Savings - customer level	Commercial Sector - Achievable Cost Effective Potential - Cumulative Annual kWh Savings - generation level	Commercial Sector - Achievable Cost Effective Potential - Cumulative Annual kW Savings - generation level	Industrial Sector - Achievable Cost Effective Potential - Cumulative Annual kWh Savings - customer level	Industrial Sector - Achievable Cost Effective Potential - Cumulative Annual kWh Savings - generation level	Industrial Sector - Achievable Cost Effective Potential - Cumulative Annual kW Savings - generation level	Total - All Sectors - Achievable Cost Effective Potential - Cumulative Annual kWh Savings - customer level	Total - All Sectors - Achievable Cost Effective Potential - Cumulative Annual kWh Savings - generation level
2008	1,238,003,055	1,307,331,226	298,477	695,000,000	733,920,000	167,562	617,600,000	652,185,600	92,967	2,550,603,055	2,693,436,826
2009	2,476,006,111	2,614,662,453	596,955	1,390,000,000	1,467,840,000	335,123	1,235,200,000	1,304,371,200	185,935	5,101,206,111	5,386,873,653
2010	3,714,009,166	3,921,993,679	895,432	2,085,000,000	2,201,760,000	502,685	1,852,800,000	1,956,556,800	278,902	7,651,809,166	8,080,310,479
2011	4,952,012,221	5,229,324,906	1,193,910	2,780,000,000	2,935,680,000	670,247	2,470,400,000	2,608,742,400	371,870	10,202,412,221	10,773,747,306
2012	6,190,015,277	6,536,656,132	1,492,387	3,475,000,000	3,669,600,000	837,808	3,088,000,000	3,260,928,000	464,837	12,753,015,277	13,467,184,132
2013	7,428,018,332	7,843,987,359	1,790,865	4,170,000,000	4,403,520,000	1,005,370	3,705,600,000	3,913,113,600	557,805	15,303,618,332	16,160,620,959
2014	8,666,021,388	9,151,318,585	2,089,342	4,865,000,000	5,137,440,000	1,172,932	4,323,200,000	4,565,299,200	650,772	17,854,221,388	18,854,057,785
2015	9,801,195,548	10,350,062,499	2,363,028	5,560,000,000	5,871,360,000	1,340,493	4,940,800,000	5,217,484,800	743,740	20,301,995,548	21,438,907,299
2016	10,936,369,708	11,548,806,412	2,636,714	6,255,000,000	6,605,280,000	1,508,055	5,558,400,000	5,869,670,400	836,707	22,749,769,708	24,023,756,812
2017	12,006,000,000	12,678,336,000	2,894,597	6,950,000,000	7,339,200,000	1,675,616	6,176,000,000	6,521,856,000	929,675	25,132,000,000	26,539,392,000
2018	11,723,651,918	12,380,176,426	2,826,524	6,255,000,000	6,605,280,000	1,508,055	5,558,400,000	5,869,670,400	836,707	23,537,051,918	24,855,126,826
2019	11,441,303,836	12,082,016,851	2,758,451	5,560,000,000	5,871,360,000	1,340,493	4,940,800,000	5,217,484,800	743,740	21,942,103,836	23,170,861,651
2020	11,138,188,112	11,761,926,646	2,685,371	4,865,000,000	5,137,440,000	1,172,932	4,323,200,000	4,565,299,200	650,772	20,326,388,112	21,464,665,846
2021	10,762,834,671	11,365,553,412	2,594,875	4,170,000,000	4,403,520,000	1,005,370	3,705,600,000	3,913,113,600	557,805	18,638,434,671	19,682,187,012
2022	10,337,663,224	10,916,572,365	2,492,368	3,475,000,000	3,669,600,000	837,808	3,088,000,000	3,260,928,000	464,837	16,900,663,224	17,847,100,365
2023	9,858,362,364	10,410,430,656	2,376,811	2,780,000,000	2,935,680,000	670,247	2,470,400,000	2,608,742,400	371,870	15,108,762,364	15,954,853,056
2024	9,379,061,503	9,904,288,948	2,261,253	2,085,000,000	2,201,760,000	502,685	1,852,800,000	1,956,556,800	278,902	13,316,861,503	14,062,605,748
2025	9,002,589,538	9,506,734,552	2,170,487	1,390,000,000	1,467,840,000	335,123	1,235,200,000	1,304,371,200	185,935	11,627,789,538	12,278,945,752
2026	8,626,117,572	9,109,180,157	2,079,721	695,000,000	733,920,000	167,562	617,600,000	652,185,600	92,967	9,938,717,572	10,495,285,757
2027	8,315,189,476	8,780,840,086	2,004,758	0	0	0	0	0	0	8,315,189,476	8,780,840,086

Appendix E

Key Assumptions for the North Carolina Energy Efficiency Potential Study

Appendix E: Key Assumptions for the North Carolina Energy Efficiency Potential Study

1. Discount rate = 10%

2. Annual rate of inflation in the future = 2.5% per year

3. Estimated annual line losses between the customer meter and the electric generation plant = 5.6%

North Carolina Utility Loss Factors
2005 Form 1 Electric Energy Account
Page 401a

Utility	Total Energy Requirement	Losses	Energy Sold		Loss Factor (Ratio of Losses to Total Requirement)		Loss Factor to apply to Metered Sales
________	(MWh)	(MWh)	(MWh)		(%)		(%)
Carolina Power & Light	61,950,539	2,321,831	59,628,708		**3.75%**		**3.89%**
Duke Energy Corporation	91,268,837	5,780,627	85,488,210		**6.33%**		**6.76%**
Weighted Average Line Losses	153,219,376				**5.29%**		**5.60%**

Prepared by GDS Associates, November 2006

4. Percent of energy efficiency measure cost paid by the Program Administrator with a financial incentive = 50%

5. Maximum achievable long term penetration rate for energy efficiency measures = 80%

6. Main strategy for energy efficiency programs = replace on burnout (not early replacement)

7. Levelized cost per kWh of electric generation in the future (including energy and capacity costs) =$.05 per kWh in $2006

8. Levelized cost per kWh of electric transmission in the future =$.003 per kWh in $2006 (Source: February 2006 EIA Annual Energy Outlook, page 78, Table 16).