ENERGY EFFICIENCY AND CONSERVATION MEASURE RESOURCE ASSESSMENT

Prepared for the

Energy Trust of Oregon, Inc.

Final Report

May 4, 2006

By

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And

Ecotope

Note: Soon after the completion of the resource assessment, Energy Trust received some estimates for an additional measure which is not included in the study. Conservation voltage regulation (CRV) is currently an initiative by the Northwest Energy Efficiency Alliance. This technology is expected to provide 5.4aMW of energy savings within the territory Energy Trust serves by 2015 at a societal cost of 3.07 cents/kWh levelized. Since the amount of savings is relatively small to the overall study potential results, it was not added to the study details but will be used in our analysis of the report.

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Project Overview

The goal of this project was to provide Energy Trust of Oregon, Inc. (Energy Trust) with the amount and cost of potential energy efficiency and renewable energy measures that could provide electricity and natural gas demand-side savings for Oregon consumers by 2017 within the Energy Trust service territory. This resource assessment is designed to inform strategic planning and the project development and selection process. By 2017, a technical potential of approximately 590 Average Megawatts (MWa) of electric savings and 106 million annual therms of gas savings were identified in this study[1].

Stellar Processes and Ecotope, Inc. reviewed existing demographic and energy efficiency measure data sources to identify and quantify the resource potential. The contractors created easily updateable planning tools to develop these estimates and for Energy Trust to incorporate in their ongoing planning processes. The tools to evaluate the cost of individual measures and packages of measures considers the measure life, equipment and installation, annual O&M expenses and the discount rate employed by the Energy Trust to produce levelized costs. Levelized costs are useful for comparing program options and conservation strategies that have different measure lives.

It is important to note that program related costs are not included because Energy Trust staff directed that they are outside the scope of this study. It is equally important to note that the levelized costs shown in this study are the entire societal cost of efficiency measures for situations where existing, working equipment is retrofit, and the incremental cost of efficiency when considering new purchases of efficiency versus standard equipment. The incentive costs to the Energy Trust are often only a portion of these "total measure costs". This study provides the basic information on the cost of measures, which the Energy Trust will combine with their knowledge of markets and programs and incentives to develop estimates of total program costs to society and (separately) to the utility system.

While this project was not intended to provide program design, it does identify and quantify estimates of gas and electricity use and measures of activity (such as number and energy use of households or total floor space) in the target markets for the residential, commercial, and industrial / agriculture sectors. Residential savings potential is quantified by housing type for new and existing single family, multifamily, and manufactured homes. Commercial savings are developed on a square footage basis for typical business type designations such as retail, grocery, and large and small office spaces. The industrial analysis quantifies savings and costs by process type such as wood products, food, and electronics.

Determining the applicability of potential measures to sub sectors of the commercial and industrial building stock can be difficult. For these sectors, many "cross cutting" measures such as lighting improvements for commercial applications or motor efficiency improvements for industrial customers were analyzed. Cross cutting measures can be

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[1] Electric measure savings are quantified in average MW as well as peak MW savings for summer and winter heavy demand periods. Gas savings are quantified in annual therms.

applicable across a wide variety of circumstances and building types. In the industrial sector, many measures are relevant for specific applications or processes rather than in discrete building types. The industrial technical potential section discusses the assumptions used to determine measure applicability.

Summary of Results

The resource potential can be considered “technical” or “achievable”. The technical potential is an estimate of all energy savings that could be accomplished immediately without the influence of any market barriers such as cost and customer awareness. As such, it provides a snapshot of everything that could be done. Technical potential does not present what can be saved through programs; it would be impossible to get every customer to install every possible measure. Furthermore, some resources may cost more than the Energy Trust or participants wish to pay. The achievable potential represents a more realistic assessment of what could be expected – taking into account the fact that not all consumers can be persuaded to participate and other real world limitations.

The following figures and tables summarize the results of this analysis for 2017. In providing summary statistics for this section, we limited measure costs to thresholds of $0.055/kWh and $1.70/therm. This provides a summary of the savings potential that has a reasonable chance of being cost effective when compared to avoided energy costs. Although the supply curves do not include the highest cost measures, the tables of measures in the Technical Appendix lists all measures considered in this study.

Figure 1 shows the estimated savings from all electricity measures would reduce electricity use by approximately 590 MWa of technical potential for measures with a levelized cost that is less than 5.5 cents/kWh in 2017.

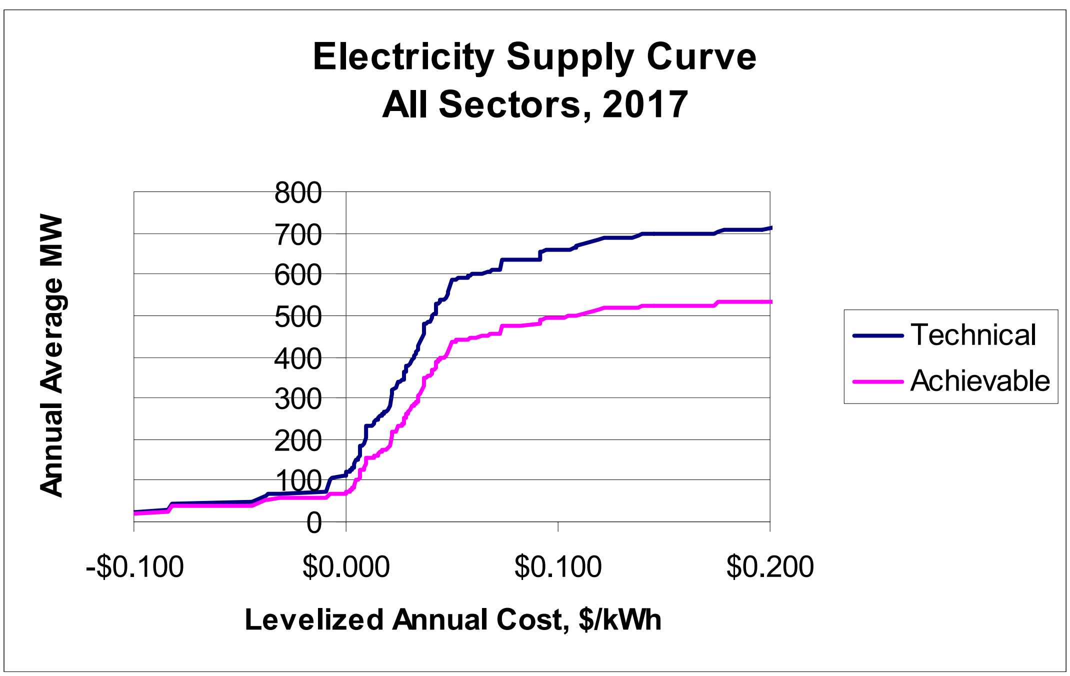

Figure 1. Electricity Supply Curve

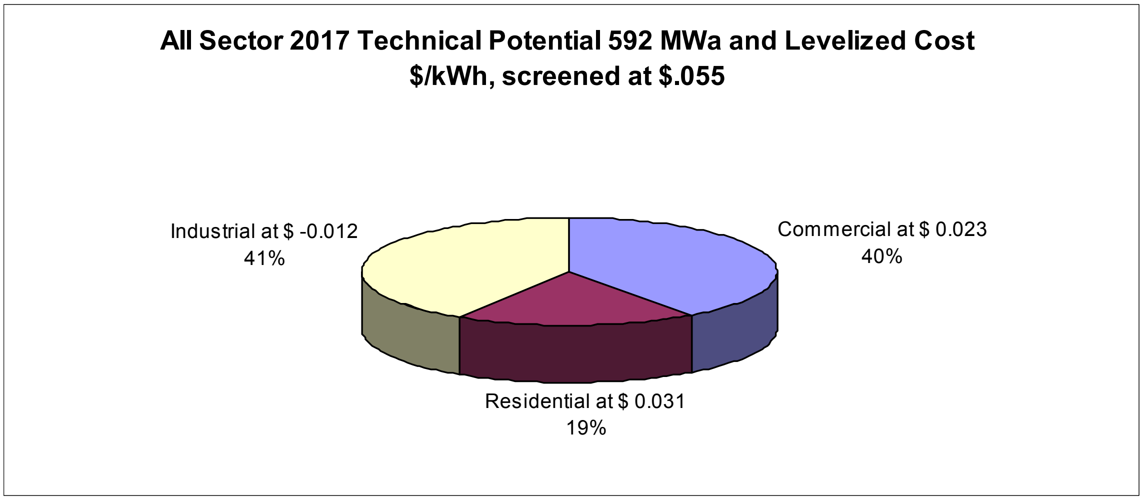

Figure 2. Electricity Technical Potential

Figure 3 shows that natural gas conservation measures could reduce consumption by about 106 million therms at a levelized cost that is less than $1.70 per therm. Note in Figure 4 that the industrial sector is only included in the electricity supply curve, not the gas supply curve. Industrial natural gas customers are not included within Energy Trust mission.

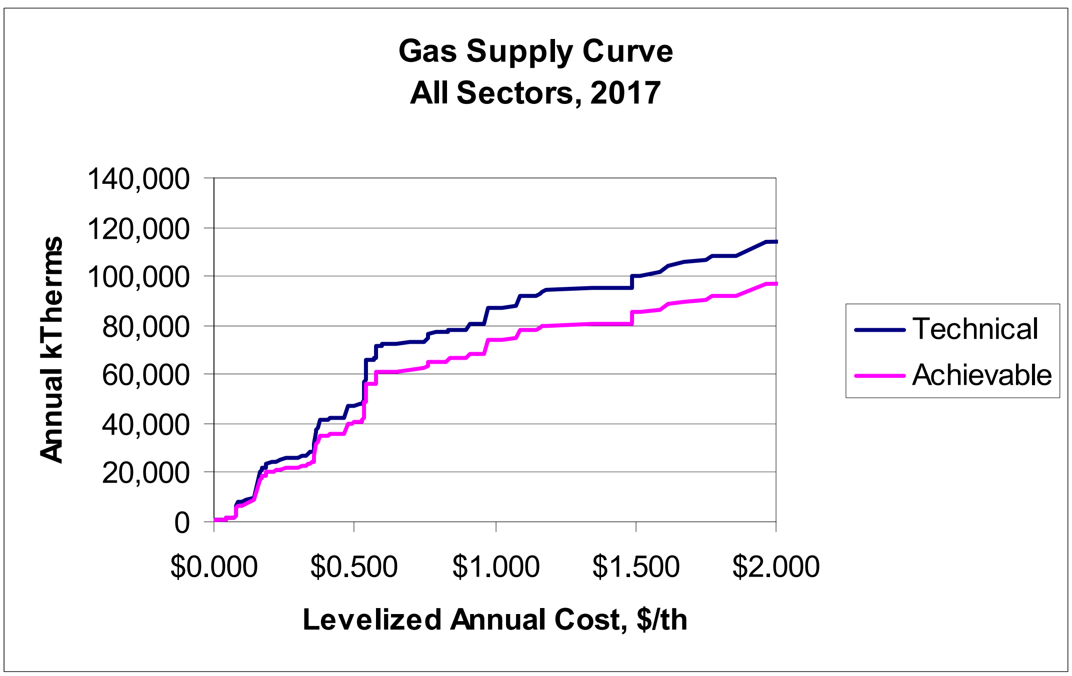

Figure 3. Natural Gas Supply Curve

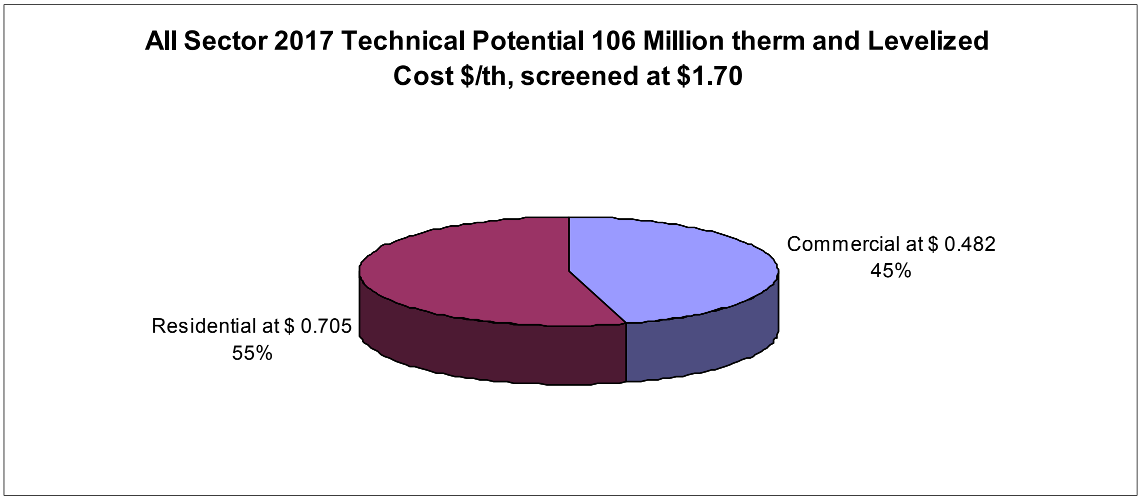

Figure 4. Natural Gas Technical Potential

Significant Conservation Efficiency Measures

Industrial Sector

Industrial customers of investor owned utilities in Oregon with over 1 MW demand have the option of using their payment to the energy efficiency portion of the public purpose charge to self-direct implementation of efficiency projects. In addition, some industrial customers are transmission customers only for the utilities. For this study, neither of these types of industrial customers were removed – that is, these results apply to all the industries within Energy Trust territory regardless of whether they are currently eligible for Energy Trust programs.

For this sector, measures can be thought of as cross-cutting or process- specific. For example, motors and lighting occur in all segments. However, other measures may be specific to paper manufacture or another process. Because it is so difficult to obtain information on specific facilities, the actual amount of process savings is likely to be much larger than estimated here.

Transformer and motor-related measures as well as lighting opportunities are important cross-cutting measures because of the widespread applicability to virtually all end uses. With this sort of study, it is important that national-level process and end use data by industry type be carefully considered and adjusted for relevance to the local industry. Energy Trust program files provided further information on process opportunities of the existing facilities with Northwest specific characteristics. As a result of this region specific analysis, detailed process measures for the electronics, paper and wood products sectors were added. Table 1 summarizes the electric technical potential savings as a fraction of current (2006) sales. This table provides assurance that the estimates are a reasonable savings fraction compared to forecast consumption.

Table 1 Industrial Sector Savings in 2006, screened at $.055/kWh

Sector	Consumption, MWa	Potential Savings, MWa	Savings Fraction
Computer & Electronic Product Mfg	200	71	35%
Paper Mfg	237	48	20%
Primary Metal Mfg	62	9	14%
Fabricated Metal Product Mfg	46	5	11%
Food Mfg	59	9	16%
Wood Product Mfg	169	38	22%
Agriculture	39	1	2%
Other Industrial	114	19	17%
Total:	927	199	21%

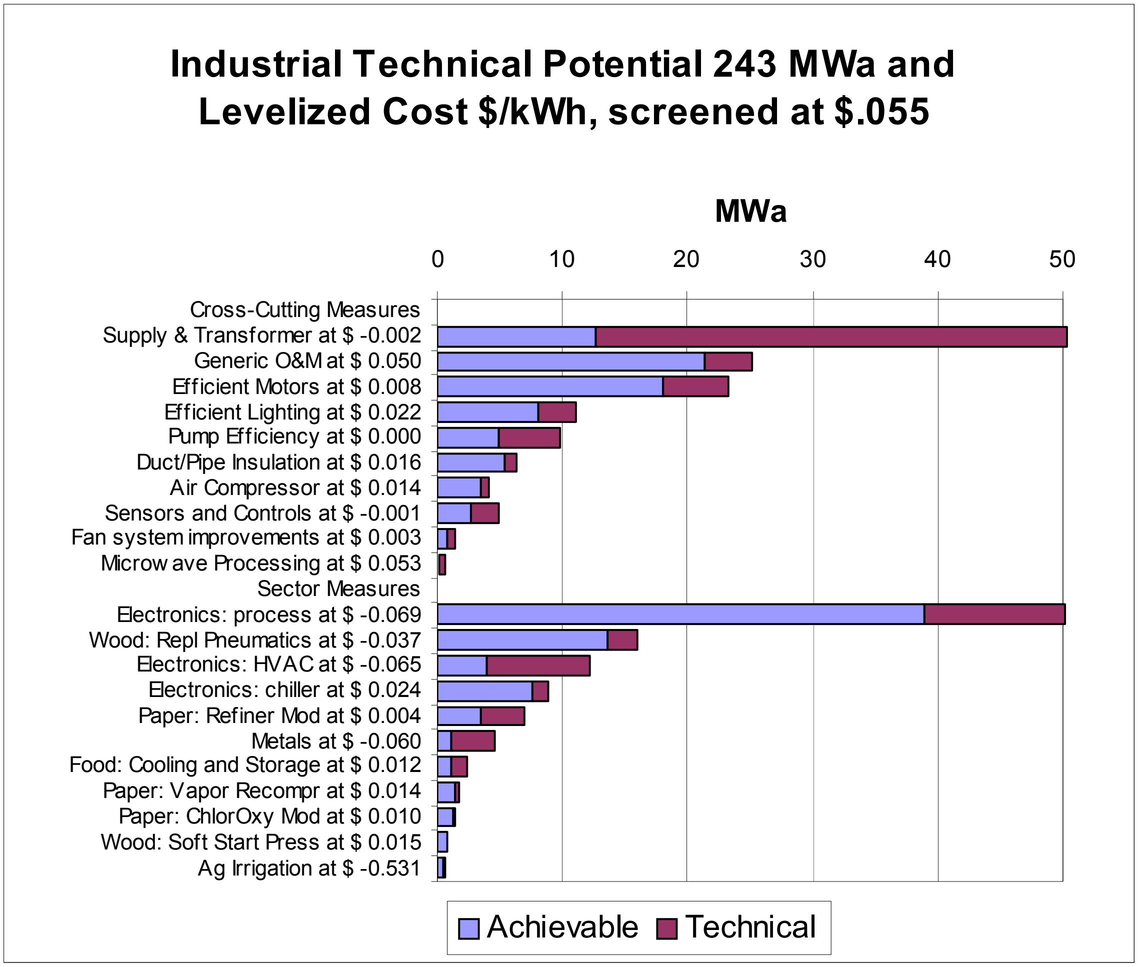

Figure 5. Major Industrial Measures

The technical and achievable potential resource shown in Figure 5 by measure is estimated for the year 2017. Supply and transformer measures show the greatest technical potential, however the largest achievable potential is shown for process measures specific to the electronics industry.

Commercial Sector

Figure 6 shows the potential for groups of measures in the commercial sector with most significant savings grouped by applicability to existing stock as repair or replacement versus those specific to new construction. 28% or 67 MWa of the 238 MWa technical potential was found for new construction with the balance, 171 MWa, applying to existing construction. In both cases, lighting opportunities dominate. In most cases, achievable potential is estimated as 85% of technical potential. One significant outlier is heat pump water heaters, which have a large technical potential but low achievable potential. Should a low-cost, high applicability model be manufactured, the achievable potential would increase significantly. Details are summarized in Table 2.

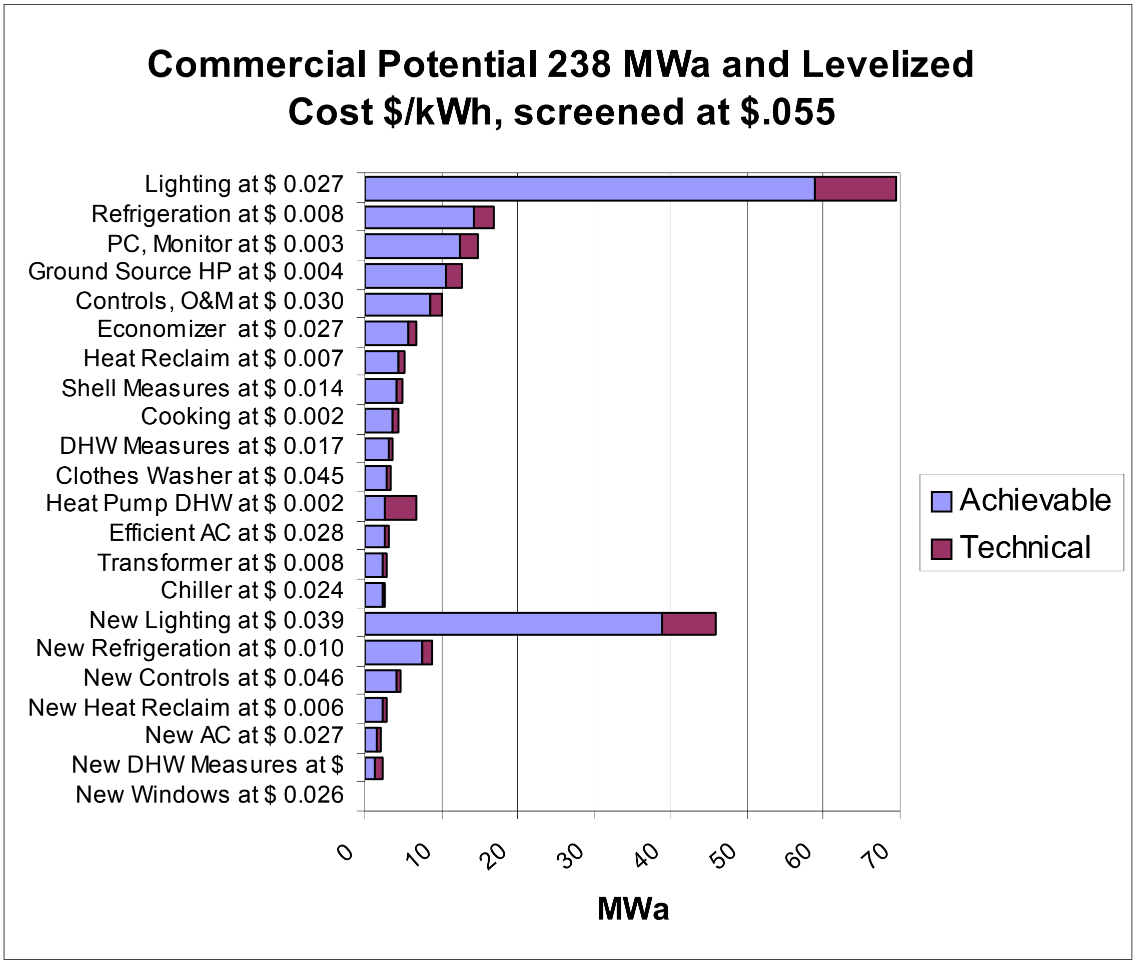

Figure 6. Major Commercial Sector Measures, Electricity

Note: Measure category names for new construction begin with “New”.

Table 2 Commercial Sector 2017 Electric Technical Potential Savings, Screened at $.055/kWh

Measure Category	MWa Savings	Winter Peak Savings, MW	Summer Peak Savings, MW	Levelized Cost, $/kWh
Lighting	69	83	108	$0.027
Refrigeration	17	20	27	$0.008
PC, Monitor	15	15	15	$0.003
Ground Source HP	13	27	24	$0.004
Controls, O&M	10	12	11	$0.030
Heat Pump DHW	10	10	10	$0.002
Economizer	7	14	13	$0.027
Heat Reclaim	5	6	8	$0.007
Shell Measures	5	15	1	$0.014
Cooking	4	4	4	$0.002
DHW Measures	4	4	4	$0.017
Clothes Washer	3	3	3	$0.045
Efficient AC	3	6	6	$0.028
Transformer	3	3	3	$0.008
Chiller	3	5	4	$0.024
New Lighting	46	47	60	$0.039
New Refrigeration	9	14	18	$0.010
New Controls	5	10	9	$0.046
New Heat Reclaim	3	3	4	$0.006
New DHW Measures	2	2	2	$0.043
New AC	2	4	4	$0.027
New Windows	<1	1	<1	$0.026
Total	**238**	**310**	**339**	**$0.023**

Potential gas conservation opportunities for 2017 are shown in Figure 7 and Table 3. Measures are grouped by similar type and by existing versus new building stock. Of the 48 million therm potential, 21% of 10 million therms apply to new buildings only. O&M and replacement of unit heaters provide the most savings potential in existing construction. Heat reclamation from refrigeration has emerged as significant due to recent regional market research. In new construction, the predominant savings measure is from HVAC controls and new unit heaters and furnaces.

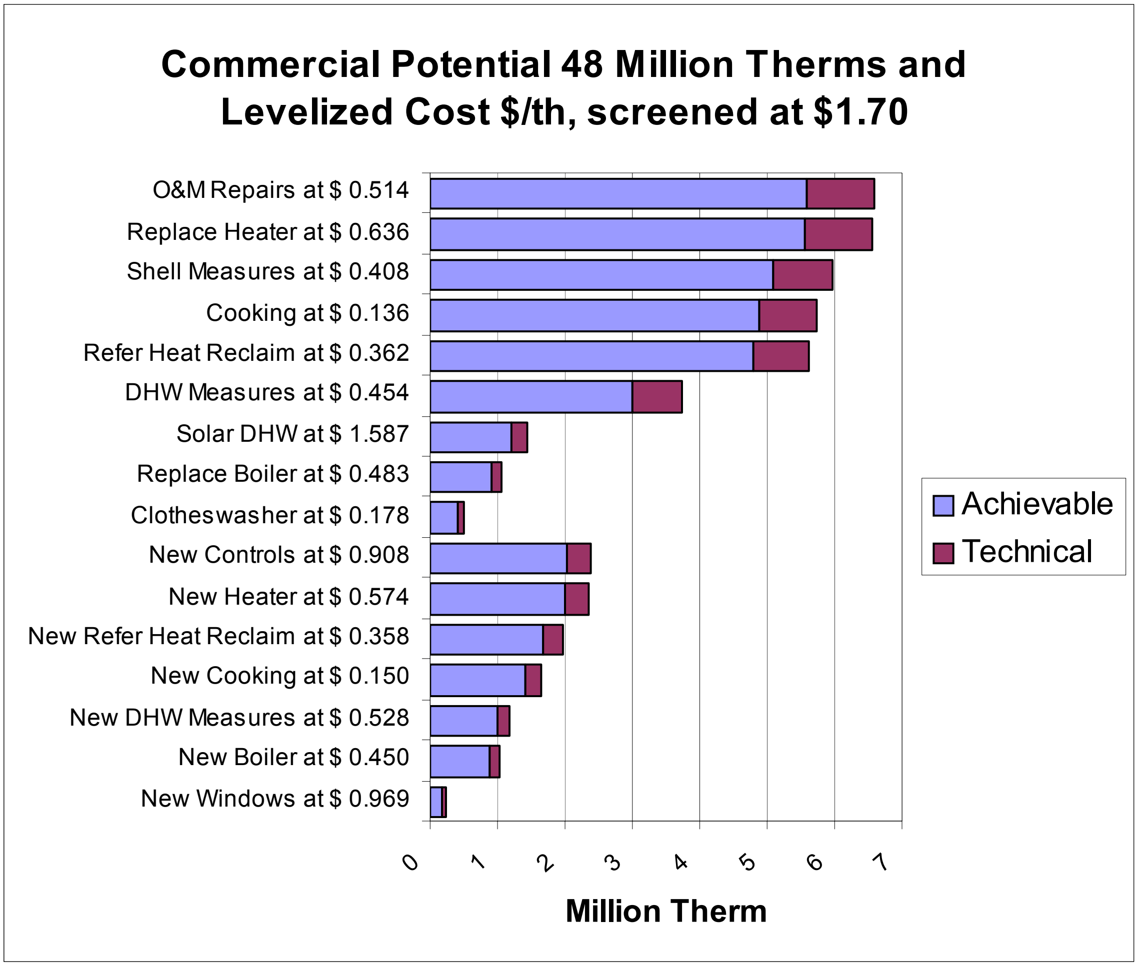

Figure 7. Major Commercial Sector Measures, Gas

Note: Measure category names for new construction begin with “New”.

Table 3 Commercial Sector Gas 2017 Technical Potential Savings, Screened at $1.70/therm

Measure Category	Million therm	$/therm
O&M Repairs	6	$0.136
Replace Heater	7	$0.514
Shell Measures	7	$0.636
Cooking	6	$0.408
Refer Heat Reclaim	6	$0.362
DHW Measures	4	$0.454
Solar DHW	1	$1.587
Replace Boiler	1	$0.178
Clothes washers	1	$0.483
New Controls	2	$0.908
New Heater	2	$0.574
New Refer Heat Reclaim	2	$0.358
New Cooking	2	$0.150
New DHW Measures	1	$0.528
New Boiler	1	$0.450
New Windows	<1	$0.969
Total	**48**	**$0.482**

Residential Sector

Figure 8 shows residential electric potential in 2017 grouped by existing and new. 28 MWa of technical potential is for new construction measures with the balance, 84 MWa, in existing construction. Lighting is the predominant opportunity. There is also significant potential for replacement of appliances, weatherization of existing buildings, and retrofit or replacement of heating systems. In new construction, lighting provides the most savings potential followed by new equipment.[2]

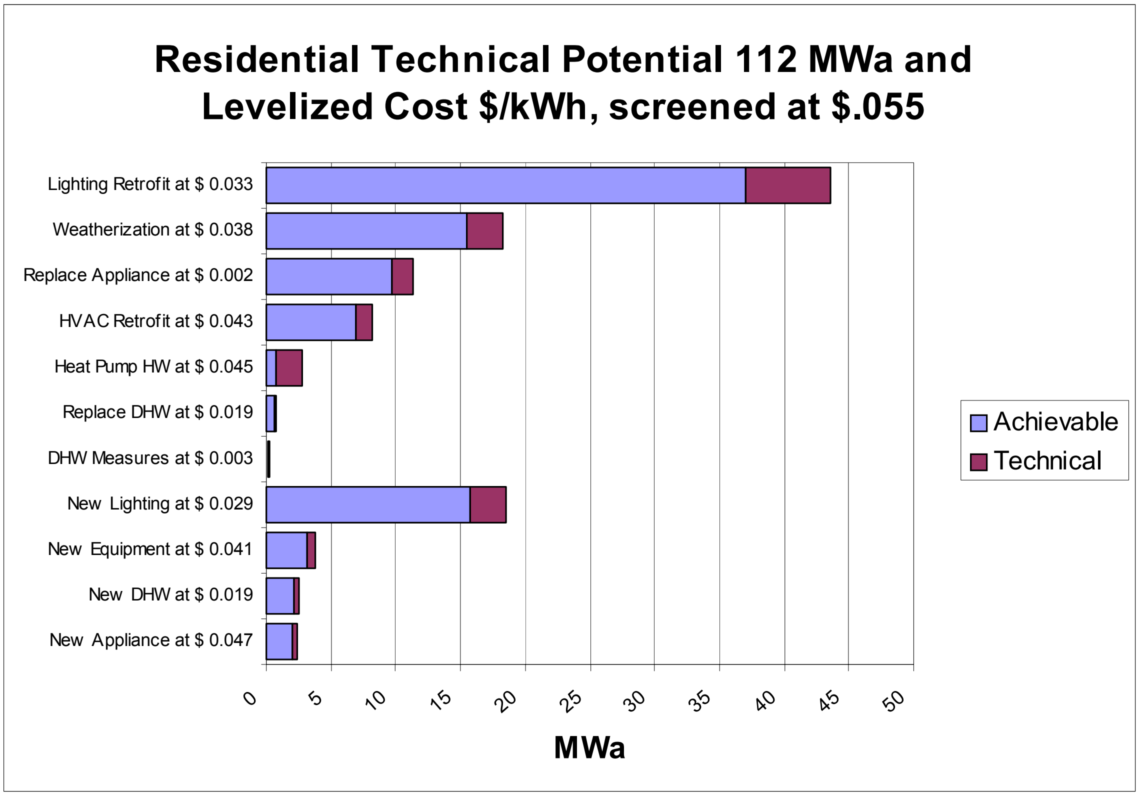

Figure 8 Major Residential Sector Measures, Electricity

[2] The new equipment category includes insulation, heat pumps, and HRV.

Table 4 Residential Sector Savings, screened at $.055/kWh

Measure	MWa Savings	Winter Peak Savings, MW	Summer Peak Savings, MW	Levelized Cost, $/kWh
Lighting Retrofit	44	45	45	$0.033
Replace Appliance (1)	11	14	12	$0.002
Weatherization	18	40	1	$0.038
HVAC Retrofit (2)	8	15	2	$0.043
Heat Pump HW	3	4	3	$0.045
Replace DHW	1	1	1	$0.019
DHW Measures	<1	<1	<1	$0.003
New Lighting	18	19	19	$0.029
New Equipment (3)	4	8	<1	$0.041
New DHW	2	3	3	$0.019
New Appliance (4)	2	3	3	$0.047
Total	**112**	**151**	**88**	**$0.031**

(1) Clothes washers, dish washers, refrigerator recycle

(2) Heat pumps, commissioning of heat pumps, duct sealing

(3) Insulation, heat pumps, HRV

(4) Clothes washers

For natural gas in new homes, the greatest opportunity lies in increasing the efficiency level of construction. Opportunities during construction include better insulation and windows, duct sealing, high efficiency furnaces[3] and heat recovery ventilation. New construction measures constitute 21 of 58 million annual therms available. The greatest opportunity for gas savings in existing buildings in is weatherization.

Upgrading to a high efficiency furnace accounts for 6 million therms within the HVAC Retrofit measure category and as an additional measure, the combination of upgrading the furnace with duct sealing contributes another 2.4 million therms.

Table 5 Residential Sector 2017 Technical Potential Gas Savings, Screened at $1.70/therm

Measure Category	Million Therm	$/therm
Weatherization Retrofit	19	$0.573
Appliance Replace (1)	10	$0.896

[3] High efficiency furnaces in new homes contribute 2.3 million therms to the technical potential

HVAC Retrofit (2)	9	$0.487
New Construction (3)	13	$1.012
New Appliance (1)	8	$0.545
Total	**58**	**$0.705**

(1) Tankless water heaters, dishwashers, and clothes washers

(2) High efficiency furnaces, duct sealing, and duct sealing with furnace upgrade

(3) Insulation, furnaces, windows, HRV

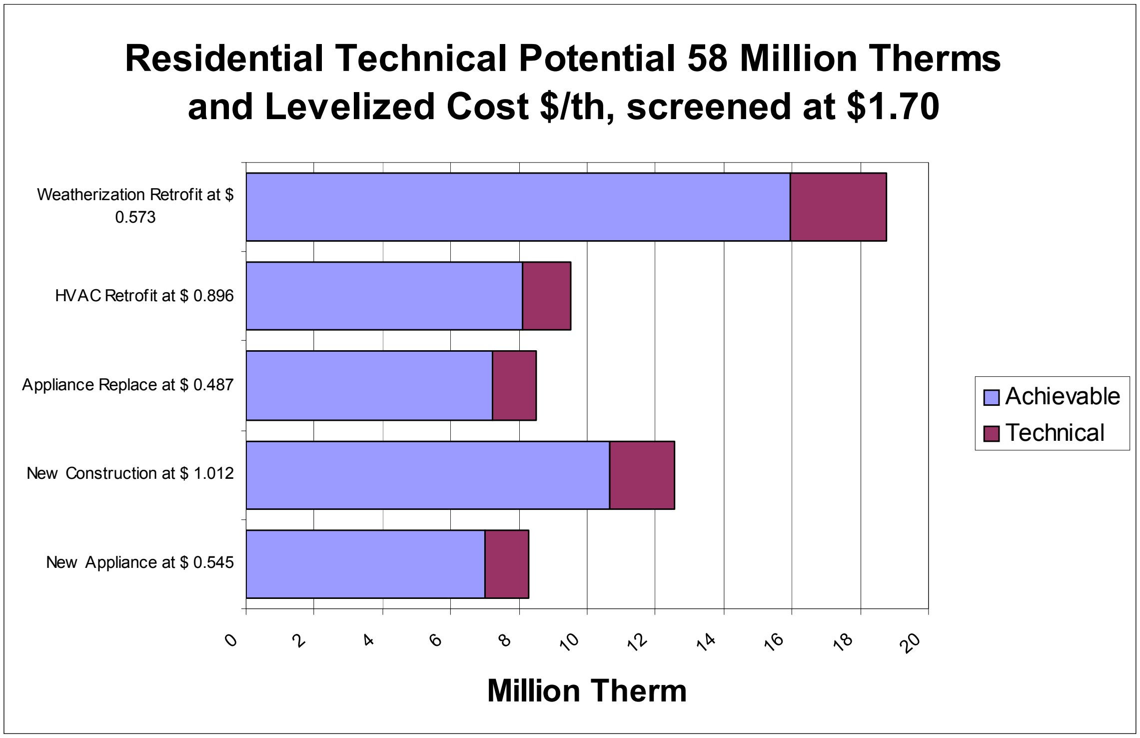

Figure 9. Major Residential Sector Measures, Gas

Note: Measure category names for new construction begin with “New”.

Emerging Technology

Emerging technologies are those that show potential savings but are still not considered mainstream in the industry. A few measures in this category deserve discussion and possible support for demonstration.

Heat reclamation from commercial refrigeration has emerged as a new measure due to recent regional market research. Although still considered emerging, it’s recognized as a significant category for gas savings in this study. Heat recovery to DHW is low cost, easy to implement and enjoys wide market acceptance. Heat recovery for space heating is more complicated and, hence, perceived as more risky and less attractive to customers. It is one of relatively few measures with large potential for gas conservation.

Heat pump water heaters are identified as having a large technical potential in both the residential and the commercial sector. However, there is no suitable product currently on the market. There is great potential for development in this area.

Similarly, Heat Recovery Ventilation (HRV) has a large technical potential in both the residential and the commercial sector. In this case, there are products available but local builders are reluctant to adopt them.

Technical Potential Savings Fraction

One perspective on the savings potential is to compare estimated savings to the amount of estimated consumption. Such a comparison may be presented as the expected fraction of end use savings. Note that the amount of consumption for new and existing building stock is quite different due to the inherently different deployment approach to achieve savings.

For existing stock, generally it is more cost-effective to replace old equipment with more efficient equipment as it wears out. We assumed that replacement of existing stock is limited to the turnover rate of the old equipment. In the case of new construction, it is technically possible to change the choice for all the new equipment at the time it is first installed. Thus, for some appliances, the potential savings fraction is higher for new installations merely because of the deployment limitations. On the other hand, because the older stock is less efficient, for some measures the existing stock offers a higher savings fraction that can be addressed.

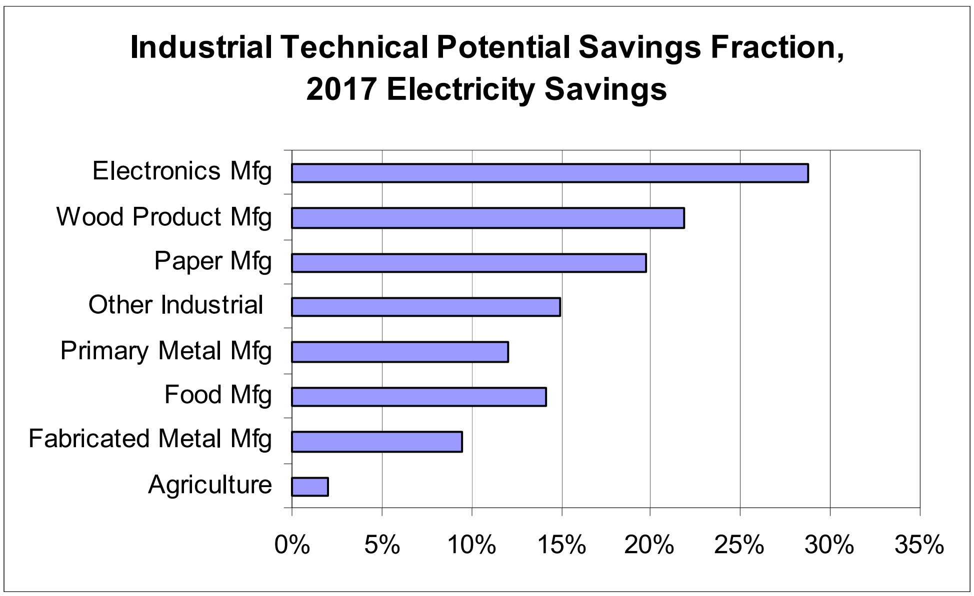

Figure 10. Savings Fractions for Industrial Sectors

Figure 10 demonstrates that our analysis focused on the sectors that account for the most energy consumption. The technical potential for the industrial sector is high and, in many cases, the cost is offset by non-energy economic benefits.

Figure 11 shows savings fractions for residential electricity consumption. The higher fraction for new Hot Water is due to the assumption that all new construction could be included while existing stock is limited to a turnover rate. Figure 12 shows savings fractions for residential gas measures.

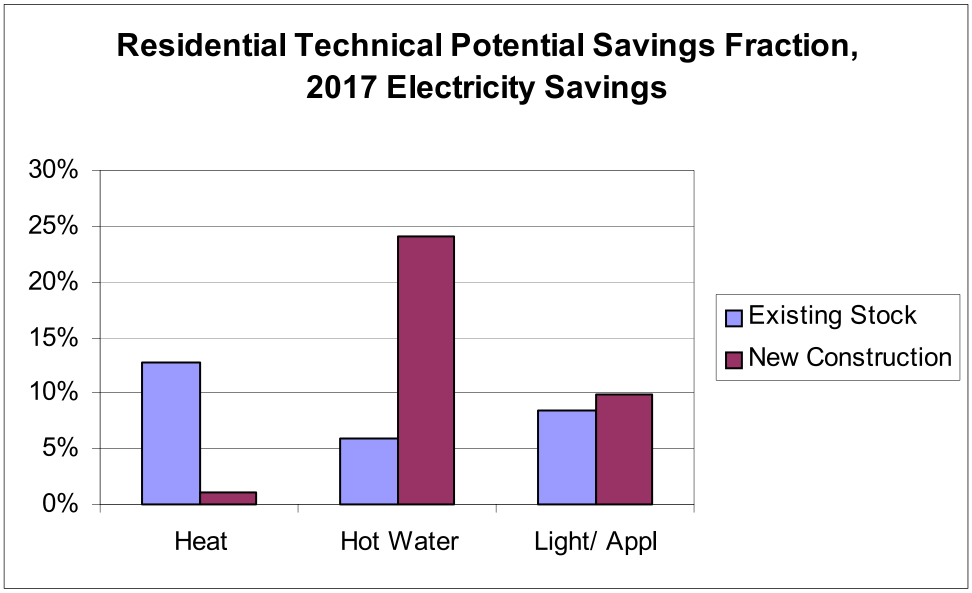

Figure 11 Residential Savings Fractions by Electricity End use

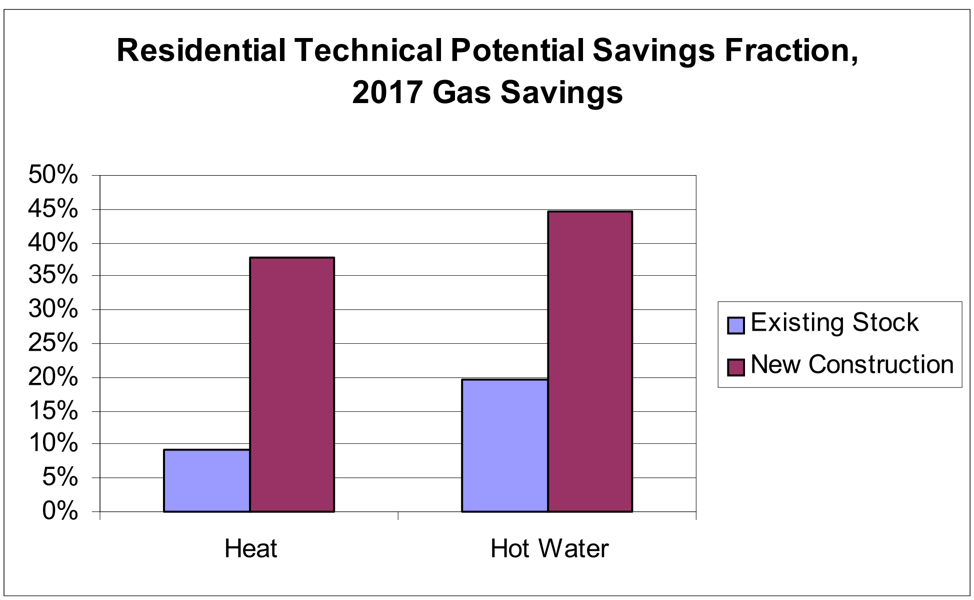

Figure 12 Residential Savings Fractions by Gas End use

Savings fractions for commercial sector are high reflecting the opportunity to use heat pumps for space and water heating.

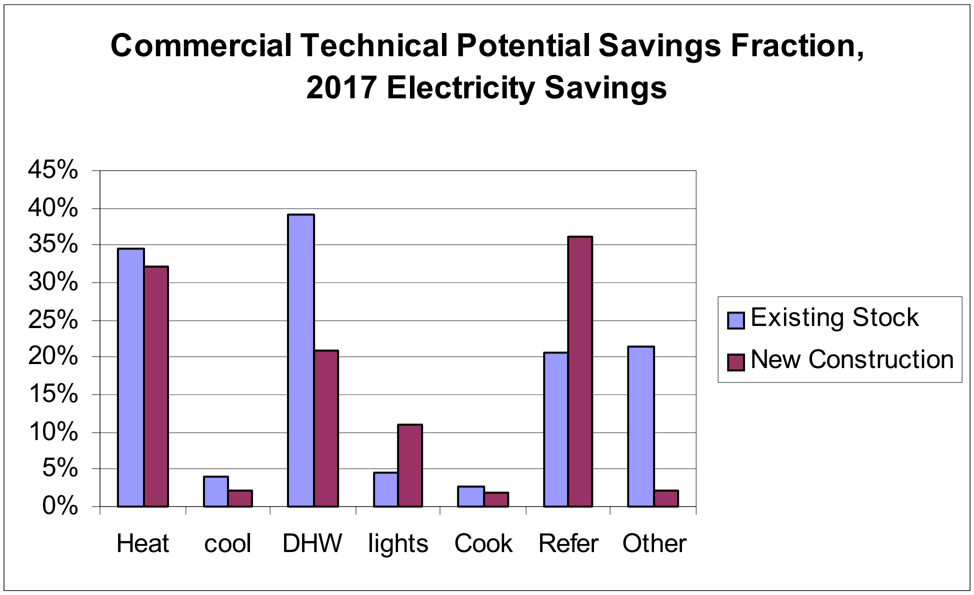

Figure 13 Commercial Savings Fractions by Electricity End use

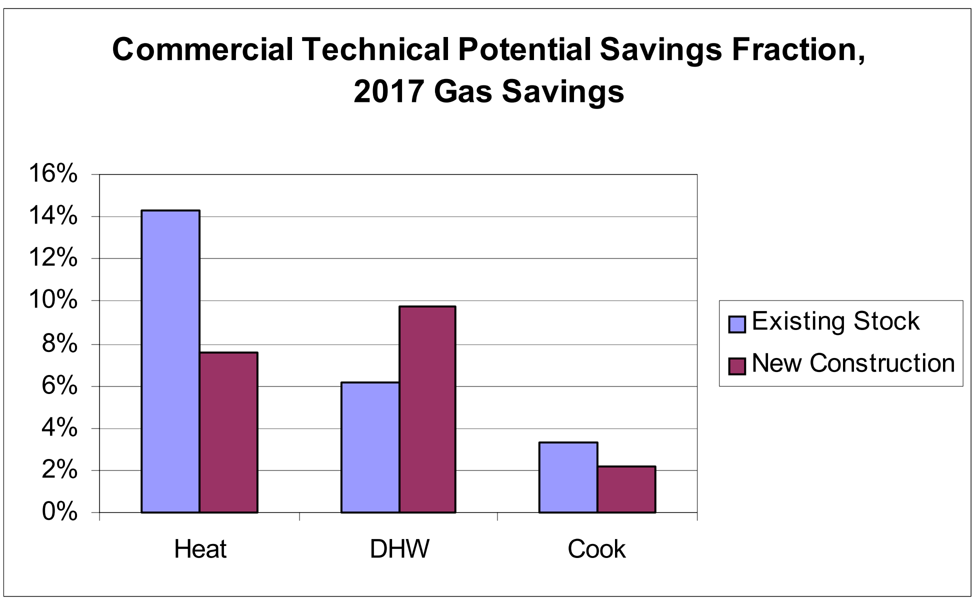

Figure 14 Commercial Savings Fractions by Gas End use

Methodology

This section describes the general methodology used in this report. Many of the assumption specifics and sources are documented in the calculation spreadsheets.

To summarize the approach, we applied the following steps in this study:

- Establish Energy Consumption Baseline.

We quantified current energy use by sector unit (residential household, commercial square footage, and industrial by typical facility) and customer type within each sector (single family, small office, wood products, etc.). It is important to understand how much energy is currently consumed for specific end uses and market segments so that the eventual savings estimates will be realistic. We utilized the utility estimates of sales by customer group and market segment and best estimates of Energy Use Index (EUI kWh/sq ft) factors to calibrate our estimates to match the actual utility sales data.

- Estimate Energy Consumption by End Use for Each Customer Type.

The methods varied by customer group. For residential sector, we applied prototype models to estimate major end use consumption, calibrated to actual sector consumption. For commercial sector, the EUI factors provided consumption by end use. For industrial sector, we estimated the “share down” factors, that is, the fraction of consumption for specific process uses.

- Forecast future consumer population.

We applied the utility forecasted growth rate to estimate the customer base available in future years.

- Compile and Screen List Of Measures, Develop Measure Details

We reviewed information on specific measures for applicability to ETO territory customers. This information includes estimates of incremental cost and savings but also assesses the market potential for specific measures. Applicability of some measures might depend on the fuel for space heating, for example. Also the amount to which the market is currently saturated affects the amount of remaining potential. We focused on measures with significant savings for a significant portion of the housing, building, or equipment stock in question. The intention was not to represent every possible measure, but represent the available cost and savings by choosing the most significant measures.

- Implement Worksheet Tool To Aggregate And Sum Conservation Potential.

We developed a series of worksheets to compute the savings potential and cost for each measure and customer type, then results are aggregated for an estimate of the total potential.

Data Collection

To develop the inputs required by the tool, the team utilized a wide variety of resources. A literature review was conducted to collect equipment and O&M costs and energy savings. This review was augmented by internal data developed by the team members for use in prior projects. Where available, the Northwest Power Planning Council’s

(NPPC) Regional Technical Forum (RTF) data was utilized in the residential sector to collect costs and energy benefits. In addition, the NPPC libraries provided cost and benefit data for many of the commercial sector measures. In some cases, technical papers or data provided by manufacturers was used. Energy Trust historical program data and measure screening analysis also provided data input for the study. The data source(s) used for each measure are noted in the Notes and Sources section of each measure workbook.

To determine the applicability of measures to the Energy Trust service territory and to assess market conditions, economic and census data was collected from Economy.com and from the U.S. Census Bureau and the Department of Housing and Urban Development. Population estimates were also collected from the Portland State University Center for Population Studies and from the Manufactured Housing Association.

Where available, public documents prepared by the individual utilities were used to generate electricity end use or device saturation and penetration rates for the Energy Trust service territory. Where not available, these rates were extrapolated from county- or state-level data.

Assessment of Potential Measures

In the industrial sector, the 2003 assessment identified 30 potential measures. We added additional measures applicable to specific sectors and based on opportunities identified in the current program. These included three measures for agricultural irrigation, three for paper manufacture, two for wood products and 14 for electronics sector.

In the commercial sector, the 2003 assessment listed 58 measures. After review of other measures adding gas measures and some redefinition, we utilized 171 measures in this sector. Each measure is developed separately for 12 building types.

In the residential sector, the 2003 assessment listed 70 measures. After review of other measures adding gas measures, we utilized 125 measures in this sector. Each measure is developed separately for three building types.

The measures identified in the initial list of measures were then analyzed for cost and performance in the Energy Trust service territory. We used a wide variety of resources to develop measure specific inputs for this study. We conducted a literature review to collect equipment and labor costs and energy benefits. Energy Trust project data and measure cost effectiveness screening models were combined with Northwest Power Planning Council's Regional Technical Forum (RTF) data and other regional sources for measure costs, savings, and non energy benefits assumptions. We studied the Oregon market to identify the total market size, infrastructure, climate, energy use, energy costs, and other variables that impact the usefulness of each of the measures in the particular market served by the Energy Trust

The study is structured to present efficiency potential by measures directed to "New Construction", "Retrofit" or "At Replacement". "At Replacement" applies to the annual turnover of equipment in any year. We can also compute this resource as a cumulative total for a future year. Retrofit applies to upgrading existing equipment that has not yet reached its useful life.

For each measure, we attempted to identify and quantify the potential market for which that measure was applicable. While this is relatively straightforward in the residential sector and only slightly problematic in the commercial sector, it is very difficult to provide the same level of detail for a technical potential assessment in the industrial sector. Nevertheless, we have provided an approximate technical potential for each measure that can be used to estimate overall program size and savings potential.

To calculate the cost of each measure, the following assumptions were generally followed. Where appropriate, exceptions have been noted within the measure workbook. Only actual equipment and labor costs were included in the measure cost calculation used in this analysis. In addition, incremental costs (or savings) related to differences in operations and maintenance were considered in the cost analysis. We did not consider program administrative costs, marketing or other overhead expenses.

For each measure, the incremental cost of the equipment examined in the measure over that required by the relevant energy code was used where applicable in new construction, renovation and replacement markets. The entire cost of substitute equipment was considered in retrofit situations[4]. These measures generally examine one-for-one equipment selections so all other costs are assumed to be the same. In cases where additional installation costs would be associated with the equipment in the measure, these incremental costs have also been included.

The impact of the measure on O&M expenses was calculated and included in the cost-effectiveness analysis. In some cases, there are negative O&M costs – that is, non-energy benefits – that are included in the analysis. In planning terms, we utilized a cost that represents the full societal cost or total resource cost (TRC).

For the technical potential savings analysis, we assumed that the measure would be applied to all applicable situations and where no related measure was applied. For retrofit measures, we assumed that the existing population would be addressed to the extent possible. For replacement measures, we first calculated a replacement rate and then assumed that the measure was applied for the cumulative number of replacements up to the target year. For ”new “ measures in new construction, we assumed that all of the applicable new construction was treated every year. Growth rates were developed based on utility projections. For replacement and new measures it is important to specify a target year sufficiently into the future that significant new resource will be counted. We utilized the year 2017 as a target year for assessment.

Retrofit and Replacement can be in conflict – if one does a retrofit that efficiency opportunity is no longer available to become a replacement candidate later. At the same time, there are measures that occur only as retrofit or only as replacement options. We worked with the measures in various ways to assure that Retrofit and replacement would not be “double-counted”. Often, the retrofit is much more expensive because the

[4] A retrofit situation is where working equipment might be replaced with more efficient equipment primarily for energy savings purposes.

replacement is only an incremental cost over replacement with a less efficient but otherwise similar piece of equipment. In cases where retrofit was clearly more expensive than grid power and pipe gas, but replacement was feasible, we ruled out the retrofit as not feasible. Another option was to compute the cumulative replacements and remove those from eligibility as retrofits. The Resource Assessment spreadsheets allow the analyst to choose an approach.

Another potential conflict can occur when two technologies go after the same energy end use. For example, heat pump water heaters and solar water heaters are competing technologies. In these cases, we divided the market between the two options to avoid double-counting.

Since we are dealing with two fuels, we must be aware of some other factors. In general, we can develop a supply curve for only one fuel at a time. That is, the gas and electricity supply curves are independent. Of course, that does not mean that efficiency opportunities for the two fuels are always independent – many measures save both electricity and gas on the same site (e.g., building energy management system) and many markets can only be effectively approached by a dual fuel program (e.g., new homes). This merely means that the impacts of investment in one fuel on energy use for the other are not captured in the supply curve graph. These impacts are maintained in the output tables and they do influence the levelized cost.

Tool Selection and Use

One of the primary goals of this project was to develop a method of analyzing measures across sectors and technology types that would provide a means of comparing anticipated costs and benefits associated with a variety of program options. A spreadsheet-based tool was adopted and modified for this purpose.

The Assessment Tool selected by the team includes several favorable features:

- Standardized program assumptions. This spreadsheet tool allows the same set of program assumptions for each measure, so that differences in the results of the analysis of any two measures were impacted only by the variables of interest (cost, benefits, technical potential).
- Updateable. The measure cost and performance, market penetration and other inputs into the tool can be easily changed to analyze a particular measure under a variety of program and cost conditions. For example, Trust personnel can easily modify the cost of the measure or number of program participants and calculate a new levelized cost.
- Consistent analysis approach. Team members individually assessed the measures with expertise in particular areas. The use of this tool ensured that measure assessments performed by different analysts were comparable.
- Record of assumptions, sources, etc. The input requirements of the tool provide a record of the data and processes used by the analysts to develop levelized costs. We believe this will be extremely informative and provide insights to the Trust that will be helpful during program design, particularly in cases where

multiple measures are combined into a single conservation package targeted at a particular customer, sub sector or building type.

Tool Limitations

While the strict data input structure of the Assessment Tool provides a consistent way to compare measures across sectors, it does impose some limitations:

- The total measure costs and benefits calculations are based on an estimate of the number of cases for which the measure is applicable; i.e., the program participation was estimated to be the total technical potential. These figures will need to be adjusted for programs that target only a portion of the identified market.
- The tool does not allow multiple-measure “what if” analysis. While we have assessed a number of combined-measure packages, the costs and benefits must be calculated and combined outside the tool and entered as one set of assumptions.
- The tool provides limited flexibility. The tool we selected did not provide optimum flexibility to analyze measures by sub sector or across sub sectors without creating multiple worksheets. While this did impose some limits on the analysis methodology, the strict requirements of the tool ensure that comparable computations across all types of measures and sectors are made.

Supply Curve of Conservation Measures

The results of our assessment are provided in the form of separate spreadsheets for the residential, commercial and industrial sectors (see end tables for the final lists of measures). For each measure or package of measures, we developed cost and savings estimates (including peak load savings), as well as an estimate of overall achievable energy savings over the next ten years. To generate both the costs and savings impacts over time, we assumed that the measure was applied to all potential candidates. These calculations could change considerably as specific programs are developed, but provide an overview of the maximum potential available from each measure. As a final step, the list of measures was ranked by overall cost-effectiveness.

Levelized Cost Calculation

To compare and prioritize measures, we calculate the levelized cost for each measure opportunity. The levelized cost calculation starts with the incremental capital cost of a given measure or package of measures as described previously. We add the present value of any net operation and maintenance (O&M) cost. The total cost is amortized over an estimated measure lifetime using a discount rate (in this case a real discount rate of 3 percent/year, which is the standard value used by Energy Trust. This annual net measure cost is then divided by the annual net energy savings (in kilowatt-hours or therm) from the measure application (again relative to a standard technology) to produce the levelized cost estimate in dollars per kWh saved, as illustrated in the following formula.

$$Levelized\ Cost = \frac{Net\ Annual\ Cost\ (\$)}{Net\ Annual\ Savings}$$

The levelized cost is a figure that can be compared with the full cost of delivering power from electricity generation options. The levelized cost approach was chosen as the most practical and useful method of comparing measures of various types and applications.

In dealing with two fuels (electricity and natural gas), we must be aware that there are cross-impacts. For example, a lighting program will save electricity but increase consumption of natural gas for space heating. In this case, we compute the Net Present Value (NPV) based on the avoided cost of natural gas and add that value to the O&M component of cost.

A more complicated case occurs when the same measure has positive savings for both fuels. In that case, we compute the NPV of avoided cost for both fuels and use the ratio of the NPV's to apportion the measure cost between the two fuels. Thus, both fuels would see a reduced levelized cost because they are only "charged" for part of the measure cost.

The final result of this analysis provides the cumulative amount of potential resource available at a given levelized cost, as shown in Figure 1.

Industrial Sector Resource Assessment Results

A list of the recommended industrial measures, ordered by the levelized cost, is provided in Table 7. This list presents individual measures, with incremental capital costs and net operations and maintenance costs (or benefits—shown as negative O&M costs) expressed in units of kWh of annual energy savings by the measure. In the section that follows, we provide a discussion of the potential application of these measures, as well as selected recommendations regarding potential program designs for the industrial sector.

Industrial Sector Characterization

There are several important caveats to understanding the industrial approach. First, it is a top-down assessment. That is, it estimates the potential for conservation starting with MWh sales. (This approach differs from the residential and commercial sectors, which build up from an estimate of the number of customers.) The study found that current sales are much smaller than estimated in 2004. The previous study started with 2000 state-wide sales, assumed robust economic growth and applied an estimated fraction to the state total in order to estimate sales in Energy Trust territory. In fact, economic growth has not been robust – the electronic sector in particular suffered from business reverses and one large paper plant withdrew from the territory. Actual sales were about 60% of the 2004 estimate. One sector that didn't follow this trend was the Wood Products sector where we found sales were twice the 2004 estimate.

Energy Trust serves participating industries but they have the option of self-direction. In fact, some industrial customers are transmission customers only for the utilities. For this study, we did not remove any of these loads – that is, these results apply to all the industries within Energy Trust territory regardless of whether they are currently eligible for Energy Trust programs.

We applied the same forecasted growth rates as used by the utilities in their planning to project future MWh sales.

To the extent that a customer produces their own electricity, we need to include that generation as part of overall consumption.

Error! Reference source not found. shows our estimate of current industrial consumption, including self-generation where that is significant.

Paper, wood products and computer equipment manufacturing are the top electricity users in the service territory. Together, these industries used approximately two-thirds of the industrial electricity consumed.

We examined the potential for further generation (CHP) but found it too difficult to generalize. Accordingly, CHP is an additional opportunity not included in this study.

The next step is to estimate how the electricity sales are distributed to various end uses and processes within the facility. Table 6 shows the estimated shares for various processes within each type of facility.

We reviewed the current program list of committed projects in determining the extent to which further measures are applicable. For example, where one paper plant has adopted a new technology under the Trust program – that measure is no longer applicable. In general, the currently committed projects account for savings of a few percent within industrial segments – so there is still plenty of remaining opportunity.

It is difficult to estimate the extent to which industrial opportunities that are technically possible are achievable in the real world. We rated measures loosely as high (85% achievable), medium (50% achievable) or low (25% achievable) based on judgment.

The following discussion of measures is divided into two groups. Cross-cutting measures, such as efficient motors, apply across all market segments. Sector measures apply only to specific industries.

Table 6 Industrial Process Share downs

	Percent Electricity by End Use															
	Motors									Process Heating						
	Pumps	Fans and Blowers	Compressed Air	Material Handling	Material Processing	Low Temp Refer	Med Temp Refer	Pollution Control	Other Motors	Drying and Curing	Heat Treating	Heating	Melting and Casting	HVAC	Lighting	Other
Comp & Elect Mfg	27%	10%	5%	3%	10%	5%		3%				5%		25%	3%	4%
Paper Mfg	26%	16%	5%	10%	17%			3%	5%	3%				1%	2%	12%
Primary Metal	2%	4%	4%	9%	6%			7%		2%	4%	20%	8%	2%	3%	29%
Fab Metal Mfg		10%	4%	10%	24%			1%	5%	3%	6%			3%	10%	24%
Food Mfg	8%	5%	4%	4%	9%	42%	12%		5%	1%				2%	8%	
Wood Mfg	3%	10%	12%	31%	23%			3%	4%	3%				1%	7%	3%
Agriculture	25%	20%		10%			10%								5%	30%
Other Manf	22%	5%	8%					1%				3%		2%	10%	49%
Total	17%	10%	6%	11%	13%	4%	1%	3%	2%	2%	1%	3%	1%	7%	5%	15%

Table 7 List of Industrial Measures

Measure Name	Incremental Cost ($/kWh)	O&M Cost ($/Yr/kWh)	Levelized cost ($/kWh)	Potential Savings (MWa)	Status
Irrigation: Ditch > Pipe	$0.074	-$1.010	-$1.001	<1	available
Electronics: Wastewater preheat of OSA	$0.419	-$0.232	-$0.183	5	available
Metal: New Arc Furnace	$0.080	-$0.160	-$0.151	1	available
Electronics: Exhaust Injector	$0.437	-$0.135	-$0.083	19	available
Electronics: Solidstate chiller	$0.493	-$0.123	-$0.082	11	emerging
Metal: Net Casting	$0.585	-$0.113	-$0.044	3	available
Wood: Replace Pneumatics	$0.275	-$0.061	-$0.037	16	available
Metal Fab: UV Curing	-$0.079	$0.000	-$0.009	<1	available
Electrical Supply System Improvements	$0.010	-$0.010	-$0.008	27	emerging
ASD Motors	$0.067	-$0.013	-$0.007	1	emerging
Sensors and Controls	$0.020	-$0.003	-$0.001	3	available
Electronics: Reduce pressure, gases	$0.001	-$0.001	-$0.001	1	emerging
Ag: High Draft Fans for Barns	$0.000	$0.000	$0.000	<1	available
Pump Efficiency Improvement	$0.154	-$0.018	$0.000	8	available
Motor Management (Prevent. Maint.)	$0.140	-$0.010	$0.002	1	available
Air Compressor Sensors	$0.042	$0.000	$0.003	1	available
Fan system improvements	$0.030	$0.000	$0.004	1	available
Paper: Refiner Mod	$0.043	$0.000	$0.004	7	available
Advanced Lubricants	$0.013	-$0.007	$0.006	2	available
Motor Systems O&M Optimize	$0.057	$0.000	$0.007	14	available
Electronics: Clean Room HVAC	$0.103	$0.000	$0.007	2	available
Food: Cooling and Storage	$0.109	$0.000	$0.009	1	available
Paper: ChlorOxy Mod	$0.114	$0.000	$0.010	1	available
Transformers	$0.188	$0.000	$0.010	15	available
Paper: Vapor Recompression	$0.007	$0.014	$0.014	1	available
Air Compressor O&M	$0.015	$0.000	$0.015	4	available

Measure Name	Incremental Cost ($/kWh)	O&M Cost ($/Yr/kWh)	Levelized cost ($/kWh)	Potential Savings (MWa)	Status
Wood: Soft Start Press	$0.185	$0.000	$0.015	1	available
Duct/Pipe Insulation	$0.090	$0.002	$0.016	5	available
Efficient Lighting Fixtures and Lamps	$0.250	$0.000	$0.017	1	available
Food: Refrig Storage O&M	$0.051	$0.000	$0.018	1	available
Irrigation: Pump Systems Adjust	$0.215	-$0.057	$0.019	<1	available
Electronics: CW to gas plant	$0.163	$0.000	$0.019	<1	available
Electronics: New chiller/tower, 2 loops	$0.176	$0.000	$0.021	7	available
Electronics: Eliminate exhaust	$0.181	$0.000	$0.021	2	emerging
HighBay Lighting	$0.160	-$0.022	$0.021	7	available
Electronics: New air compressor	$0.183	$0.000	$0.021	1	available
Electronics: VSD tower pumps	$0.200	$0.000	$0.023	<1	available
Electronics: Chiller optimize	$0.187	$0.011	$0.033	3	available
Efficient Lighting Design	$0.499	$0.000	$0.034	1	available
SR Motor	$0.384	$0.000	$0.045	1	emerging
Electronics: Change filter strategy	$0.049	-$0.002	$0.049	4	available
Generic O&M	$0.000	$0.050	$0.050	21	available
Microwave Processing	$0.450	$0.000	$0.053	<1	available
Electronics: Reduce CW pressure, reset CHW	$0.494	$0.000	$0.058	<1	available
Irrigation: Nozzles	$0.222	$0.000	$0.078	<1	available
Irrigation: Water Management	$0.179	$0.067	$0.106	<1	available
Electronics: Chiller heat recovery	$1.071	$0.000	$0.126	<1	available
Advanced Industrial HVAC	$0.650	$0.050	$0.126	1	available
Other: Wastewater Biomanagement	$0.001	$0.258	$0.258	3	available
Irrigation: Pump Systems Repair	$1.693	-$0.010	$0.262	<1	available
Metal Fab: IR Heating	$0.450	$0.375	$0.427	<1	available
Food: RF Heat	$0.450	$0.500	$0.553	<1	emerging
Electronics: Vacuum Pump Upgrade	$0.809	$0.768	$0.945	4	available

Note: Shaded measures are not cost-effective by the screening criteria used for this analysis.

Cross Cutting Measures

Electric Supply System

Two broad energy efficiency opportunities exist at the internal plant electricity distribution level. Equipment not operated at its original electric supply specifications may experience efficiency and performance degradation. In particular, over- or under-voltage conditions and unbalanced phases can significantly reduce the efficiency (for example, by 5 percent) of motors while also leading to premature equipment failure. Surveys have indicated that these conditions are far more common that is normally recognized. While incrementally the electricity savings and financial costs of voltage and phase correction are both modest, the pervasive nature of the problems addressed means that these corrections in internal plant power quality can result in significant savings (Nadel et al. 2002). Because this opportunity is seldom recognized, we assumed a low achievable potential.

Transformers

Similarly, all electric power passes through one or more transformers on its way to service equipment, lighting, and other loads. Currently available materials and designs can considerably reduce both load and no-load losses. The new NEMA TP-1 standard is used as the reference definition for energy-efficient products. Tier-1 represents TP-1 dry-type transformers while Tier-2 reflects a switch to liquid immersed TP-1 products. More efficient transformers with attractive payback periods are estimated to save 40 to 50 percent of the energy lost by a "typical" transformer, which translates into a one to three percent reduction in electric bills for commercial and industrial customers. Typical paybacks range from 3 to 5 years (Nadel, et al. 1998). Unfortunately, the application of high-efficiency transformers offers no significant non-energy benefits, which limits adoption of this measure in commercial and industrial applications. For that reason, we assumed a low achievable potential.

Motor Management (Preventative Maintenance)

Since almost two-thirds of industrial electricity flows through motors, motor efficiency is a logical focus for efficiency opportunities. Motors are inherently efficient devices, and the implementation in 1997 of the minimum-efficiency standards in Energy Policy Act of 1992 (EPAct) eliminated the least-efficient products from the new-motor market. A new standard, NEMA Premium™, defining energy efficiency criteria for more efficient motors, was introduced in 2001, and several advanced motor designs (including copper rotor, switch reluctance and written-pole motors) are becoming available. While the NEMA Premium motors are cost effective in many high-use industrial applications, the current potential for advanced motors is limited by their cost.

Many experts feel that focusing on changing the existing motor stock is more important, because motors can last for more than 30 years, so most motors now operating are pre-EPAct. Under normal circumstances, these motors will be repaired four times before being replaced. As a result, the focus needs to shift to affecting repair and replacement decisions. The foundation of this activity is the implementation of motor-management plans at industrial facilities, which is the major focus of the national Motor Decisions Matter ™ initiative, sponsored by "a consortium of motor industry manufacturers and service centers, trade associations, electric utilities and government agencies" (see http://www.motorsmatter.org/). This initiative focuses on affecting planned motor repair and replacement decisions to encourage replacement of old motors with new EPAct or Premium motors, and to ensure that motors are repaired properly so that their efficiency is maintained. In addition, these improved management practices can lead to greater motor system reliability, resulting in very substantial improvements in productivity and reductions in process downtime (Nadel et al. 2002). Because motor replacement has been a previous program focus and because it is well understood by the industry, we assume a relatively high achievable potential.

Advanced Lubricants

A related motor O&M measure is the use of advanced lubricants. While these engineering lubrication products have been on the market for more than twenty years, they have seen somewhat limited market penetration due to their significantly higher cost compared with conventional petroleum-based lubricants. These advanced lubricants, however, offer a number of distinct advantages. In addition to energy savings, these advantages include extended re-lubrication intervals. Life-cycle savings in labor and lubricant often more than offset the higher lubricant costs. In addition, since the leading cost of rotating equipment failure is bearing failure, the improved lubricant life has been demonstrated to improve equipment reliability (Nadel et al. 2002). Due to ease of implementation, we assume a high achievable potential.

Motor Systems O&M Optimize

A number of techniques have been used for many years to assess the performance of motors. These techniques have ranged from monitoring the temperature of bearings, monitoring vibration, and measuring the voltage and currents for the different phases, to extensive test bench evaluations for performance and efficiency. These tests can detect changes in motors that indicate that it should be resized for a changing load, repaired or replaced before it fails. However, in the past these test procedures have been labor intensive and expensive, often requiring that the motor be removed from service. As a result, these tests are infrequently used, and the motor is left in service until failure (Nadel et al. 2000).

Over the past decade, a number of new diagnostic devices have been introduced that make in-service testing much easier. These tests make use of advanced sensors and on-board computing to measure temperature, voltage, current, harmonics and flux density. These data allow for various analyses such as current signature that can assess performance and efficiency and detect problems before they lead to an in-service motor failure, allowing them to be repaired during normal service cycles (Nadel et al 2000). While there may be some secondary energy savings, it is unclear that this family of technologies offers any direct energy savings. The primary benefit is reduced downtime (Boteler 2000). Conditioned-based monitoring of motors offers a number of significant non-energy benefits. By identifying motors prior to failure, additional damage resulting from the failure can be avoided, thus reducing repair costs and avoiding potential permanent damage to the motors (Nadel et al 2000). By preventing most in-service failures, system availability is significantly increased, thus increasing annual throughput. This additional production capability can avoid the need to make capital investments to expand production (Boteler 2000).

The major barriers to the adoption of motor diagnostics are the first cost of the equipment and the need to implement management practices necessary to realize the benefits. Case studies and education of end-users on the benefits are the most important actions to encourage more rapid adoption of the technology. Several programs, such as those offered by Sacramento Municipal Utility District and the Northwest Energy Efficiency Alliance have already begun to development programs to build customer awareness of this technology (Nadel, et al., 2000).

While small differences in motor efficiency can result in significant energy savings, even greater savings can be realized through improvements in the efficiency of the systems that electric motors operate. A number of related system opportunities exist, including efficiency improvements in pump, fan and compressed air systems. While some opportunity for savings exists in the selection of more efficient pumps, fans and compressors, the greatest opportunity involves correctly sizing the equipment to meet current operating demands. This frequently involves removing dampers and pressure-reducing valves, and instead reducing system pressure, slowing the fans, or trimming pump impellers. In many cases, the motor that runs the system can then be downsized, moving its operating point to a range of greater efficiency. In compressed air systems, there is a particularly large opportunity for the elimination of inappropriate applications of compressed air, which has been shown to waste up to 50 percent of the compressed air produced (Nadel et al. 2002). Because these are small measures to implement, we assume a high achievable potential.

ASD Motors

Adjustable speed drives (ASD) have revolutionized motor systems by allowing for affordable, reliable speed control using rugged conventional induction motors. ASDs work by varying the frequency of the electricity supplied to the motor, thus changing the motor’s speed relative to its normal supply frequency, which in the U.S. is 60 Hz. This trick is accomplished by rectifying supplied alternating current to direct current and then synthesizing an alternating current at another frequency. The current method of synthesization is accomplished using an inverter, which is a solid-state device in modern ASDs. Ideally, the waveform of this synthesized current should look like a smooth sine wave. Unfortunately, the three major kinds of inverters in use: voltage-source (VSI), plus-width modulation (PWM) and current-source (CSI), with PWM being the most common used in integral horsepower drives. All create an approximation of a sine wave, though with some distortion. This distortion creates losses in the motor due to heating of the conductors and vibration, which have the effect of shortening the life of the motor. Special inverter duty motors are made which use a higher rating of insulation that extends motor life. The ideal solution would however be to design an inverter that produced a smoother wave pattern (Nadel et al. 2000).

A number of researchers are actively working on the development of different inverter topologies (Peng 2000, von Jouanne 2000). Most of these topologies fall into the category of soft-switching inverters, which significantly reduce the voltage spikes that characterize PWM inverters. Reductions in these spikes can dramatically increase the life of the attached motor (Kueck 2000). One example of this technology is the snubber inverter developed at Oak Ridge National Laboratory. ASDs using this technology have an efficiency of about 98 percent compared to a PWM drive at 96 percent efficiency, for drives operating in the 10-20 kHz range. These soft-switching inverters enable the design of faster switching devices, which can further improve the waveform of the output (Peng 2000). Several manufacturers, including Rockwell Automation and Allen Bradley, have begun to offer softswitched inverters as premium products for use in sensitive applications such as medical devices. While these advanced inverters require more complex control strategies than do PWN inverters, they allow the substitution of semiconductor devices for electronic components such as filters. In addition, the improved inverter efficiency will make thermal management in the drives easier, reducing the mass of heat sink required and allowing for more compact packaging of the drive. These tradeoffs are likely to reduce the cost to about the same level as PWM drives. In the long run, soft-switching inverters could displace PWM inverters in most applications if the costs can be brought down (Peng 2000).

These drives face a number of barriers. The most significant appears to be the cost of these drives due in large part the manufacturers' investment in existing technology. Another issue is that of intellectual property. While manufacturers have expressed interest in licensing the ORNL technology, they were unable to come to terms with the Lab. They have subsequently developed their own soft-switching technology (Peng 2000).

Even greater system savings can be achieved through the optimization of the motor-driven system. This opportunity results from a systematic evaluation of the process system to determine the optimal flow and pressure requirements serviced by the motor system. These evaluations can be time-consuming and often require the use of external engineering contractors, but the savings achieved through system optimization can be dramatic—often exceeding 50 percent of initial system electricity use. Once the actual operating requirements are identified, motor-driven equipment can be correctly sized, and speed control technologies including adjustable speed drives can be effectively applied as part of a system control package. In addition to significant energy savings, system optimization in most cases results in improvements in process control and product quality (Nadel et al. 2002). Because these are large, complex projects, we assume a low achievable potential.

Sensors and Controls

A key element to implementing system optimization is the application of sensors and controls. These allow processes to be monitored and systems adjusted to minimize energy consumption. Perhaps more importantly from the consumer's perspective, these systems allow better control of the process that can improve product quality and reduce scrap rates. Since most scrap and waste generating events occur towards the end of the production process when the imbedded energy content is greatest, the resulting waste reduction can reduce in significant net energy savings, as well as other productivity and cost benefits (Martin et al. 2000). This measure is poorly understood by the customer but has the benefit of being vendor-driven. Accordingly, we assume it is moderately achievable.

Industrial HVAC

Because industrial HVAC (heating, ventilation, and air conditioning) use more electricity in the ETO service territory than the nationwide average, improvements in these end-uses represent relatively greater savings opportunities than in other locations. In part, the high consumption is due to industrial process areas (such as electronic clean rooms) require a level of environmental control that exceeds that normally delivered by commercial building systems. Clean room HVAC is discussed as a separate measure.

Industrial Lighting

High-bay lighting, required to provide overall ambient lighting throughout manufacturing and storage spaces, is typically provided by high-intensity discharge (HID) sources, including metal halide, high-pressure sodium and mercury vapor lamps. HID accounts for approximately 60 percent of industrial lighting energy consumption (Johnson 1997). Supplementary lighting is used to provide low-bay and task-specific lighting for inspection, equipment operation, and fine assembly activities. Fluorescent, compact fluorescent and incandescent light sources are commonly used for task lighting needs and together account for approximately 40 percent of industrial lighting energy.

One measure is the replacement of HID lighting with high-intensity fluorescent lighting in high-bay applications. New high-intensity fluorescent lighting systems incorporate high-efficiency twin-tube or linear T5 fluorescent lamps, advanced electronic ballasts, and high-efficacy fixtures that maximize light output to the work plane. Each of the system components confers advantages over traditional HID fixtures. Advantages include: lower energy consumption; lower lumen depreciation over the lifetime of the lamp; better dimming options; faster start-up and restrike (virtually “instant-on” capability); better color rendition; higher pupil lumens ratings (translating into improved worker productivity and performance); and less glare (given fixture design and the more diffuse nature of the fluorescent light source) (Rogers and Krepchin 2000).

The greatest opportunity for savings in industrial lighting, however, is through improved design practices. Industrial lighting design is more challenging due to the application-specific nature of the designs and more demanding performance requirements relative to commercial design. In addition to energy savings, substantial productivity and safety benefits have been documented to result from improved industrial lighting designs (Martin et al 2000). Unfortunately, designers with industrial lighting experience are in short supply.

We broke the lighting measure into High Bay and other configurations. The cost and savings for the lighting measures are based on the same measures in commercial buildings. Since High Bay lighting and industrial HVAC are unlikely to disrupt processes, we assume a high achievable potential. However, lighting and HVAC in clean rooms and other critical environments is considered disruptive by the facility staff and we assume a low achievable potential.

Air Compressor O&M

Achieving peak compressed air system performance requires addressing the performance of individual components, analyzing the supply and demand sides of the system, and assessing the interaction between the components and the system. This "systems approach" moves the focus away from components to total system performance. System opportunities have been shown to be the area of greatest efficiency opportunity. At the system level, savings opportunities can be grouped into three general categories: leaks, inappropriate uses of CA, and system pressure level. The goal of a management plan is to minimize all three.

The best strategy to avoid further problems is to set up a prevention program that monitors the system for new leaks and fixes them as they develop (DOE 1998). Reductions in wasted air due to inadequate maintenance, leaks, and inappropriate uses can save 20-30 percent of CA energy. A system's pressure level should be set at the lowest pressure that meets all requirements of the facility. Lowering the compressed air header pressure by 10 psi reduces the air leak losses by approximately 5 percent and improves centrifugal compressor capacity by 2-5 percent. One element of this may be the application of controls. Reducing system pressure also decreases stress on system components, lessening the likelihood of future leaks (DOE 1998). It is necessary to implement an ongoing maintenance program by plant staff, which requires both awareness and technical training (DOE 1998). Most of the barriers to improved compressed air result from lack of awareness of the opportunity. The staff reductions that have become common in United States industry and a hesitation to pay for outside consultants compound this problem. The Compressed Air Challenge (CAC) has developed a CA management training program that is available for plant staff, and the Compressed Air and Gas Institute (CAGI) has developed a CA training.

Air Compressor Sensors

Most compressed air systems typically consist of several compressors delivering air to a common header. Controls match the air supply from the compressors with system demand, regulating the pressure between two levels called the control range. The objective is to shut off or delay starting a compressor until it is needed. To this end, the controls try to operate all units at full-load, except the one used for trimming (adjusting compressed air supply based on the fluctuations in compressed air demand). In the past, control technologies were slow and imprecise. This resulted in wide control ranges and higher compressor set points than needed to maintain the system pressure above a minimum level. Most systems were controlled using an approach known as cascading set points. The set points for each individual compressor would either add or subtract the compressor capacity to follow the system load. This approach led to wide swings in system pressure (DOE 1998).

Modern microprocessor-based technologies allow for much tighter control ranges as well as lower system pressure-control points. The largest benefits of these controls can be obtained in multi-compressor systems, which are much more complex and sophisticated. Controls for single compressors can be relatively simple. System controls coordinate the operation of multiple individual compressors when meeting the system requirements. In addition, to energy savings, the application of controls can eliminate the need for some existing compressors, allowing extra compressors to be sold or kept for backup. Alternatively, capacity can be expanded without the purchase of additional compressors. The reduced operating pressure will reduce system maintenance requirements. Also, a more constant pressure level can enhance production quality control by providing more precise operation of pneumatic equipment (DOE 1998).

In spite of the attractive return, there are two principal barriers to the use of this technology: higher first cost, and lack of appreciation of the importance of compressed air system efficiency. Educational efforts, such as the Compressed Air Challenge (CAC 2000), are key to the expanded deployment of these technologies. Due to relative ease of installation and suitability to vendors, we assume a high technical potential.

Duct/Pipe Insulation

ACEEE identified repair and replacement of insulation as a conservation measure. Savings apply to processes that transfer heat or cooling. Because these are relatively easy to implement, we assume they are highly achievable.

Fan System Improvements

Just as motor systems benefit from optimal design and sizing, so do fan systems. Air distribution systems are often oversized, leaky and poorly designed. ACEEE has identified a cross-cutting opportunity for all sectors. Since facility operators are reluctant to change process equipment we assume it is only moderately achievable. ACEEE has identified efficient ventilation fans as a measure for confined animal production. This is a small sub-sector in Oregon but there is some production of poultry and livestock where it might apply. Since retrofit would be relatively easy, we consider this to be highly achievable.

Generic O&M

ACEEE identified an overall opportunity for O&M that applies to all motors and processes. The measure is low-cost to implement but is short-lived. Due to ease of implementation, we assume it is highly achievable.

Microwave Processing

ACEEE identified a wide range of applications for microwave heating that apply across most of the sectors for heating operations. Since facility operators are reluctant to change process equipment we assume it is low achievability.

Pump Efficiency Improvement

Pumps consume approximately 20 percent of industrial electricity. The selection of a pump for a given application requires the consideration of the flow requirements, required delivered pressure, and the system effects. While most engineers are trained to select pumps to meet requirements as specified in a design, many motor selection decisions are based upon estimates of operating conditions that may not be close to the true operating conditions. Once a system is placed in operation, the conditions may change further, moving the pump into a range of operation that is not only inefficient, but potentially even destructive. These changes result from changes in application, such as increases, or more frequently, decreases in the flow requirements. System resistance can increase as a result of fouling and/or scaling, and the pump impeller can erode, changing its effective system curve. Many of these changes are gradual and so may not be evident (Nadel et al 2000). System improvements include installing a parallel pump in which the second pump is used as necessary. This may prevent the need to oversize the pump. For applications in which load varies, energy savings may be achieved through the replacement of throttle valves with variable speed drives (NEEA,2000).

The savings from right-sizing a pump can be dramatic. Because large pumps frequently require the largest motors at a facility, downsizing the pump can frequently also achieve significant electricity demand savings, thus reducing demand charges paid by the facility. In addition to the electricity savings, right-sizing pumps can lead to more stable system operation. Pulsation and flow variations that often result from pumps operated outside of their system curve can disrupt processes. Correction of these problems can improve product quality, and in some cases increase the capacity of systems that depend upon the pump. Sometimes the downsizing of a pump can free up space that can offer additional options for process improvements. Frequently, these benefits will be the driving motivation for project implementation (Nadel et al. 2000, Hovstadius 2000).

Many engineers understand the approach but are not experienced in conducting these analyses. Software tools, such as the pump system assessment tool developed by DOE and the Hydraulic Institute (DOE-OIT 2000b), provide a means of addressing this issue. Engineers need to be made aware of this and similar tools, and receive training in its application. The consumers must be made aware of the opportunity and encouraged to seek out these services. Because engineers understand the measure, we assume a moderately achievable potential.

Switched Reluctance (SR) Motor

Motors consume about 60 percent of industrial electricity, and a number of types of motors are available to meet specific application needs in industry. Most applications make use of a constant-speed motor, while some applications require some degree of speed control. The most common motor type is the NEMA standard poly-phase induction motor. For operations that require speed control, these motors are coupled with an adjustable speed drive (ASD). These motor/drive combinations are now reliable and cost-effective for many applications.

The switched reluctance motor is an old concept for designing a variable speed motor that has advanced recently with progress in solid-state electronics and software. The switched reluctance (SR) drive itself is a compact, brushless, electronically-commutated AC motor with high efficiency and torque, and simple construction. Available in virtually any size, the SR motor offers the advantage of variable speed capability (very low to very high) and precision control. As for its design, the motor comes as a package integrated with a controller. This setup enables some models to operate at speeds as low as 50-rpm and as high as 100,000-rpm (Howe et al. 1999). The rugged rotor of a SR motor is much simpler than that of other motors, since it has no field coils or embedded magnetic materials. However, the coils and magnets attached to the rotor can be subjected to very high stresses (Albers 1998). Both torque and efficiency are, in general, higher in SR drives (motor and controls) than in induction motors with ASDs. The current generation of SR drives have relatively flat efficiency curves with maximum efficiencies around 93 percent in integral-hp models and the low- to mid-80 percent range in fractional-hp units (Albers 1998).

Because of its simplicity, the SR motor in mass production should theoretically cost no more than, and perhaps less than, mass-produced induction motor/ASD packages of comparable size. But at this time, automating the manufacturing of integral horsepower and larger fractional horsepower SR motors is proving difficult and it is uncertain whether the hoped-for price reductions will materialize (Wallace 1998, Albers 1998, Boteler 1999). Currently, an SR motor and its associated controls, starter, and enclosure cost 50 percent more than comparably sized and equipped induction motors with variable speed controls (Wallace 1998, Albers 1998, Means 1997). This amounts to about a $2,000 premium for a 20-hp installation. For this analysis we assume that the price premium will be cut in half, to 25 percent (or $1,000 for a 20-hp motor), once SR motors are more widely adopted.

Because of their precise and wide range of speed control and their ruggedness of design, SR motors are attractive in a broad range of commercial and industrial applications. Most SR research and application in the U.S. is in fractional-hp printer, copier, precision motion tasks and appliances. SR motors are now also being used in residential and commercial washing machines. Industrial applications include manufacturing equipment, process fans and pumps, and machine (servo) control (Wallace 1998). In addition, SR motors with control systems are competing to supplant induction motors with variable speed drives in a number of applications. For example, SR motors are most attractive in new and OEM (original equipment manufacturer) installations where the full benefits of their speed control can be realized. In the future, there may be some retrofit applications for both general-purpose applications and as replacements for DC drives in process equipment, but the availability and understanding of how to use these motors has not yet progressed to the point that this is feasible. SR motors could potentially replace 20 to 50 percent of the existing general-purpose motors in service today (Albers 1998, Motor Challenge Clearinghouse 1998). We assume the middle of this range (35 percent) as the level of feasible applications once the technology matures.

The primary technical challenge facing SR motor technology is the fact that while the motor is simple conceptually, it is complex to engineer and manufacture (Wallace 1998). Unless the cost premium can be reduced, it will limit SR motors to applications that require the unique features of this motor. Noise has been an issue in some designs. The development and commercialization effort is primarily through manufacturers, OEMs, and EPRI-funded R&D. The motor's recent introduction in the Maytag horizontal-axis clothes washer should help speed the SR motor's market development (Nadel et al. 2000). Since introduction of the motor depends on the manufacturer at the national level, we assume a low achievable potential in terms of being a local measure.

Specific Industrial Sectors

Metal Sector

Primary metal production occurs in a few facilities within the Trust territory. There is one steel mill operating on recycled scrap and one exotic metal plant. Without specific audits of these individual facilities, we estimate the potential based on national level assumptions provided by ACEEE. The suggested potential should be considered as likely but not verified.

Metal: Net Casting

Currently, the casting and rolling process is a multi-step process. The liquid steel is first cast continuously into blooms, billets, or slabs. Liquid steel flows out of the ladle into the tundish (or holding tank), and then is fed into a water-cooled copper mold. Solidification begins in the mold, and continues through the caster. The strand is straightened, torch-cut, then discharged for intermediate storage (Kozak and Dzierzawski 2000). Most steel is reheated in reheating furnaces, and rolled into final shape in hot and cold rolling mills or finishing mills. Near net shape casting is a new technology that integrates the casting and hot rolling of steel into one process step, thereby reducing the need to reheat the steel before rolling it. As applied to flat products, instead of casting slabs in a thickness of 120-300 millimeters, strip is cast directly to a final thickness between 1 and 10 mm. (De Beer et al. 1998a, Opalka 1999, Worrell, Bode, and de Beer 1997). The steel is essentially cast and formed into its final shape without the reheating step. An intermediate technology, thin-slab casting casts slabs 30-60 mm thick and then reheats them (the slabs enter the furnace at higher temperatures than current technology thereby saving energy). This technology is already commercially applied in the U.S. and other countries. The energy consumption of a thin strip caster is significantly less than the current process of continuous casting. Given the narrow application (only one plant in the territory), we assume a low achievable potential.

Metal: New Arc Furnace

While modern EAFs are generally more energy efficient many technologies exist to improve energy efficiency in existing furnaces, such as process control, efficient transformers, oxy-fuel injection, bottom stirring, post-combustion, eccentric bottom-tapping and scrap preheating (Worrell et al. 1999). Several new EAF-designs are under development, which combine energy saving features like increased fuel and oxygen injection with scrap preheating (Greissel 2000, IISI 2000b). The aim is to produce a semicontinuous process with enhanced productivity through reduced resource use (e.g. refractories, electrodes) and reduced tap-to-tap times. At the same time increased product quality also demands increased feedstock flexibility (e.g. scrap, DRI or pig iron). Different developers are involved in new EAF-process design, the most important being the Twin Electrode DC (IHI, Japan), Comelt (Voest Alpine, Austria) and Contiarc and Conarc (SMS Demag, Germany). The production costs are expected to be $9-13 lower per ton steel produced (Reichelt and Hofman 1996; Mannesmann 1998), or up to a 20 percent reduction. Given the narrow application (only one plant in the territory), we assume a low achievable potential.

Metal Fabrication

This sector includes rolling and casting. In our territory, there is some steel rolling and exotic metal casting. Within this sector we also include manufacture of transportation equipment. In general, the other measures specific to this sector are the cross-cutting general measures.

Metal Fab: UV Curing

ACEEE has identified an opportunity for UV curing as an alternative to painting steps that require heat-treating. In general, the other measures specific to this sector are the cross-cutting general measures. Given the novelty of the measure, we assume low achievable potential.

Metal Fab: Infra-Red Heating

ACEEE identified an opportunity for infra-red heating that applies to metal heating operations. This measure is directed at electric savings although savings of other fuels are likely involved as well. This measure is expensive and not cost effective. We assumed it to be only moderately achievable.

Food Sector

Refrigeration in the food sector is a large energy consumer and is mainly used for freezing of vegetables. Many options exist to improve the performance of industrial refrigeration systems. System optimization and control strategies combined show a large potential for energy efficiency improvement of up to 30 percent (Brownell 1998). Opportunities include system design, component design (e.g. adjustable speed drives), as well as improved operation and maintenance practices. We focus on new system designs. Adjustable speed drives and process control systems have been discussed elsewhere. New system designs include the use of adsorption heat pumps, gas engine driven adsorption cooling, new working fluids (e.g. ammonia, $CO2$) and alternative approaches (e.g. thermal storage). Due to the wide variety, we focus on selected technology developments in the areas of gas engines, thermal storage and new working fluids. Because these are new technologies, we assume a low achievable potential.

Food: Refrigerated Storage O&M

Although the processing of frozen food tends to be seasonal, the product is stored throughout the year in refrigerated warehouses. This application is a large consumer of energy within the food sector. Simple O&M practices have been identified as providing savings. Such measures include tune-up and cleaning of compressor systems and control sensors. (DEER, 2005). Due to ease of implementation, we assume a high achievable potential.

Food: RF Heat

ACEEE has identified the opportunity for radio frequency (microwave) processing of food products. Without specific audits of these individual facilities, we estimate the potential based on national level assumptions provided by ACEEE. The suggested potential should be considered as likely but not verified. Given that the seasonal nature of the business will discourage investment, we assume low achievable potential.

Agriculture Sector

Agriculture is important to the rural economy but a difficult sector for the utility to serve. That is because these loads tend to be highly seasonal. By far the largest agricultural use is for irrigation pumping. However, the pumping season lasts for only a few months, resulting in poor utilization of the capital investment. Nursery stock has become a major part of the local economy and consumes electricity for cooling. Animal production of poultry and containment livestock is a small sub-sector with year-round requirement for ventilation and lighting.

Irrigation: Ditch to Pipe Conversion

PacifiCorp's IRP previously identified a narrow niche for this measure. A small amount of irrigation involves the pumping of water from unlined ditches. If the ditches are replaced with a piped system, there is sufficient gravity head that pumping is no longer needed. More importantly, the conversion saves water that would otherwise have leaked from the ditch. The saved water is a valuable commodity that can be used by the farmer or resold for wildlife or other users. While the applicability is small, the non-energy benefits can be large. We assume a high achievable where potential exists.

Irrigation: Pump Systems

The industry consists of multiple pump users including both farmers and water suppliers, such as irrigation districts. Irrigation is a difficult industry target for energy efficiency initiatives. However, there is inefficiency due to the fragmented nature. For instance, 80% of pumps in this industry are older than 15 years, resulting in poor efficiency. Pump efficiency tests performed by utilities were discontinued in the early 1990s due to budget constraints. As a result, awareness of energy efficiency and operating cost savings as well as knowledge of new technologies has decreased. Efficiency initiatives could be targeted at creating awareness of such practices as properly sizing pumps and replacing older equipment (NEEA). Pump efficiency testing and impeller improvements have long been part of program in the Northwest. Net savings from pump testing and impeller improvements are unclear, difficult to verify and not long-lived. We considered these savings to be moderately achievable.

Irrigation: Water Management

Scientific scheduling of irrigation utilizes direct measurement of soil moisture combined with local meteorological forecasts of crop transpiration. The result is a way of determining the proper amount of water to apply at just the right time. Net savings are unclear, difficult to verify and not long-lived. We considered them to be moderately achievable.

Paper Sector

Paper manufacture is one of the largest industrial consumers. Trust territory includes only a few firms but they have been actively participating in the efficiency program. For the most part, these firms produce different products and do not compete with each other. That also means that conservation measures appropriate to one plant are probably not transferable to other plants.

There is one exception in two plants that come close to similar operations. Both produce newsprint using primarily recycled paper fiber. However, the first plant produces coated paper such as is used in the advertising supplements. The second produces unfinished newsprint. The first plant has utilized Trust incentives for a major retrofit of their fiber refining process that provided large energy savings. It is possible that a similar retrofit could benefit the second plant.

ACEEE has referred to several technical innovations in paper forming -- high consistency forming and heat recovery enclosing hoods. High consistency forming is useful in the production of boxboard, such as is used for milk cartons. However, Oregon facilities are not producing this product.

There are several systems for heat recovery hoods that can improve energy efficiency. One new system involves the installation of enclosed hoods and sensors on the drying section of the paper machine. Paper machines with enclosed hoods can require up to one-half the amount of air per ton of water evaporated than paper machines with canopy hoods. Thermal energy demands are reduced since a smaller volume of air is heated. Electricity requirements in the exhaust fan are also reduced optimizing drying efficiency (Elaahi and Lowitt 1988, CADDET 1994d). Another promising system further upgrades this waste heat by means of heat pumps and mechanical vapor recompression (MVR) (Van Deventer 1997, Abrahamsson et al. 1997). A different technology approach, which involves the heating provided to the cylinders, is to use stationary siphons to better extract the exhausted steam from the cylinders (Morris 1998). The heat can also be recuperated from the ventilation air of the drying section and used for heating of the facilities (de Beer et al. 1994).

However, most of the savings would be for the fuel used to provide thermal heat; Furthermore, the industry has previously upgraded hoods. Thus, the electricity savings from these hoods is not clear without a more careful and detailed study of the specific plants. We did not include these hoods as a potential measure.

Other Measures

Boiler auxiliaries such as powered fans for induced draft and pollution control have been previously identified as an opportunity for improvement (PP&L). This is a relatively small measure but typical of opportunities for continuous improvement of O&M practices. In general, the other measures specific to this sector are the cross-cutting general measures. These plants rely on large motors for refining, pumping, pressing and other processes. The facilities have staff dedicated to maintaining plant operations and are usually well informed about energy savings opportunities. Accordingly, we assume that measures in this sector are likely to be achievable.

Conveyor systems are broadly defined as a piece of equipment moving material from one place to another. There are multiple types including blowers and pumps. Together they account for one of the largest energy uses within these facilities. The industry is fragmented with many smaller vendors. As a result, this is a difficult market to pursue energy efficiency initiatives. However, there are areas of improvement for the use of conveyor systems. These include: regular maintenance of the conveyor, installation of a VSD where loads vary significantly and replacement of inefficient pneumatic conveyors.

The Wood Products sector is large and diverse. It includes facilities that mill and cure lumber or veneer. It also includes facilities that process these products into chipboard, plywood and manufactured lumber. This sector is unique in that current Trust programs have already captured part (3%) of the opportunity for process improvements. We adjusted applicability for this fact.

Electronics Sector

This sector is one of the largest, accounting for 40% of PGE’s industrial sales. This industry sector is comprised of a small number of companies, whose facilities are known to exhibit a wide variation in energy use, depending on their design, vintage and management philosophy. Most of these firms are self- directors. One smaller firm is cooperating eagerly with the PE program and another firm, although a self-director, has also been willing to accept Trust incentives for efficiency improvements.

There is an understandable reluctance to make changes in their process equipment (also known as "tools") because the processes are finely tuned to produce specific, repeatable results within extremely tight tolerances, and are sensitive to contamination. These process tool sets are persistent. For example, a manufacturer is still making 386 and 486 computer chips. Although these chips may be 20 years obsolete for desktop computers, they are still in demand for "smart appliances" or other applications. So the original process and facility is still in operation.

There may be an opening to address new measures to both tools and facility loads during the design of new facilities. However, existing facilities may operate for a long time without permitting any major overhaul. Thus, while there is large technical potential, the reluctance to participate is shown by a low achievable potential for these sorts of measures.

Process Shares

The industry in Oregon differs from national averages. There is no longer any silicon melt operation in Oregon. Instead, the plants focus on wafer and chip production. While the MWh data include a small amount of instrument assembly and compressed gas production, chip plants dominate and require clean rooms with high HVAC consumption. Table 8 shows process shares for this sector. Note that the shares are split into those at the process line and those treated as part of the central facility. That is because the process lines may be more difficult for the program to access.

Table 8 Electronics Sector Process Shares

Electricity Process Shares	Total	Facility	Process
Pumps	27%	2%	25%
Fans	10%	10%	
Air Compressor	5%	5%	
Material Handling	3%	3%	
Material Processing	10%	5%	5%
Refrigeration	5%	5%	
Pollution Control	3%	3%	
Drying	0%		
Heating	5%		5%
HVAC	25%	25%	
Lighting	3%	2%	1%
Other Process	4%		4%
All Electric	100%	60%	40%
All Motors	83%		

Specific Measures

We applied a higher achievable potential to measures that could be implemented without disruption of the process line. There are two potential openings here. To the extent that central facility operations (e.g. chiller plant) could be changed without disrupting a process line, those operations are moderately achievable. We also identified a few replacement opportunities for smaller equipment that would be achievable without disruption of processes.

Even so, it must be recognized that replacement of some parts of the process support equipment (for example, vacuum pumps) requires "re-qualifying" the process line. That is, it takes staff days to properly tune and calibrate all the mass flow, heating and cooling operations in a process tool – every time something changes they have to go through the calibration again. Of course, the same problem occurs if any equipment breaks or fails so there are continual replacement openings, albeit they cannot be scheduled.

Highly Achievable Measures

We focused on etch tools and wet benches processes that etch and clean the wafers. This equipment runs continuously, with little electric load variation during times it is processing wafers. The equipment is so difficult to properly set up and calibrate that engineers are reluctant to let it go idle. We estimate there are about 5000 of these "benches" in Oregon. Components include 4 kW of vacuum pumps, the treatment equipment and trim chillers. The trim chiller consumes about 4.5 kW of electricity. Its role is to adjust the process cooling water temperature to that required by the process tool. The fabricating process produces dangerously reactive gases that are collected in a powered exhaust system.

Upgrade vacuum pump

The vacuum pumps are rebuilt periodically but slow to be replaced. Current units are 50% more efficient than the old units still in place. Replacement is not welcome since the process line must be "re-qualified" with every change. An efficiency incentive would encourage new replacement rather than re-build of older units. However, given that the units will eventually be replaced anyway, accelerating the upgrade is not cost effective.

Alternative Chiller

The trim chillers are large and inefficient and lack effective feedback controls. They can be replaced by a smaller, thermoelectric system that incorporates more effective feedback, does a better job of controlling temperature and increase throughput. Electricity savings are 90%. The thermoelectric system also save about $5000 annually on decreased maintenance. There is another significant benefit in that the smaller unit has a much smaller footprint. We did not attempt to quantify the value of clean room floor space savings but it is considerable. Nor did we quantify the value of increased process throughput. The thermoelectric system permits more usable wafers per batch; better feedback controls decrease the risk of process flaws. Estimates derived from industry data sources.

Alternative Exhaust Injector

Etch tools use a point of use (POU) exhaust system to pre-treat the etch effluent before it enters the house exhaust system. The POU exhaust system consumes process gases and cleaned makeup air. It requires resistance heating and needs periodic maintenance. The alternative system uses a jet of nitrogen gas to flush (or “inject”) the exhaust from the etch tool into the house exhaust header. It saves 100% of the resistance heat as well as about $6000 annually in process gases. We estimate there about 400 applications in Oregon. Estimates derived from industry data sources.

Reduce Pressure of Process Gases (Dry Air and Nitrogen)

This is a no-cost O&M measure. Sematech survey indicated that most tools could operate at 80 psi or less but that 100 psi is routinely provided. Reducing pressure by 20 psi is estimated to save 10% in compressor energy as well as reduce consumption of process gases.

<u>Moderately Achievable Measures</u>

We consider the next set of measures to be moderately achievable because central facility operations (e.g. chiller plant) could be changed without disrupting a process line. The barriers here are the usual ones of reluctance to invest capital in major changes. In many cases, the cost and savings of the measures came from an Supersymmetry report on a typical facility. Many of these measures are specific opportunities that correct operations and design problems at Supersymmetry’s case example. While Oregon facilities will not be identical, we assume that the measures identified by Supersymmetry are proxies for similar opportunities that exist in Oregon plants.

Electronics: Chiller optimize

Based on audit of a typical plant, Supersymmetry suggested a variety of simple changes to improve the overall system performance. These included elimination of unnecessary chillers, reset of CW temperature, combining pipe runs and controls for parallel operation of multiple chillers.

Electronics: Change filter strategy

New immerging filter technologies (HEPA/ULPA filters) offer the opportunity to significantly reduce filter energy use by reducing filter pressure drops (Tschudi 2000). Supersymmetry noted for their case example that less expensive filters could be used in part of the operations in order to offset the cost of more expensive filters in other operations.

Electronics: Clean Room HVAC

Several HVAC technologies that have emerged recently which when combined, can achieve significant energy savings. Currently a large amount of energy is expended in heating, cooling, and filtering air that is then exhausted. Air re-circulation is another large HVAC energy user. Recirculation air velocity can be turned down (from, say, 90 fpm to 80) without affecting cleanliness levels. Sensors and the use of laser-based particle counters are both technologies that can be applied to more efficiently moderate airflow. Additionally, more efficient airflow equipment that is near commercial (e.g. low face velocity fans, efficient duct systems, more efficient filter units) could be combined to further reduce recirculation fan energy requirements. Existing practices can also be applied in conjunction with these technologies to further enhance energy savings, such as “right-sizing” of exhaust air flow for each specific tool, improved design guidance for ducting and other systems, and limiting the floor area that requires clean air flow to a smaller “micro” environment. This measure has been screened to avoid double counting with other HVAC measures. Combined with the other HVAC measures, clean room technologies have the potential to reduce electricity consumption of the average clean-room facility by 25-30 percent, or an average of 145 kWh/ft2. Additionally, they are accompanied by several additional non-energy benefits including improved productivity and a reduction in emissions without sacrificing any product quality.

Electronics: Eliminate exhaust

Minimizing exhaust flow reduces the amount of make up air that needs to be reconditioned. Ultra low fume hoods, a technology developed at Lawrence Berkeley National Laboratory, require 25 percent of normal exhaust flow. This technology is now being piloted in field trials (Tschudi 2000). Supersymmetry’s audit noted that full exhaust is required for only 50% of operating hours. Use of controllers and VSD fans would reduce unneeded exhaust with significant savings on makeup air. Phil Naughton, SEMATECH, noted that various process tools could be reduced by about 30% of the exhaust requirement.

Electronics: Reduce pressure, reset CHW

In their audit, Supersymmetry notes that the existing tower experiences poor flow. The plant staff expected to increase pumping power to compensate. Instead, Supersymmetry suggested a number of ways to remove flow obstructions and lower pumping power. Also, they suggested reset of CW temperature to lower flow rate.

Electronics: VSD Tower Pumps

In their audit, Supersymmetry notes that tower pumps are staged off and on which results in unequal pressure drops to the different pumps. Use of VSD drives would allow for even distribution of flows and saved pump energy.

Electronics: Wastewater Preheat Of OSA

Conditioning of makeup air is a major HVAC energy requirement whether for heating in the winter or cooling in the summer. Supersymmetry noted that preconditioning with the plant wastewater would provide savings in both seasons.

<u>Low Achievable Measures</u>

These measures are considered unlikely to be achievable either because they require a major re-investment in plant capital or a major re-design in handling processes. Facility operators may be reluctant for both reasons.

Electronics: CW to gas plant

In their audit, Supersymmetry noted the opportunity to provide more efficient cooling to the compressors that provide cleaned air and process gases to the process line.

Electronics: Chiller heat recovery

In their audit, Supersymmetry noted opportunities to recover waste heat from the chillers. The waste heat can be used for pre-conditioning makeup air or other low temperature applications. The savings quantified here are primarily due to improving chiller performance by better heat removal.

Electronics: New air compressor

In their audit, Supersymmetry noted that two large air compressors were scheduled for replacement with an existing used compressor. Replacement with new, efficient compressors would provide savings. Cost would be the incremental cost over the planned replacement.

Electronics: New chiller/tower, 2 loops

In their audit, Supersymmetry noted the opportunity to replace the chiller system with a better designed new one. The new system would be designed to maximize free cooling, a VSD chiller and would include splitting the CW system into two pipe loops – one cold and one moderate loop. The overall system performance would be improved by utilizing two loop temperatures. While savings are considerable, this would be a major capital investment.

Table 9 Summary of Measures -- Electronics Sector

Opportunity	Measure Name	Cost	Savings, kWh	O&M/yr	Life	LC
Highly	Thermoelectric Chiller	$20,000	40,571	-$5000	10	-$0.065
Achievable	Exhaust Injector	$20,000	45,815	-$6170	10	-$0.083
	Reduce Gas Pressure	$0	3,260	-$46	10	-$0.001
	Vacuum pump, incremental over rebuild	$51,000	63,072		5	$0.177
Moderately	Chiller optimize	$50,000	1,736,000		10	$0.003
Achievable	Change filter strategy	$9,200	1,463,000		1	$0.006
	Clean Room HVAC	$20/sqft	144/sqft		20	$0.010
	Eliminate exhaust	$80,000	442,000		10	$0.021
	Reduce pressure, reset CHW	$40,000	81,000		10	$0.058
	VSD tower pumps	$50,000	187,000		10	$0.031
	Wastewater preheat of OSA	$325,000	776,000	-$180,000	10	-$0.183
Low	CW to gas plant	$40,000	245,000		10	$0.019
Achievable	Chiller heat recovery	$30,000	28,000		10	$0.126
	New air compressor	$50,000	273,000		10	$0.021
	New chiller/tower, 2 loops	$800,000	4,539,000		10	$0.021

Industrial Sources And References:

Note: Other references not explicitly listed here are quoted from ACEEE, 2001.

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Solid State Cooling Systems, 2005, vendor information on thermoelectric chiller.

Paragon Exhaust Injector system, 2005, vendor information supplied by Chris Robertson.

Ducker Worldwide, "Energy Efficiency within the Pulp & Paper, Water & Wastewater, and Irrigation Markets in the Pacific Northwest: An Examination of Pumps, Fans/Blowers, and Conveyor Equipment", NEEA, 2000.

NEEA Chiller Efficiency Study, NEEA, 12/15/3

Commercial Sector Resource Assessment Results

A list of the major commercial measures, listed by the levelized cost, is provided in Table 13 and Table 14. These lists present individual measures, with costs and benefits resulting from the applicable population.

Commercial Sector Characterization

Characterizing the commercial sector reveals certain difficulties. For example, industrial customers often have a relatively large percentage of overall floor space devoted to end uses that would typically be thought of as commercial. We included a portion of “industrial” sales as really belonging to commercial uses. New construction square footage estimates were also developed using utility estimates although these appear to assume optimistic growth.

Description of Commercial Measures

Measures were previous described in the 2004 report. For this study, the detailed measure descriptions are included in Table 13 and Table 14. Significant changes from the 2004 include a more thorough development of refrigeration measures and an updating of lighting measure costs based on the recent Northwest BEST survey of current code compliance (NEEA, April 2006).

Large Refrigeration Energy Efficiency Measures

Four energy efficiency measures were developed from Supermarket Energy Efficiency (NEEA, 2005) for large supermarket refrigeration systems.

Floating heat pressure has very large energy savings and a relatively high current saturation. It includes floating head pressure controls with variable set point control to maintain a 10F delta T to a minimum coil temperature of 70F.

Heat Reclaim has huge savings for the heating fuel but a significant electric interaction penalty with floating head pressure. Currently, heat reclaim is most common in the limited form of heating service hot water with refrigeration superheat. This measure is the use of condenser heat in a heat reclaim coil installed in the space heating system. This measure assumes that floating head pressure is installed and heat reclaim holdback valves are used to maintain the refrigerant’s SCT in the reclaim coil, regardless of the SCT at the condenser, thereby allowing the condenser to “float” with ambient. This greatly reduces the savings from floating head pressure and is accounted for as a negative electric savings for this measure.

Refrigeration Case Package. This measure includes efficient evaporator fans, case lighting, and low energy anti-sweat heaters.

Efficient Refrigeration Systems. This measure includes efficient compressor, efficient condenser fans, mechanical sub-cooling, and controls.

Lighting Measures

The new evaluation has made several adjustments to the cost and savings assumptions and the calculation methods used in the lighting evaluation.

The most significant changes were to the calculation methods used. Previously savings were calculated using an assumed Lighting Power Density (LPD), hours of operation, and an array of engineering factors. The LPD was a code maximum LPD that was often high. The new method calculates savings as a fraction of the lighting EUI (same EUI as used in the calibration step) as determined from average LPD (from regional surveys) and building simulation studies. There is also credit for cooling savings and debit for increased heating. The value of this approach is that it assures consistency with the actual electricity consumption for this end use. Given that lighting efficiency current practice has greatly improved, it is important to reflect actual consumption.

Lighting equipment cost data were reviewed and adjusted to agree with current cost data as developed by NEEA in the NW BEST evaluation. The underlying data was developed primarily by Michael Lane of the Lighting Design Lab and Jim Benya from actual project experience. Labor was not evaluated so little change has occurred in retrofit applications. High performance T8 costs are significantly reduced in the replacement case.

The lighting measure savings increment was adjusted in several instances. The base T8 wattage was assumed to be 58 watts rather then 64 watts, so that the baseline fixture was more in line with the lumen output of the measure fixture. This reduced per fixture savings 36%. The HID lighting baseline was assumed to be pulse start reducing baseline watts from 460 to 365. This reduced per fixture savings approximately 50%.

Overall high performance T8 technology is highly attractive and should be pursued aggressively. The high/low bay lighting is much less clear. Further evaluation of this niche is warranted. Hours of operation and available control strategies will have a large impact on savings and as such solutions most likely need to be evaluated on a case by case basis. Ceramic metal halide remains highly attractive but expensive option for display light situations. It definitely delivers same to better quality light and less frequent bulb changes and as such is an upgrade in most situations. As such even though this fixture is not cost effective in most situations it should be evaluated on a situation-by-situation basis.

Window Measures

Window energy savings were predicted with building energy simulation models for the 2004 ETO evaluation. The window market was divided into vinyl and aluminum frame, and tinted versus untinted. The tinted versus un-tinted is significant because without tint windows must be include a low emissivity coating to pass the SHGC code requirement. This generally brings the window SHGC and U-value below the code requirements by a significant margin, reducing savings available.

The Oregon code has low and high glazing fraction paths. The high glazing path requires maximum performance windows, which pretty much excludes them from utility programs. Therefore, we limited this evaluation to the lower glazing path and window populations (application factor) were reduced by 40% to remove the high glazing buildings (>30% in zone 1 and >25% in zone 2) from the target population.

For each of these cases, savings were predicted for various measures. For the aluminum frames, several U-value targets were established with the assumption that the target buildings would evenly divide into these groups.

Table 10 Window Measure Details

Window	SHGC	U-Value	Measure Code, At Replacement	Measure Code, New	Measure Name
Code Requirement	0.57	Z1 0.54 Z2 0.50			
Aluminum, tinted					
Model Base	0.52	0.50			
Class 45 tint	0.35	0.45	E120	E129	Windows - Tinted AL Code to Class 45
Class 40 tint	0.35	0.40	E121	E130	Windows - Tinted AL Code to Class 40
Class 36 tint	0.35	0.36	E122	E131	Windows - Tinted AL Code to Class 36
Aluminum, not tinted					
Model Base	0.43	0.48			
Class 45	0.43	0.45	E117	E126	Windows - Non-Tinted AL Code to Class 45
Class 40	0.43	0.40	E118	E127	Windows - Non-Tinted AL Code to Class 40
Class 36	0.43	0.36	E119	E128	Windows - Non-Tinted AL Code to Class 36
Vinyl, tinted					
Model Base	0.54	0.50			
Add Low E	0.35	0.35	E114	E123	Windows - Add Low E to Vinyl Tint
Add Low E + Argon	0.35	0.31	E115	E125	Windows - Add Low E and Argon to Vinyl Tint
Vinyl, not tinted					
Model Base	0.43	0.35			
Add Argon	0.43	0.31	E116	E124	Windows - Add Argon to Vinyl Lowe

A list of the recommended residential measures, prioritized by the levelized cost, is provided in Table 15 and Table 16. This list presents individual measures, with costs and benefits expressed on a per unit of occupancy basis. In most cases, the technical potential was independently calculated for the single family, multi family and manufactured home sectors.

Residential Sector Characterization

For this analysis, three residential sub sectors were considered: single family, manufactured homes and multi-family units. We further divided these sub sectors, at the request of the Energy Trust, into low income, medium low income, and all other income levels (see the ResSectorChar.xls spreadsheet). For this analysis, only electricity savings were considered (excluding gas, propane, or other fuel savings). Therefore, for most residential measures, only electrically heated homes were included in the technical potential estimates provided here. There were three exceptions; the lighting and appliance measures were applied to homes heated with all fuel types, and the fan efficiency improvement measure was applied to homes with either gas or electric forced air furnaces. In cases where the nature of the measure limits its applicability to a portion of the homes (for example, duct measures exclude homes with basements), adjustments to the technical potential are contained in the workbook for that measure.

Description of Residential Measures

Detailed list of measures in included as Table 15 and Table 16. These tables provide results for the measures applied to the appropriate population. A short description of assumptions used to develop these measures follows. Savings estimates for heating consumption are based on simulations by Ecotope's SEEM model, which is specifically designed to include effects of duct distribution losses and other regional measures.

HVAC

1. PTCS Duct Sealing (New/Replacement)

Duct sealing in accordance with PTCS standards for new construction. The distribution efficiency associated with the duct sealing measure is .85.

2. PTCS Duct Repair (Retrofit)

Duct sealing in accordance with PTCS standards for existing construction, requiring a 50% reduction in leakage, was examined for several heating system types.

3. PTCS Heat Pump Upgrade (New/Replacement/Retrofit)

Heat pump upgrade from HSPF 7.7 to 9.5, with PTCS-level commissioning and duct sealing. For the retrofit sector, the efficient heat pump was examined both as a retrofit from an older, working heat pump and from an electric furnace base case.

4. Geothermal Heat Pumps (New)

Install geothermal heat pump in lieu of standard air source heat pump.

5. Higher Efficiency AC (New/Replacement)

We examined a measure to upgrade a central forced air AC system to SEER 15 from SEER 13. We also examined a measure to upgrade a standalone window unit to Energy Star levels (base case EER 9.7 upgraded to 10.7).

6. Diagnostic Heat Pump tuneup (Retrofit)

A program based on field visits that offers minor adjustments to HVAC equipment (adjust charge, clean filters, check settings) to optimize efficiency. The requirements for each system will vary, but cost and savings are based on overall expectations if a large population is treated.

7. Evaporative Cooling (New/Replacement/Retrofit)

Install a direct/indirect evaporative cooler in lieu of a SEER 13 central AC for new and replacement models. Savings for the retrofit sector are from “existing condition”. The SEER for the existing condition varied based on vintage.

8. High Efficiency Gas Furnace (New/Replacement)

This measure describes an upgraded gas furnace from AFUE .8 to .9. A separate measure adds duct leakage improvements of 15%.

9. Gas Boiler Combo (with DHW)

For this measure, both the upgrade from a furnace with an AFUE of .8 to a boiler AFUE of .85 and a 15% duct leakage improvement were included.

Envelope

1. Window Upgrades (New/Replacement)

Improvement from U=.4 to U=.3. This measure is applicable to both electrically-heated and gas-heated homes.

2. Heat Recovery Ventilation, including infiltration reduction (New)

Addition of heat recovery to ventilation system and whole house sealing. This measure is applicable to both electrically-heated and gas-heated homes.

3. Upgrade insulation to Energy Star levels (New).

This measure was examined both as a stand-alone measure and combined with a PTCS-level duct system. For this measure, the base case was R-21 in the floor and walls, and R-38 insulation in the attic. The Energy Star package requires the same wall and attic insulation performance, but also requires advanced framing for the walls and R-30 insulation in the floor. This measure is applicable to both electrically-heated and gas-heated homes.

4. Insulation improvements (Retrofit)

For the retrofit sector, the base cases were drawn from the existing building prototypes, weighted by vintage using data from the US Census. For these measures, the candidate home must have no existing wall insulation, ceiling insulation of R-11 or less, and floor insulation of R-19 or less. All measures utilize blown-in or batt insulation to achieve the increased R-value. The measure assumes that the home will be treated with the two most cost-effective measures (floor, wall or attic insulation), based on the specific characteristics of each home. This measure applies to both electrically-heated and gas-heated homes.

Lighting

1. Efficient fluorescent bulbs and fixtures (New/Replacement/Retrofit)

For the retrofit sector, four CFL bulb replacement measures were considered. The first measure assumes that two CFL bulbs are provided to the owner or tenant to be used to replace regular 75 Watt incandescent bulbs in the fixture of his or her choice, which could include non-hardwired fixtures such as table and floor lamps. The three remaining bulb replacement measures apply to both the new/replacement and retrofit sectors. These measures assume that CFL bulbs are used to replace incandescent bulbs in hardwired fixtures. For these three measures, the placement of the CFL bulbs is assumed to be in the most heavily used areas first (i.e., kitchens and bathrooms). We examined replacing 10, 25, and 30 interior bulbs.

We also examined a measure that assumed 100% of the interior and exterior light fixtures would use CFL or high efficiency T8 technology. For this measure, fixture upgrades to units that would only accept efficient fluorescent fixtures was also assumed.

For multi-family units, a retrofit measure to replace incandescent bulbs in common areas with fluorescent technology was also examined.

Domestic Hot Water

1. Tank wrap (Retrofit)

This measure assumes a R-6 tank wrap is installed in water heaters older than 5 years, and applies to both gas and electric units.

2. Hot water pipe wrap (Retrofit)

This measure assumes that the hot and cold water pipes are insulated with an R-2 wrap, and applies to both gas and electric water heat.

3. Water Heater Upgrade (New/Replacement)

Two water heater upgrade measures were examined for the new and replacement markets. The primary difference is in the quality of the unit. For electric water heat, the first measure upgrades the water heater from an EF of .86 to .93, with a 20 year warrantee. The second measure costs less for a unit with a 10 year warrantee. The efficiency improvement for that measure is from an EF of .86 to .94. For the gas sector, the measures included a water tank upgraded from EF=.59 to EF=.65, as well as an upgrade to a condensing gas furnace with an EF of .86.

4. Heat Pump Water Heater (New/Replacement)

This measure assumes that an electric water heater is replaced with a heat pump water heater (EF from .95 to 2.0).

5. Solar Water Heater (New/Replacement)

This measure assumes that an electric or gas water heater is replaced with a solar water heater with backup, reducing the water heating load by about 60%.

Appliances

1. Energy Star Clothes Washer (New/Replacement)

For this measure, the federal standard (MEF 1.26) that will take effect in a few months (Jan 1, 2007) was used as the base case. The Energy Star clothes washer was assumed to have an MEF of 1.72. Note that this measure and the following measure compete for the same population. For this analysis, the population was split between the two measures.

2. Improvement over Energy Star Clothes Washer (New/Replacement)

The most advanced clothes washers have an MEF of 2.1, used for this measure. The base case remained MEF 1.26. Note that this measure and the preceding measure compete for the same population. For this analysis, the population was split between the two measures.

3. Energy Star Dishwasher (New/Replacement)

The base case for this measure is the federal standard (EF=.46). For the measure, the EF was assumed to be .58. Note that this measure and the following measure compete for the same population. For this analysis, the population was split between the two measures.

4. Energy Star Refrigerator (New/Replacement)

For this measure, the basis for savings is approximately 15% over federal standards. These standards vary greatly by model and features, which were combined and averaged for both the base case and the measure. Note that this measure and the following measure compete for the same population. For this analysis, the population was split between the two measures.

5. Improvement over Energy Star Refrigerator (New/Replacement)

There are a substantial number of refrigerator models available that perform much more efficiently than Energy Star standards. This measure averages savings from units that are at least 10% better than the Energy Star standard. Note that this measure and the previous measure compete for the same population. For this analysis, the population was split between the two measures.

6. High Efficiency Computer Monitor (New/Replacement)

For this measure, a CRT monitor is upgraded to an efficient LCD model.

Technical Appendix: Detailed Measure Descriptions

Table 11 Detailed Measure Description, Industrial Electricity

Conservation Measure	First Cost ($/kWh)	Enduse App	% Savings	Measure Acceptance	Achievable Potential	Lifetime	Annual O&M Cost ($/kWh)	Levelized Cost ($/kWh)	Source
Advanced Industrial HVAC	$0.650	HVAC	15%	40%	85%	10	$0.050	$0.126	ACEEE,2004
Advanced Lubricants	$0.013	All Motors	3%	23%	85%	1	($0.007)	$0.006	ACEEE,2001
Ag: High Draft Fans for Barns	$0.000	Fan	4%	23%	85%	10		$0.000	ACEEE,2004
Air Compressor O&M	$0.015	Fan	25%	23%	85%	1		$0.015	ACEEE,2001
Air Compressor Sensors	$0.042	Air Comp	4%	23%	85%	15		$0.003	ACEEE,2001
ASD Motors	$0.067	All Motors	2%	45%	25%	15	($0.013)	($0.007)	ACEEE,2001
Duct/Pipe Insulation	$0.090	Heat, Refer,HAVC	5%	80%	85%	7	$0.002	$0.016	ACEEE,2004
Efficient Lighting Design	$0.499	Lights	20%	70%	25%	20		$0.034	Ecotope
Efficient Lighting Fixtures and Lamps	$0.250	Lights	25%	70%	50%	20		$0.017	Ecotope
Electrical Supply System Improvements	$0.010	All Electric	3%	100%	25%	5	($0.010)	($0.008)	ACEEE,2004
Electronics: Change filter strategy	$0.049	Fans	40%	10%	60%	1	($0.002)	$0.049	Supersymmetry, NEEA Chiller
Electronics: Chiller heat recovery	$1.071	HVAC	3%	10%	25%	10	$0.000	$0.126	Supersymmetry
Electronics: Chiller optimize	$0.187	HVAC	17%	25%	50%	10	$0.011	$0.033	Supersymmetry
Electronics: Clean Room HVAC	$0.103	HVAC	9%	30%	25%	20		$0.007	ACEEE,2001, NEEA Chiller
Electronics: CW to gas plant	$0.163	HVAC	1%	50%	25%	10	$0.000	$0.019	Supersymmetry
Electronics: Eliminate exhaust	$0.181	HVAC	5%	80%	25%	10	$0.000	$0.021	Supersymmetry, NEEA Chiller
Electronics: Exhaust Injector	$0.437	Heat	100%	35%	85%	10	($0.135)	($0.083)	Paragon
Electronics: New air compressor	$0.183	Air Comp	17%	50%	25%	10	$0.000	$0.021	Supersymmetry
Electronics: New chiller/tower, 2 loops	$0.176	HVAC	34%	15%	25%	10	$0.000	$0.021	Supersymmetry
Electronics: Solidstate chiller	$0.493	HVAC	90%	20%	85%	15	($0.123)	($0.082)	Solid State
Electronics: Reduce pressure, gases	$0.001	Refrig, Air Comp	10%	50%	85%	3	($0.001)	($0.001)	Supersymmetry, NEEA Chiller
Electronics: Reduce CW pressure, reset CHW	$0.494	HVAC	1%	50%	25%	10	$0.000	$0.058	Supersymmetry
Electronics: VSD tower pumps	$0.200	HVAC	1%	50%	25%	10	$0.000	$0.023	Supersymmetry, NEEA Chiller
Electronics: Wastewater preheat of OSA	$0.419	HVAC	15%	50%	25%	10	($0.232)	($0.183)	Supersymmetry, NEEA Chiller
Electronics: Vacuum Pump Upgrade	$0.809	Process Pump	50%	13%	85%	5	$0.768	$0.945	Phil Naughton, 2005
Fan system improvements	$0.030	Fan	6%	20%	50%	10		$0.004	ACEEE,2001

Conservation Measure	First Cost ($/kWh)	Enduse App	% Savings	Measure Acceptance	Achievable Potential	Lifetime	Annual O&M Cost ($/kWh)	Levelized Cost ($/kWh)	Source
Food: Cooling and Storage	$0.109	Refer	20%	20%	25%	15		$0.009	ACEEE,2001
Food: Refrig Storage O&M	$0.051	Refer	4%	50%	85%	3		$0.018	DEER
Food: RF Heat	$0.450	Process Drying	1%	50%	25%	10	$0.500	$0.553	ACEEE,2004
Generic O&M	$0.000	Process	5%	80%	85%	1	$0.050	$0.050	ACEEE,2004
HighBay Lighting	$0.160	Lighting	25%	70%	85%	4	($0.022)	$0.021	ACEEE,2005
Irrigation: Ditch > Pipe	$0.074	Pump	60%	3%	85%	10	($1.010)	($1.001)	PP&L
Irrigation: Nozzles	$0.222	Pump	0%	70%	50%	3		$0.078	ETO
Irrigation: Pump Systems Repair	$1.693	Pump	0%	70%	50%	7	($0.010)	$0.262	ETO
Irrigation: Pump Systems Adjust	$0.215	Pump	2%	70%	50%	3	($0.057)	$0.019	ETO
Irrigation: Water Management	$0.179	Pump	1%	70%	50%	5	$0.067	$0.106	ACEEE,2004
Metal Fab: IR Heating	$0.450	Heat, Treating	15%	50%	25%	10	$0.375	$0.427	ACEEE,2004
Metal Fab: UV Curing	($0.079)	Curing	60%	50%	25%	10		($0.009)	ACEEE,2004
Metal: Net Casting	$0.585	Process Heat	90%	20%	25%	10	($0.113)	($0.044)	ACEEE,2001
Metal: New Arc Furnace	$0.080	Process Heat	45%	10%	25%	10	($0.160)	($0.151)	ACEEE,2001
Microwave Processing	$0.450	Process Drying	3%	50%	25%	10		$0.053	ACEEE,2004
Motor Management (Prevent. Maint.)	$0.140	All Motors	1%	11%	85%	15	($0.010)	$0.002	ACEEE,2001
Motor Systems O&M Optimize	$0.057	Pump,Fan	20%	11%	85%	10	$0.000	$0.007	ACEEE,2001
Other: Wastewater Biomanagement	$0.001	Pump	25%	50%	85%	10	$0.258	$0.258	ACEEE,2004
Paper: ChlorOxy Mod	$0.114	Process	51%	10%	85%	15		$0.010	Program files
Paper: Refiner Mod	$0.043	Process	60%	53%	85%	15		$0.004	Program files
Paper: Vapor Recompression	$0.007	Process	60%	10%	85%	15	$0.014	$0.014	Program files
Pump Efficiency Improvement	$0.154	Pump,Fan	17%	23%	50%	10	($0.018)	$0.000	ACEEE,2001
Sensors and Controls	$0.020	Process	3%	30%	50%	10	($0.003)	($0.001)	ACEEE,2001
SR Motor	$0.384	Pump, Fan, Air, Process	3%	9%	25%	10		$0.045	ACEEE,2001
Transformers	$0.188	All Electric	2%	100%	25%	30		$0.010	ACEEE,2004, NEEA Chiller
Wood: Replace Pneumatics	$0.275	Pneumatic Conveyor	75%	85%	85%	15	($0.061)	($0.037)	Program files
Wood: Soft Start Press	$0.185	Process	58%	25%	85%	15		$0.015	Program files

Table 12. Detailed Measure Results, Industrial Sector, 2017 Electricity Technical Potential

Conservation Measure	Potential Savings (MWh/yr)	Levelized Cost ($/kWh)
Advanced Industrial HVAC	5,948	$0.126
Advanced Lubricants	16,273	$0.006
Ag: High Draft Fans for Barns	709	$0.000
Air Compressor O&M	33,791	$0.015
Air Compressor Sensors	5,407	$0.003
ASD Motors	12,057	($0.007)
Duct/Pipe Insulation	53,188	$0.016
Efficient Lighting Design	10,400	$0.034
Efficient Lighting Fixtures and Lamps	13,001	$0.017
Electrical Supply System Improvements	265,698	($0.008)
Electronics: Change filter strategy	40,328	$0.049
Electronics: Chiller heat recovery	3,200	$0.126
Electronics: Chiller optimize	28,416	$0.033
Electronics: Clean Room HVAC	18,052	$0.007
Electronics: CW to gas plant	737	$0.019
Electronics: Eliminate exhaust	26,744	$0.021
Electronics: Exhaust Injector	200,581	($0.083)
Electronics: New air compressor	11,276	$0.021
Electronics: New chiller/tower, 2 loops	70,633	$0.021
Electronics: Solidstate chiller	120,349	($0.082)
Electronics: Reduce pressure, gases	13,266	($0.001)
Electronics: Reduce CW pressure, reset CHW	2,407	$0.058
Electronics: VSD tower pumps	2,579	$0.023
Electronics: Wastewater preheat of OSA	50,145	($0.183)
Electronics: Vacuum Pump Upgrade	46,563	$0.945
Fan system improvements	11,060	$0.004
Food: Cooling and Storage	13,791	$0.009
Food: Refrig Storage O&M	7,068	$0.018
Food: RF Heat	32	$0.553
Generic O&M	198,280	$0.050

Conservation Measure	Potential Savings (MWh/yr)	Levelized Cost ($/kWh)
HighBay Lighting	68,494	$0.021
Irrigation: Ditch > Pipe	3,120	($1.001)
Irrigation: Nozzles	144	$0.078
Irrigation: Pump Systems Repair	121	$0.262
Irrigation: Pump Systems Adjust	2,669	$0.019
Irrigation: Water Management	1,213	$0.106
Metal Fab: IR Heating	1,081	$0.427
Metal Fab: UV Curing	4,324	($0.009)
Metal: Net Casting	28,239	($0.044)
Metal: New Arc Furnace	7,060	($0.151)
Microwave Processing	4,625	$0.053
Motor Management (Prevent. Maint.)	7,045	$0.002
Motor Systems O&M Optimize	140,899	$0.007
Other: Wastewater Biomanagement	32,030	$0.258
Paper: ChlorOxy Mod	9,612	$0.010
Paper: Refiner Mod	59,595	$0.004
Paper: Vapor Recompression	11,308	$0.014
Pump Efficiency Improvement	74,463	$0.000
Sensors and Controls	31,979	($0.001)
SR Motor	9,769	$0.045
Transformers	141,706	$0.010
Wood: Replace Pneumatics	140,220	($0.037)
Wood: Soft Start Press	7,510	$0.015

Table 13. Detailed Measure Table, Commercial Sector, Electricity Savings, 2017 Technical Potential

Measure Code	Measure Description	Comment	Construction Type	Measure End Use	Total MWh Savings	Winter MW	Summer MW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	Levelized Cost, $/th
Co116rep	Estar Steam Cooker	Install Energy Star Steam Cooker	At Replacement	Cooking	25,899	3.05	3.05	0	593,803	$0.0018	na
C103	CEE Tier 2 3 ton (at rep)	Install high efficiency cooling equipment complying with CEE Tier 2.	At Replacement	Cooling	7,576	1.88	1.64	0	36,981	$0.0123	na
C104	CEE Tier 2 7.5 ton (at rep)	Install high efficiency cooling equipment complying with CEE Tier 2.	At Replacement	Cooling	4,216	1.05	0.91	0	36,981	$0.0260	na
C105	CEE Tier 2 15 ton (at rep)	Install high efficiency cooling equipment complying with CEE Tier 2.	At Replacement	Cooling	6,720	1.67	1.45	0	36,981	$0.0290	na
C105	CEE Tier 2 25 ton (at rep)	Install high efficiency cooling equipment complying with CEE Tier 2.	At Replacement	Cooling	7,627	1.89	1.65	0	63,603	$0.0440	na
C106	High Efficiency Chiller	Replace chillers or installing new chillers to purchase units with efficiencies averaging 0.51kW/ton air conditioning (AC), rather than the standard new unit, which has an efficiency of 0.65kW/ton. In practice, some fraction of chiller replacements may involve the early retirement of units with lower efficiencies (perhaps 0.90 kW/ton), and thus achieve higher savings in the first few years of the measure installation,	At Replacement	Cooling	8,267	0.97	0.97	0	45,226	$0.0316	na
C107	Chiller System Optimization	The "chiller system optimization" measure includes improvements in efficiency and reduction in parasitic losses in pumps, fans, and other (non-chiller) electric motor-driven systems associated with chillers.	At Replacement	Cooling	8,550	2.12	1.85	0	72,361	$0.0052	na
C108	Chiller Tower 6F approach	Install low approach cooling tower	At Replacement	Cooling	6,557	1.63	1.42	0	72,361	$0.0377	na
H100	Economizer Diagnostic, Damper Repair & Reset	Applicable to single zone packaged systems. The outdoor make-up air damper and control are often set incorrectly or not functioning. This measure is the general checking . . . Savings derive from reduced cooling due to restored economizer function and reduced heating from reduced minimum outdoor air.	Retrofit	Cooling	58,150	14.42	12.56	2,589	156,813	$0.0273	$0.3090
H124	Install Economizer	Economizer retrofit on unit with no economizer	Retrofit	Cooling	3,453	0.86	0.75	0	7,841	$0.1236	na
H126rep	Indirect/Direct	Install indirect/direct evaporative cooling	At	Cooling	15,108	3.75	3.26	0	28,268	$0.3894	na

Measure Code	Measure Description	Comment	Construction Type	Measure End Use	Total MWh Savings	Winter MW	Summer MW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	Levelized Cost, $/th
	Evaporative Cooling ~20 ton	in commercial building HVAC system in 20 to 60 ton range	Replacement								
H127rep	Indirect/Direct Evaporative Cooling >60 ton	Install indirect/direct evaporative cooling in commercial building HVAC system in large systems <60 ton range. Original ETO evaluation evaluated at 20, 150 and 300tons with all being essentially equivalent	At Replacement	Cooling	15,108	3.75	3.26	0	28,268	$0.1780	na
E101	Wall Insulation - Blown R11	Wall Insulation - Blown R11. Application: Old buildings	Retrofit	Heating	9,431	3.24	0.29	0	5,441	$0.0085	na
E102	Wall Insulation - Spray On for Metal Buildings	Wall Insulation - Spray On for Metal Buildings (Cellulose) Unfinished. Application: Old buildings	Retrofit	Heating	748	0.26	0.02	0	364	$0.0086	na
E103	Roof Insulation - Rigid R0-11	Roof Insulation - Rigid R0-11-not including re-roofing costs but including deck preparation. Application: Old buildings with flat roofs and no attics	At Replacement	Heating	5,474	1.88	0.17	0	1,188	$0.0085	na
E104	Roof Insulation - Rigid R0-22	Roof Insulation - Rigid R0-22-- not including re-roofing costs but including deck preparation and ~4" rigid.. Application: Old buildings with flat roofs and no attics	At Replacement	Heating	6,256	2.15	0.19	0	1,188	$0.0129	na
E105	Roof Insulation - Rigid R11-22	Roof Insulation - Rigid R11-22 2" rigid added to an existing foam roof insulation at re-roof, includes some surface prep. Application: Old buildings with flat roofs, no attics, and some insulation	At Replacement	Heating	8,575	2.94	0.27	0	3,586	$0.0154	na
E106	Roof Insulation - Rigid R11-33	Roof Insulation - Rigid R11-33: add 4' of insulation at reroof. Application: Old buildings with flat roofs, no attics, and some insulation	At Replacement	Heating	3,319	1.14	0.10	0	3,586	$0.0597	na
E107	Roof Insulation - Blanket R0-19	Roof Insulation - Blanket R0-19. Application: Buildings with open truss unfinished interior	Retrofit	Heating	1,041	0.36	0.03	0	291	$0.0105	na
E108	Roof Insulation - Blanket R0-30	Roof Insulation - Blanket R0-30. Application: Buildings with open truss unfinished interior	Retrofit	Heating	1,092	0.38	0.03	0	291	$0.0113	na
E109	Roof Insulation - Blanket R11-30	Roof Insulation - Blanket R11-30. Application: Buildings with open truss unfinished interior	Retrofit	Heating	356	0.12	0.01	0	726	$0.0770	na
E110	Roof Insulation - Blanket R11-41	Roof Insulation - Blanket R11-41. Application: Buildings with open truss unfinished interior	Retrofit	Heating	427	0.15	0.01	0	726	$0.0722	na
E111	Roof Insulation - Attic R0-30	Roof Insulation - Attic R0-30. Application: Buildings with uninsulated attics	Retrofit	Heating	2,420	0.83	0.08	0	870	$0.0052	na
E112	Roof Insulation - Attic	Roof Insulation - Attic 11-30. Application:	Retrofit	Heating	3,266	1.12	0.10	0	4,094	$0.0178	na

Measure Code	Measure Description	Comment	Construction Type	Measure End Use	Total MWh Savings	Winter MW	Summer MW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	Levelized Cost, $/th
	11-30	Buildings with partially insulated attics									
E113	Roof Insulation - Roofcut 0-22	Roof Insulation - Roofcut 0-22. Application: Buildings with uninsulated flat roofs at reroofing time	At Replacement	Heating	16	0.01	0.00	0	24	$0.0514	na
E114	Windows - Add Low E to Vinyl Tint	Windows - Add Low E to Vinyl Tint. Application: Old buildings	At Replacement	Heating	1,624	0.56	0.05	0	5,623	$0.0202	na
E115	Windows - Add Low E and Argon to Vinyl Tint	Windows - Add Low E and Argon to Vinyl Tint. Application: Old buildings	At Replacement	Heating	2,000	0.69	0.06	0	5,623	$0.0256	na
E116	Windows - Add Argon to Vinyl Lowe	Windows - Add Argon to Vinyl Lowe. Application: Old buildings	At Replacement	Heating	1,356	0.47	0.04	0	15,773	$0.0507	na
E117	Windows - Non-Tinted AL Code to Class 45	Windows - Non-Tinted AL Code to Class 45. Application: Old buildings	At Replacement	Heating	326	0.11	0.01	0	6,231	$0.1533	na
E118	Windows - Non-Tinted AL Code to Class 40	Windows - Non-Tinted AL Code to Class 40. Application: Old buildings	At Replacement	Heating	910	0.31	0.03	0	6,231	$0.0825	na
E119	Windows - Non-Tinted AL Code to Class 36	Windows - Non-Tinted AL Code to Class 36. Application: Old buildings	At Replacement	Heating	1,388	0.48	0.04	0	6,231	$0.1352	na
E120	Windows - Tinted AL Code to Class 45	Windows - Tinted AL Code to Class 45. Application: Old buildings	At Replacement	Heating	355	0.12	0.01	0	4,400	$0.0609	na
E121	Windows - Tinted AL Code to Class 40	Windows - Tinted AL Code to Class 40. Application: Old buildings	At Replacement	Heating	634	0.22	0.02	0	4,400	$0.0513	na
E122	Windows - Tinted AL Code to Class 36	Windows - Tinted AL Code to Class 36. Application: Old buildings	At Replacement	Heating	882	0.30	0.03	0	4,400	$0.0921	na
H101	Warm Up Control	This measure is designed to implement a shut down of outside air when the building is coming off night setback. Usually the capability for this is available in a commercial t-stat but either the extra control wire is not attached or the unit itself has not been set up to receive the signal. Cost is based on labor cost to enable this ability in existing controllers	Retrofit	Heating	5,008	-	-	0	14,704	$0.0172	na
H102	DCV	Applicable to single zone packaged systems with large make -up air fractions either because of intermittent occupancy or because of code requirements. In most cases the outdoor air is reset to 5% or less with CO2 build-up modulating ventilation.	Retrofit	Heating	10,472	2.60	2.26	0	13,116	$0.0396	na
H103	Ducts	Duct retrofit of both insulation and air sealing	Retrofit	Heating	3,291	0.82	0.71	0	3,640	$0.0463	na
H128	Ground Source Heat	Install GSHP in place of air source heat	At	Heating	110,509	27.40	23.87	0	1,028	$0.0043	na

Measure Code	Measure Description	Comment	Construction Type	Measure End Use	Total MWh Savings	Winter MW	Summer MW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	Levelized Cost, $/th
	Pump - Air Source HP Base	pumps.	Replacement								
R106rep	Heat Reclaim	Large Grocery - Heat recovery to space heating. Assumes floating head control exists and must be changed to allow HR.	At Replacement	Heating	45,719	6.26	8.22	0	7,262	$0.0066	na
L103	T12 fluorescent to T8		Retrofit	Lighting	155,948	21.36	28.02	-1,481	101,146	$0.0244	na
L104	T12 to HP T8		Retrofit	Lighting	256,200	35.08	46.04	-2,433	101,146	$0.0214	na
L105rep	T8 to HP T8		At Replacement	Lighting	172,410	23.61	30.98	-1,711	204,780	$0.0365	na
L106ret	HID to T5 High Bay Medium		Retrofit	Lighting	31,993	4.38	5.75	-409	23,614	$0.0669	na
L107ret	HID to T5 High Bay Large		Retrofit	Lighting	15,235	2.09	2.74	-195	11,245	$0.0679	na
L112	Exit signs		Retrofit	Lighting	23,008	2.71	2.71	-240	3,155	$0.0282	na
L113	Ceramic Metal Halide		At Replacement	Lighting	36,168	4.95	6.50	-275	7,732	$0.1392	na
H105rep	Efficient Standalone Refrigeration Cases	Install efficient stand alone cases. This measure is based upon current rebates and SAIC savings numbers	At Replacement	Misc.	144,670	17.02	17.02	0	841,316	$3.6848	na
M101r	PCs and Monitors - Energy Management Software	There is a solution to automate the enabling of Power Management in commercial computers and monitor/displays called Surveyor by EZConserve.	At Replacement	Misc.	120,807	14.21	14.21	-1,197	158,017	$0.0428	na
M102r	LCD Monitors	Replace CRT with LCD monitor at replacement time	At Replacement	Misc.	59,989	7.06	7.06	-594	141,087	$0.6403	na
R104rep	Package Refrigeration - Ice makers, Vending machines	Install machines with package of measures akin to ADL low cost	At Replacement	Misc.	13209.08	1.553892	1.553892	0	841315.8	1.524119	na
R101rep	Floating Head Control	Large Grocery - Add floating head control. This is considered measure for the independent grocery chains that are less likely to implement this feature.	At Replacement	Refrigeration	15,424	2.11	2.77	0	9,405	$0.0031	na
R102rep	Refrigeration Case Package	Efficient Evap Fans, case lighting, low energy anti-sweat heaters	At Replacement	Refrigeration	16,967	2.32	3.05	0	18,810	$0.0727	na
R103rep	Efficient Refrigeration systems	Large Grocery - Efficient Comp, Sub-cooling, controls	At Replacement	Refrigeration	132,466	18.14	23.80	0	18,810	$0.0090	na
M103	Transformers		Retrofit	Total	24,684	2.90	2.90	0	116,112	$0.0076	na
M104	EMS Retrofit for Restaurants	Many commercial establishments have no means of operating facility lighting, heating, air conditioning, refrigeration, etc., except to rely upon employees to manually switch equipment on/off before,	Retrofit	Total	69,680	8.20	8.20	0	5,807	$0.0286	na

Measure Code	Measure Description	Comment	Construction Type	Measure End Use	Total MWh Savings	Winter MW	Summer MW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	Levelized Cost, $/th
		during and after a typical work day. This is especially true in restaurants. A proper EMS installation in such facilities can reduce existing gas and electric energy usage by about 10% or more.									
W101	DHW Wrap	Insulate the surface of the storage water heater or an unfired storage tank to R-5 to reduce standby losses.	Retrofit	Water Heat	2,410	0.28	0.28	0	29,620	$0.0086	na
W102	DHW Shower Heads	Install low flow shower heads (2.0 gallons per minute) to replace 3.4 GPM shower heads.	Retrofit	Water Heat	5,759	0.68	0.68	0	7,125	$0.0100	na
W103	DHW Faucets	Add aerators to existing faucets to reduce flow from 3.4 gallons per minute to 2.0 GPM.	Retrofit	Water Heat	768	0.09	0.09	0	4,750	$0.0187	na
W104	DHW Pipe Ins	Add 1" insulation to pipes used for steam or hydronic distribution; particularly effective when pipes run through unheated spaces.	Retrofit	Water Heat	7,800	0.92	0.92	0	53,519	$0.0285	na
W123r	HiEff Clothes Washer	Install high performance commercial clothes washers - residential sized units	At Replacement	Water Heat	29,034	3.42	3.42	0	1,027	$0.0445	na
W124r	Computerized Water Heater Control	Install intelligent controls on the hot water circulation loops.	Retrofit	Water Heat	9,706	1.14	1.14	0	13,771	$0.0175	na
W125r	Solar Hot Water	Install solar water heaters on large use facility such as multifamily or lodging	Retrofit	Water Heat	33,344	3.92	3.92	0	34,284	$0.0586	na
W126r	Heat Pump Water Heat	0	Retrofit	Water Heat	80,712	9.49	9.49	0	52,294	$0.0134	na
W127r	Waste Water Heat Exchanger	Install HX on waste water	Retrofit	Water Heat	4,819	0.57	0.57	0	5,229	$0.0086	na
Co116	Estar Steam Cooker	Install Energy Star Steam Cooker	New	Cooking	6,232	0.73	0.73	0	100,367	$0.0018	na
C100	CEE Tier 2 3 ton (new)	Install high efficiency cooling equipment complying with CEE Tier 2.	New	Cooling	2,660	0.66	0.57	0	12,704	$0.0121	na
C101	CEE Tier 2 7.5 ton (new)	Install high efficiency cooling equipment complying with CEE Tier 2.	New	Cooling	1,481	0.37	0.32	0	12,704	$0.0255	na
C102	CEE Tier 2 15 ton (new)	Install high efficiency cooling equipment complying with CEE Tier 2.	New	Cooling	2,360	0.59	0.51	0	12,704	$0.0284	na
C102	CEE Tier 2 25 ton (new)	Install high efficiency cooling equipment complying with CEE Tier 2.	New	Cooling	2,678	0.66	0.58	0	21,849	$0.0431	na
H126	Indirect/Direct Evaporative Cooling ~20 ton	Install indirect/direct evaporative cooling in commercial building HVAC system in 20 to 60 ton range	New	Cooling	4,775	1.18	1.03	0	8,740	$0.3814	na
H127	Indirect/Direct Evaporative Cooling >60 ton	Install indirect/direct evaporative cooling in commercial building HVAC system in large systems <60 ton range. Original ETO evaluation evaluated at 20, 150 and 300tons with all being essentially equivalent	New	Cooling	4,775	1.18	1.03	0	8,740	$0.1744	na

Measure Code	Measure Description	Comment	Construction Type	Measure End Use	Total MWh Savings	Winter MW	Summer MW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	Levelized Cost, $/th
E123	Windows - Add Low E to Vinyl Tint	Windows - Add Low E to Vinyl Tint. Application: New Construction	New	Heating	483	0.17	0.02	0	1,977	$0.0222	na
E124	Windows - Add Low E and Argon to Vinyl Tint	Windows - Add Low E and Argon to Vinyl Tint. Application: New Construction	New	Heating	587	0.20	0.02	0	1,977	$0.0285	na
E125	Windows - Add Argon to Vinyl Lowe	Windows - Add Argon to Vinyl Lowe. Application: New Construction	New	Heating	399	0.14	0.01	0	5,475	$0.0576	na
E126	Windows - Non-Tinted AL Code to Class 45	Windows - Non-Tinted AL Code to Class 45. Application: New Construction	New	Heating	116	0.04	0.00	0	2,094	$0.1455	na
E127	Windows - Non-Tinted AL Code to Class 40	Windows - Non-Tinted AL Code to Class 40. Application: New Construction	New	Heating	315	0.11	0.01	0	2,094	$0.0807	na
E128	Windows - Non-Tinted AL Code to Class 36	Windows - Non-Tinted AL Code to Class 36. Application: New Construction	New	Heating	474	0.16	0.01	0	2,094	$0.1342	na
E129	Windows - Tinted AL Code to Class 45	Windows - Tinted AL Code to Class 45. Application: New Construction	New	Heating	101	0.03	0.00	0	1,539	$0.0736	na
E130	Windows - Tinted AL Code to Class 40	Windows - Tinted AL Code to Class 40. Application: New Construction	New	Heating	184	0.06	0.01	0	1,539	$0.0604	na
E131	Windows - Tinted AL Code to Class 36	Windows - Tinted AL Code to Class 36. Application: New Construction	New	Heating	258	0.09	0.01	0	1,539	$0.1080	na
H122	HVAC System Commissioning	HVAC system commissioning. Includes testing and balancing, damper settings, economizer settings, and proper HVAC heating and compressor control installation. This measure includes the proper set-up of single zone package equipment in simple HVAC systems. The majority of the Commercial area is served by this technology. Work done in Eugene (Davis, et al, 2002) suggests higher savings than the other documented commissioning on more complex systems.	New	Heating	10,250	2.54	2.21	0	19,372	$0.1029	na
H123	HVAC controls	Control set up and algorithm. This assumes the development of an open source control package aimed at describing scheduling and control points throughout the HVAC system, properly training operators so that scheduling can be maintained and adjusted as needed, and providing operator back up so that temperature reset, pressure reset, and minimum damper settings are set at optimum levels for the current occupancy.	New	Heating	17,938	4.45	3.87	0	16,950	$0.0516	na

Measure Code	Measure Description	Comment	Construction Type	Measure End Use	Total MWh Savings	Winter MW	Summer MW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	Levelized Cost, $/th
R106	Heat Reclaim	Large Grocery - Heat recovery to space heating. Assumes floating head control exists and must be changed to allow HR.	New	Heating	13,226	1.81	2.38	0	2,067	$0.0065	na
L101	CF 9W to 39W hardwired		New	Lighting	45,053	6.17	8.10	-543	14,039	$0.0344	na
L102	High Efficacy Display		New	Lighting	6,700	0.92	1.20	-48	1,629	$0.2861	na
L105	T8 to HP T8		New	Lighting	60,700	8.31	10.91	-616	73,111	$0.0364	na
L106	HID to T5 High Bay Medium		New	Lighting	5,005	0.69	0.90	-63	4,860	$0.0425	na
L107	HID to T5 High Bay Large		New	Lighting	2,383	0.33	0.43	-30	2,314	$0.0431	na
L108	Daylight Control (overhead)		New	Lighting	33,414	4.58	6.00	-355	17,577	$0.1773	na
L109	Sweep Control		New	Lighting	29,147	-	-	-236	16,863	$0.0319	na
L110	Daylight perimeter zone		New	Lighting	5,331	0.73	0.96	-81	10,591	$0.3138	na
L111	Occupancy Sensors		New	Lighting	2,559	-	-	-36	4,553	$0.2340	na
L114	Ceramic Metal Halide		New	Lighting	11,937	1.63	2.15	-93	2,639	$0.1376	na
L115	Daylighting Overhead		New	Lighting	54,889	7.52	9.86	-1,148	20,056	$0.0479	na
L120	Lighting Scheduling/Controls	Lighting scheduling and control. This measure includes the commissioning of any occupancy and sweep controls, and the review and proper setting of daylighting controls. Since these are largely a function of schedule settings (except in cases where daylighting controls are integrated into the energy management software), we have included only the impact of properly controlled lighting and occupancy.	New	Lighting	19,725	2.32	2.32	0	39,017	$0.0414	na
M101	PCs and Monitors - Energy Management Software	There is a solution to automate the enabling of Power Management in commercial computers and monitor/displays called Surveyor by EZConserve.	New	Misc.	7,739	0.91	0.91	-77	10,122	$0.0428	na
M102	LCD Monitors	Replace CRT with LCD monitor at replacement time	New	Misc.	3,843	0.45	0.45	-38	9,038	$0.6403	na
R104	Package Refrigeration - Ice makers, Vending machines	Install machines with package of measures akin to ADL low cost	New	Misc.	2,403	0.28	0.28	0	130,056	$1.5241	na
R105	Efficient Standalone Refrigeration Cases	Install efficient stand alone cases. This measure is based upon current rebates and SAIC savings numbers	New	Misc.	24,169	2.84	2.84	0	130,056	$3.6848	na

Measure Code	Measure Description	Comment	Construction Type	Measure End Use	Total MWh Savings	Winter MW	Summer MW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	Levelized Cost, $/th
R101	Floating Head Control	Large Grocery - Add floating head control. This is considered measure for the independent grocery chains that are less likely to implement this feature.	New	Refrigeration	4,377	0.60	0.79	0	2,669	$0.0031	na
R102	Refrigeration Case Package	Efficient Evap Fans, case lighting, low energy anti-sweat heaters	New	Refrigeration	4,815	0.66	0.87	0	5,338	$0.0727	na
R103	Efficient Refrigeration systems	Large Grocery - Efficient Comp, Sub-cooling, controls	New	Refrigeration	37,591	5.15	6.75	0	5,338	$0.0090	na
H125	ECM Fan Powered Boxes	Install ECM motors in VAV fan powered terminals with PSC motors	New	Ventilation	4,250	1.05	0.92	-41	5,816	$0.0219	na
W123	HiEff Clothes Washer	Install high performance commercial clothes washers - residential sized units	New	Water Heat	5,542	0.65	0.65	0	196	$0.0445	na
W124	Computerized Water Heater Control	Install intelligent controls on the hot water circulation loops.	New	Water Heat	934	0.11	0.11	0	3,205	$0.0408	na
W125	Solar Hot Water	Install solar water heaters on large use facility such as multifamily or lodging	New	Water Heat	2,255	0.27	0.27	0	7,884	$0.1954	na
W126	Heat Pump Water Heat		New	Water Heat	3,995	0.47	0.47	0	11,467	$0.0423	na
W127	Waste Water Heat Exchanger	Install HX on waste water	New	Water Heat	3,459	0.41	0.41	0	12,121	$0.0272	na

Table 14. Detailed Measure Table, Commercial Sector, Gas Savings, 2017 Technical Potential

Measure Code	Measure Description	Measure Description	Construction Type	Measure End Use	Gas Impacts kTherms	Levelized Cost, $/kWh	Levelized Cost, $/th
Co107	Infared Fryer		At Replacement	Cooking	4,019	na	$0.0803
Co109	Infared Griddle		At Replacement	Cooking	356	na	$0.5997
Co110	Power Range Burner		At Replacement	Cooking	515	na	$0.4121
Co116rep	Estar Steam Cooker	Install Energy Star Steam Cooker	At Replacement	Cooking	860	na	$0.0397
E103	Roof Insulation - Rigid R0-11	Roof Insulation - Rigid R0-11-not including re-roofing costs but including deck preparation. Application: Old buildings with flat roofs and no attics	At Replacement	Heating	577	$0.0106	$0.1719
E104	Roof Insulation - Rigid R0-22	Roof Insulation - Rigid R0-22-- not including re-roofing costs but including deck preparation and ~4" rigid.. Application: Old buildings with flat roofs and no attics	At Replacement	Heating	660	$0.0159	$0.2596
E105	Roof Insulation - Rigid R11-22	Roof Insulation - Rigid R11-22 2" rigid added to an existing foam roof insulation at re-roof, includes some surface prep. Application: Old buildings with flat roofs, no attics, and some insulation	At Replacement	Heating	815	$0.0221	$0.3592
E106	Roof Insulation - Rigid R11-33	Roof Insulation - Rigid R11-33: add 4' of insulation at reroof. Application: Old buildings with flat roofs, no attics, and some insulation	At Replacement	Heating	316	$0.0724	$1.1796
E113	Roof Insulation - Roofcut 0-22	Roof Insulation - Roofcut 0-22. Application: Buildings with uninsulated flat roofs at reroofing time	At Replacement	Heating	2	$0.0550	$0.8951
E114	Windows - Add Low E to Vinyl Tint	Windows - Add Low E to Vinyl Tint. Application: Old buildings	At Replacement	Heating	102	$0.0250	$0.3582
E115	Windows - Add Low E and Argon to Vinyl Tint	Windows - Add Low E and Argon to Vinyl Tint. Application: Old buildings	At Replacement	Heating	142	$0.0325	$0.4660
E116	Windows - Add Argon to Vinyl Lowe	Windows - Add Argon to Vinyl Lowe. Application: Old buildings	At Replacement	Heating	167	na	$1.0231
E117	Windows - Non-Tinted AL Code to Class 45	Windows - Non-Tinted AL Code to Class 45. Application: Old buildings	At Replacement	Heating	47	na	$2.7429
E118	Windows - Non-Tinted AL Code to Class 40	Windows - Non-Tinted AL Code to Class 40. Application: Old buildings	At Replacement	Heating	130	na	$1.4868
E119	Windows - Non-Tinted AL Code to Class 36	Windows - Non-Tinted AL Code to Class 36. Application: Old buildings	At Replacement	Heating	200	na	$2.4173
E120	Windows - Tinted AL Code to Class 45	Windows - Tinted AL Code to Class 45. Application: Old buildings	At Replacement	Heating	7	$0.0575	$0.8239
E121	Windows - Tinted AL Code to Class 40	Windows - Tinted AL Code to Class 40. Application: Old buildings	At Replacement	Heating	40	$0.0550	$0.7885
E122	Windows - Tinted	Windows - Tinted AL Code to Class 36. Application: Old buildings	At	Heating	71	$0.1035	$1.4827

Measure Code	Measure Description	Measure Description	Construction Type	Measure End Use	Gas Impacts kTherms	Levelized Cost, $/kWh	Levelized Cost, $/th
	AL Code to Class 36		Replacement				
H111	SPC Hieff Boiler Replace	Install near condensing boiler. Assumed seasonal combustion efficiency of 82% over base of 75%	At Replacement	Heating	143	na	$0.3414
H112	SPC Cond Boiler Replace	Install condensing boiler. Assumed seasonal combustion efficiency of 88% over base of 75%	At Replacement	Heating	266	na	$0.5690
H114	Hi Eff Unit Heater (replace)	Install power draft units (80% seas. Eff) inplace of natural draft (64% seas. Eff)	At Replacement	Heating	1,802	na	$0.1850
H115a	Cond Unit Heater from Nat draft(replace)	Install condensing power draft units (90% seas. Eff) inplace of natural draft (64% seas. Eff)	At Replacement	Heating	3,124	na	$0.5754
H115b	Cond Unit Heater from power draft (replace)	Install condensing power draft units (90% seas. Eff) inplace of power draft (80% seas. Eff)	At Replacement	Heating	800	na	$1.1641
H116	Cond Furnace (repl)	Condensing / pulse package or residential-type furnace with a minimum AFUE of 92%.	At Replacement	Heating	821	na	$1.3428
R106rep	Heat Reclaim	Large Grocery - Heat recovery to space heating. Assumes floating head control exists and must be changed to allow HR.	At Replacement	Heating	5,624	na	$0.3624
W119	Combo Hieff Boiler (repl)	Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.	At Replacement	Heating	219	na	$0.2978
W120	Combo Cond Boiler (repl)	Replace with boiler using condensing or pulse technology to achieve steady-state combustion efficiencies of 89% to 94% (this analysis used 90% efficiency for savings calculations).	At Replacement	Heating	428	na	$0.5708
W108	DHW Condensing Tank (repl)	Costs and savings are incremental over a Code-rated tank (combustion efficiency of 80%) for a condensing tank with a minimum combustion efficiency of 94% and an R-16 tank wrap.	At Replacement	Water Heat	1,074	na	$0.3333
W113	DHW Hieff Boiler (repl)	Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.	At Replacement	Water Heat	220	na	$0.5424
W114	DHW Cond Boiler (repl)	Replace with boiler using condensing or pulse technology to achieve steady-state combustion efficiencies of 89% to 94% (this analysis used 90% efficiency for savings calculations).	At Replacement	Water Heat	429	na	$0.8339
W123r	HiEff Clothes Washer	Install high performance commercial clothes washers - residential sized units	At Replacement	Water Heat	398	na	$0.9779
Co112	Infared Fryer		New	Cooking	1,052	na	$0.0780
Co114	Infared Griddle		New	Cooking	132	na	$0.5715
Co115	Power Range Burner		New	Cooking	195	na	$0.4058
Co116	Estar Steam Cooker	Install Energy Star Steam Cooker	New	Cooking	268	na	$0.0397
E123	Windows - Add Low E to Vinyl Tint	Windows - Add Low E to Vinyl Tint. Application: New Construction	New	Heating	39	$0.0305	$0.4391
E124	Windows - Add Low E and Argon to Vinyl Tint	Windows - Add Low E and Argon to Vinyl Tint. Application: New Construction	New	Heating	52	$0.0398	$0.5734
E125	Windows - Add	Windows - Add Argon to Vinyl Lowe. Application: New Construction	New	Heating	59	na	$1.1674

Measure Code	Measure Description	Measure Description	Construction Type	Measure End Use	Gas Impacts kTherms	Levelized Cost, $/kWh	Levelized Cost, $/th
	Argon to Vinyl Lowe						
E126	Windows - Non-Tinted AL Code to Class 45	Windows - Non-Tinted AL Code to Class 45. Application: New Construction	New	Heating	20	na	$2.6788
E127	Windows - Non-Tinted AL Code to Class 40	Windows - Non-Tinted AL Code to Class 40. Application: New Construction	New	Heating	54	na	$1.4936
E128	Windows - Non-Tinted AL Code to Class 36	Windows - Non-Tinted AL Code to Class 36. Application: New Construction	New	Heating	82	na	$2.4548
E129	Windows - Tinted AL Code to Class 45	Windows - Tinted AL Code to Class 45. Application: New Construction	New	Heating	2	$0.0797	$1.1493
E130	Windows - Tinted AL Code to Class 40	Windows - Tinted AL Code to Class 40. Application: New Construction	New	Heating	16	$0.0705	$1.0158
E131	Windows - Tinted AL Code to Class 36	Windows - Tinted AL Code to Class 36. Application: New Construction	New	Heating	27	$0.1290	$1.8602
H117	SPC Hieff Boiler (new)	Install near condensing boiler. Assumed seasonal combustion efficiency of 82% over base of 75%	New	Heating	264	na	$0.3162
H118	SPC Cond Boiler (new)	Install condensing boiler. Assumed seasonal combustion efficiency of 88% over base of 75%	New	Heating	493	na	$0.5265
H119	HiEff Unit Heater (new)	Install power draft units (80% seas. Eff) inplace of natural draft (64% seas. Eff)	New	Heating	649	na	$0.1706
H120a	Cond Unit Heater from Nat Draft(new)	Install condensing power draft units (90% seas. Eff) inplace of natural draft (64% seas. Eff)	New	Heating	1,124	na	$0.5306
H120b	Cond Unit Heater From Power Draft (new)	Install condensing power draft units (90% seas. Eff) inplace of power draft (80% seas. Eff)	New	Heating	288	na	$1.0736
H121	Cond Furnace (new)	Condensing / pulse package or residential-type furnace with a minimum AFUE of 92%.	New	Heating	291	na	$1.1494
H122	HVAC System Commisioning	HVAC system commissioning. Includes testing and balancing, damper settings, economizer settings, and proper HVAC heating and compressor control installation. This measure includes the proper set-up of single zone package equipment in simple HVAC systems. The majority of the Commercial area is served by this technology. Work done in Eugene (Davis, et al, 2002) suggests higher savings than the other documented commissioning on more complex systems.	New	Heating	1,361	$0.1490	$1.7737
H123	HVAC controls	Control set up and algorithm. This assumes the development of an open source control package aimed at describing scheduling and control points throughout the HVAC system, properly training operators so that scheduling can be maintained and adjusted as needed, and providing operator back up so that temperature reset, pressure reset, and minimum damper settings are set at optimum levels for the current occupancy.	New	Heating	2,382	$0.0712	$0.9077

Measure Code	Measure Description	Measure Description	Construction Type	Measure End Use	Gas Impacts kTherms	Levelized Cost, $/kWh	Levelized Cost, $/th
R106	Heat Reclaim	Large Grocery - Heat recovery to space heating. Assumes floating head control exists and must be changed to allow HR.	New	Heating	1,974	na	$0.3583
W121	Combo Hieff Boiler (new)	Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.	New	Heating	94	na	$0.2767
W122	Combo Cond Boiler (new)	Replace with boiler using condensing or pulse technology to achieve steady-state combustion efficiencies of 89% to 94% (this analysis used 90% efficiency for savings calculations).	New	Heating	183	na	$0.5265
W109	DHW Condensing Tank (new)	Costs and savings are incremental over a Code-rated tank (combustion efficiency of 80%) for a condensing tank with a minimum combustion efficiency of 94% and an R-16 tank wrap.	New	Water Heat	483	na	$0.3296
W115	DHW Hieff Boiler (new)	Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.	New	Water Heat	118	na	$0.5187
W116	DHW Cond Boiler (new)	Replace with boiler using condensing or pulse technology to achieve steady-state combustion efficiencies of 89% to 94% (this analysis used 90% efficiency for savings calculations).	New	Water Heat	230	na	$0.7487
W123	HiEff Clothes Washer	Install high performance commercial clothes washers - residential sized units	New	Water Heat	89	$0.0779	$0.9637
W124	Computerized Water Heater Control	Install intelligent controls on the hot water circulation loops.	New	Water Heat	73	na	$0.8963
W125	Solar Hot Water	Install solar water heaters on large use facility such as multifamily or lodging	New	Water Heat	149	na	$4.2923
W127	Waste Water Heat Exchanger	Install HX on waste water	New	Water Heat	279	na	$0.5975
E101	Wall Insulation - Blown R11	Wall Insulation - Blown R11. Application: Old buildings	Retrofit	Heating	1,322	$0.0089	$0.1455
E102	Wall Insulation - Spray On for Metal Buildings	Wall Insulation - Spray On for Metal Buildings (Cellulose) Unfinished. Application: Old buildings	Retrofit	Heating	241	na	$0.1845
E107	Roof Insulation - Blanket R0-19	Roof Insulation - Blanket R0-19. Application: Buildings with open truss unfinished interior	Retrofit	Heating	332	$0.0136	$0.2215
E108	Roof Insulation - Blanket R0-30	Roof Insulation - Blanket R0-30. Application: Buildings with open truss unfinished interior	Retrofit	Heating	348	$0.0146	$0.2375
E109	Roof Insulation - Blanket R11-30	Roof Insulation - Blanket R11-30. Application: Buildings with open truss unfinished interior	Retrofit	Heating	113	$0.0993	$1.6167
E110	Roof Insulation - Blanket R11-41	Roof Insulation - Blanket R11-41. Application: Buildings with open truss unfinished interior	Retrofit	Heating	136	$0.0932	$1.5181
E111	Roof Insulation - Attic R0-30	Roof Insulation - Attic R0-30. Application: Buildings with uninsulated attics	Retrofit	Heating	194	$0.0062	$0.1012
E112	Roof Insulation - Attic 11-30	Roof Insulation - Attic 11-30. Application: Buildings with partially insulated attics	Retrofit	Heating	270	$0.0214	$0.3479
H101	Warm Up Control	This measure is designed to implement a shut down of outside air when the building is coming off night setback. Usually the capability for this is available in a commercial t-stat but either the extra control wire is not attached or the unit itself has not been set up to receive the signal. Cost is based on labor cost to enable this ability in existing controllers	Retrofit	Heating	496	na	$0.3720

Measure Code	Measure Description	Measure Description	Construction Type	Measure End Use	Gas Impacts kTherms	Levelized Cost, $/kWh	Levelized Cost, $/th
H102	DCV	Applicable to single zone packaged systems with large make -up air fractions either because of intermittent occupancy or because of code requirements. In most cases the outdoor air is reset to 5% or less with CO2 build-up modulating ventilation.	Retrofit	Heating	791	$0.0615	$0.6946
H103	Ducts	Duct retrofit of both insulation and air sealing	Retrofit	Heating	383	$0.0703	$0.8336
H104	Hot Water Temperature Reset	Controller automatically resets the delivery temperature in a hot water radiant system based on outside air temperature. The reset reduces the on-time of the heating equipment and the occurrence of simultaneous heating and cooling through instantaneous adjustments.	Retrofit	Heating	1,188	na	$0.0883
H105	HW Boiler Tune	Tune up in accordance with Minneapolis Energy Office protocol. Can include derating the burner, adjusting the secondary air, adding flue restrictors, cleaning the fire-side of the heat exchanger, cleaning the water side, or installing turbulators. Other modifications may include uprating the burner to reduce oxygen or derating the burner to reduce stack temperature. Note: In gas systems, excess air and stack temperatures are often within reasonable ranges, so the technical potential for this measure is limited. Combining this measure with the vent damper and power burner measures increases both applicability and cost effectiveness, and was assumed for this analysis.	Retrofit	Heating	50	na	$0.0725
H106	Steam Balance	Single-pipe steam systems are notorious for uneven heating, which wastes energy because the thermostat must be set to heat the coldest spaces and overheating other spaces. Steam balances corrects these problems by: 1) Adding air venting on the main line or at the radiators; 2) Adding boiler cycle controls; 3) Adding or subtracting radiators. Energy savings accrue from lowering the overall building temperature.	Retrofit	Heating	755	na	$0.1153
H107	Vent Damper	Install vent damper downstream of the draft relief to prevent airflow up the stack, while allowing warm air from the boiler to spill into the conditioned space as heat or into the boiler room to reduce jacket losses. This measure is most cost-effective when combined with the boiler tune up and power burner measures.	Retrofit	Heating	182	na	$0.2981
H108	Power burner	Replace standard burner with a power burner to optimize combustion and reduce standby losses in the stack. Note: Costs and savings assume that this measure will be performed in conjunction with a boiler tune up when appropriate.	Retrofit	Heating	1,880	na	$0.5781
H129	Steam Trap Maintanence	Set up a in-house steam trap maintenance program with equipment, training, and trap replacement. An alternative procedure is to just pay for an outside contractor to conduct a steam survey.	Retrofit	Heating	853	na	$1.1620
W101	DHW Wrap	Insulate the surface of the storage water heater or an unfired storage tank to R-5 to reduce standby losses.	Retrofit	Water Heat	83	na	$0.1854
W102	DHW Shower Heads	Install low flow shower heads (2.0 gallons per minute) to replace 3.4 GPM shower heads.	Retrofit	Water Heat	401	na	$0.2097
W103	DHW Faucets	Add aerators to existing faucets to reduce flow from 3.4 gallons per minute to 2.0 GPM.	Retrofit	Water Heat	54	na	$0.3914
W104	DHW Pipe Ins	Add 1" insulation to pipes used for steam or hydronic distribution; particularly effective when pipes run through unheated spaces.	Retrofit	Water Heat	133	na	$0.6492
W105	DHW Recirc Controls	Install electronic controller to hot water boiler system that turns off the boiler and circulation pump when the hot water demand is reduced (usually in residential type occupancies) or can be reset to meet the hot water load. (Steel boilers also require a mixing valve to prevent water temperatures from dropping below required levels).	Retrofit	Water Heat	431	na	$0.8400
W124r	Computerized	Install intelligent controls on the hot water circulation loops.	Retrofit	Water	631	na	$0.3656

Measure Code	Measure Description	Measure Description	Construction Type	Measure End Use	Gas Impacts kTherms	Levelized Cost, $/kWh	Levelized Cost, $/th
	Water Heater Control			Heat			
W125r	Solar Hot Water	Install solar water heaters on large use facility such as multifamily or lodging	Retrofit	Water Heat	1,429	na	$1.5867
W127r	Waste Water Heat Exchanger	Install HX on waste water	Retrofit	Water Heat	271	na	$0.2124

Table 15 Detailed Measure Table, Residential Sector, Electricity Savings, 2017 Technical Potential

Measure Code	Measure Description	Measure Group	Average Lifetime	Total Incremental Cost	Total O&M Impact ($)	Total kWh Savings	Winter Peak Savings, kW	Summer Peak Savings, kW	Gas Savings Therms	Level Cost, $/kWh	Level Cost, $/th
RN-A101	Estar Refrigerator	ResAppliance New	12	5,997,672	0	7,097,624	835	835	-64,502	$0.091	na
RN-A102	Estar Washer	ResAppliance New	12	19,657,499	-3,629,701	17,153,977	2,482	2,079	48,207	$0.091	$0.982
RN-A103	Estar Dishwasher	ResAppliance New	13	27,606,293	-2,067,023	9,055,025	1,310	1,097	-50,401	$0.269	na
RN-A105	Hi-eff Refrigerator	ResAppliance New	12	11,427,997	0	5,354,348	630	630	-48,659	$0.221	na
RN-A106	Hi-eff Washer	ResAppliance New	12	13,394,933	-3,466,830	20,672,442	2,992	2,506	70,475	$0.047	$0.502
RN-A107	Hi-eff Computer	ResAppliance New	5	4,942,050	0	874,915	103	103	-19,665	$1.250	na
R-A101	Estar Refrigerator	ResApplianceReplace	15	6,392,468	0	4,652,959	547	547	-88,829	$0.129	na
R-A102	Estar Washer	ResApplianceReplace	15	16,407,621	-25,422,992	22,496,270	3,256	2,727	196,511	-$0.031	-$0.329
R-A103	Estar Dishwasher	ResApplianceReplace	13	33,950,163	-19,003,077	25,711,259	3,721	3,116	600,519	$0.043	$0.494
R-A104	Refrigerator Recycle	ResApplianceReplace	12	3,645,772	0	24,024,311	2,826	2,826	-631,200	$0.034	na
R-A105	Hi-eff Refrigerator	ResApplianceReplace	15	1,485,396	0	428,064	50	50	-8,172	$0.305	na
R-A106	Hi-eff Washer	ResApplianceReplace	15	11,180,414	-24,282,217	27,143,510	3,928	3,290	244,267	-$0.037	-$0.395
R-A107	Hi-eff Computer	ResApplianceReplace	5	13,168,401	0	3,546,462	417	417	-67,705	$0.825	na
R-C101	AC Tune - up (Zone 1)	ResCooling	18	29,374,107	0	7,036,141	0	3,209		$0.304	na
R-C102	High SEER CAC, (SEER 15) (Zone 1)	ResCooling	18	198,275,225	0	15,927,875	0	7,264		$0.905	na
R-C103	Evaporative Cooling (Direct/indirect) (Zone 1)	ResCooling	18	11,079,504	0	3,392,196	0	1,547		$0.237	na
R-C104	Room AC (Zone 1)	ResCooling	18	972,340	0	280,232	0	128		$0.252	na
R-C105	AC Tune - up (Zone 2)	ResCooling	18	19,237,652	0	4,842,367	0	2,208		$0.289	na
R-C106	High SEER CAC, (SEER 15) (Zone 2)	ResCooling	18	76,193,121	0	7,379,272	0	3,365		$0.751	na
R-C107	Evaporative Cooling (Direct/indirect) (Zone 2)	ResCooling	18	13,946,209	15,584,512	4,449,319	0	2,029		$0.483	na
R-C109	High SEER CAC, (SEER 15) (Zone 1)	ResCoolingnew	18	42,285,327	0	4,060,207	0	1,852		$0.757	na
R-C110	Evaporative Cooling (Direct/indirect) (Zone 1)	ResCoolingnew	18	4,640,361	0	1,422,791	0	649		$0.237	na
R-C111	Room AC (Zone 1)	ResCoolingnew	18	823,032	0	211,356	0	96		$0.283	na
R-C112	High SEER CAC, (SEER 15) (Zone 2)	ResCoolingnew	18	16,151,008	0	2,303,613	0	1,051		$0.510	na
R-C113	Evaporative Cooling (Direct/indirect) (Zone 2)	ResCoolingnew	18	1,556,764	0	653,354	0	298		$0.173	na
R-C114	Room AC (Zone 2)	ResCoolingnew	18	381,509	0	141,355	0	64		$0.196	na
R-WN101	Tank upgrade (50 gal)-10 yr warranty	ResDHWNewElec	10	1,565,834	0	10,110,816	1,463	1,225	0	$0.018	na
R-WN102	Tank upgrade (50 gal)-20 yr	ResDHWNewElec	20	3,355,359	0	11,452,960	1,657	1,388	0	$0.020	na

Measure Code	Measure Description	Measure Group	Average Lifetime	Total Incremental Cost	Total O&M Impact ($)	Total kWh Savings	Winter Peak Savings, kW	Summer Peak Savings, kW	Gas Savings Therms	Level Cost, $/kWh	Level Cost, $/th
	warranty										
R-WN103	Heat pump water heater (50 gal)	ResDHWNewElec	15	6,258,558	3,272,157	14,938,310	2,162	1,811	0	$0.053	na
R-WN104	Heat pump water heater (80 gal)	ResDHWNewElec	15	2,397,873	862,218	3,943,489	571	478	0	$0.069	na
R-WN105	Solar hot water heater (50 gal) - Solar Zone 2. With electric backup.	ResDHWNewElec	20	78,271,185	0	48,460,363	6,559	20,588	0	$0.109	na
R-W101	Tank upgrade (50 gal)-10 yr warranty	ResDHWReplace	10	621,853	0	4,015,391	581	487		$0.018	na
R-W102	Tank upgrade (50 gal)-20 yr warranty	ResDHWReplace	20	666,271	0	2,274,204	329	276		$0.020	na
R-W103	Heat pump water heater (50 gal)	ResDHWReplace	15	3,214,319	140,773	8,821,780	1,277	1,069		$0.032	na
R-W104	Heat pump water heater (80 gal)	ResDHWReplace	15	325,355	9,800	668,675	97	81		$0.042	na
R-W105	Solar hot water heater (50 gal) - Solar Zone 2. With electric backup.	ResDHWReplace	20	49,519,794	0	35,297,783	4,778	14,996		$0.094	na
R-W106	Tank wrap (in accordance with EWEB guidelines or equivalent)	ResDHWRetrofit	10	12,820	0	288,453	34	34		$0.005	na
R-W107	Hot water pipe wrap	ResDHWRetrofit	10	33,577	0	1,556,733	183	183		$0.003	na
R-H101	Duct Sealing, Heat Pump, Zone 1	ResHVACRetrofitelec	20	16,411,838	0	23,307,502	3,896	977	0	$0.047	na
R-H102	Duct Sealing, Elect Resis, Zone 1	ResHVACRetrofitelec	20	22,243,980	0	38,400,754	9,663	268	0	$0.039	na
R-H103	Heat Pump, (HP Upgrade), Zone 1	ResHVACRetrofitelec	18	3,569,660	0	3,700,798	619	155	0	$0.070	na
R-H104	Heat Pump, (ER Base), Zone 1	ResHVACRetrofitelec	18	188,053,669	954,734	186,829,008	47,011	1,306	0	$0.074	na
R-H105	Commissioning (HP), Zone 1	ResHVACRetrofitelec	5	1,531,306	0	6,031,512	1,008	253	0	$0.055	na
R-H107	Duct Sealing, Elect Resis, Zone 2	ResHVACRetrofitelec	20	10,113,189	0	6,273,983	1,579	44	0	$0.108	na
R-H108	Heat Pump, (HP Upgrade), Zone 2	ResHVACRetrofitelec	18	2,461,000	0	3,983,768	666	167	0	$0.045	na
R-H109	Heat Pump, (ER Base), Zone 2	ResHVACRetrofitelec	18	63,999,182	324,919	23,258,932	3,888	975	0	$0.201	na
N-L101	Direct install (10 lamps)	ResLightingNew	7	9,802,885	0	62,256,621	7,324	7,324	-648,050	$0.033	na
N-L102	Direct install (25 lamps)	ResLightingNew	7	4,831,786	0	33,126,682	3,897	3,897	-327,935	$0.031	na
N-L103	Direct install (30 lamps)	ResLightingNew	30	6,091,732	406,115	35,197,114	4,141	4,141	-394,436	$0.020	na
N-L104	Direct install, fixture upgrade (50 lamps)	ResLightingNew	30	7,879,099	354,559	26,793,314	3,152	3,152	-323,732	$0.027	na

Measure Code	Measure Description	Measure Group	Average Lifetime	Total Incremental Cost	Total O&M Impact ($)	Total kWh Savings	Winter Peak Savings, kW	Summer Peak Savings, kW	Gas Savings Therms	Level Cost, $/kWh	Level Cost, $/th
N-L105	Common Area Lighting (MF Only)	ResLightingNew	7	657,426	0	4,314,358	508	508	-111,699	$0.043	na
R-L101	Retail Lights (2 lamps)	ResLightingRetrofit	7	1,422,187	0	8,744,679	1,029	1,029	-94,241	$0.034	na
R-L102	Direct install (10 lamps)	ResLightingRetrofit	7	13,340,158	0	81,386,406	9,574	9,574	-880,667	$0.034	na
R-L103	Direct install (25 lamps)	ResLightingRetrofit	9	13,869,670	0	90,828,016	10,685	10,685	-962,956	$0.027	na
R-L104	Direct install (30 lamps)	ResLightingRetrofit	30	18,238,087	23,232,783	98,922,785	11,637	11,637	-1,056,570	$0.031	na
R-L105	Direct install, fixture retrofit (50 lamps)	ResLightingRetrofit	30	23,624,604	20,837,370	75,881,726	8,927	8,927	-862,823	$0.040	na
R-L106	Common Area Lighting (MF Only)	ResLightingRetrofit	7	2,077,884	0	26,233,280	3,086	3,086	-603,716	$0.029	na
N-C101	E* Insulation, Ducts (HP, Zone1)	ResPkgNewElec	45	13,105,799	0	8,374,453	1,400	351		$0.064	na
N-C102	Window U=.3 (HP, Zone1)	ResPkgNewElec	45	7,056,968	0	2,135,776	357	90		$0.135	na
N-C103	Window U=.3 (ER, Zone1)	ResPkgNewElec	45	22,079,808	0	8,628,095	2,171	60		$0.104	na
N-C104	E* Insulation (ER, Zone1)	ResPkgNewElec	45	25,234,067	0	24,292,363	6,113	170		$0.042	na
N-C105	E* HP HSPF 7.7>9.5 (Zone 1) w. cx	ResPkgNewElec	18	11,492,152	0	13,611,248	2,275	570		$0.061	na
N-C106	E* GSHP HSPF 12 (Zone 1)	ResPkgNewElec	18	4,541,313	0	601,458	101	25		$0.549	na
N-C107	HRV, E* (HP Zone 1)	ResPkgNewElec	18	15,888,666	0	12,581,757	2,103	527		$0.092	na
N-C108	HRV (only, Zone 1)	ResPkgNewElec	18	47,313,875	0	6,974,630	1,755	49		$0.493	na
N-C109	E* Insulation, Ducts (HP, Zone 2)	ResPkgNewElec	45	1,105,659	0	1,583,685	265	66		$0.028	na
N-C110	Window U=.3 (HP, Zone 2)	ResPkgNewElec	45	595,355	0	299,490	50	13		$0.081	na
N-C111	Window U=.3 (ER, Zone 2)	ResPkgNewElec	45	1,862,744	0	1,080,497	272	8		$0.070	na
N-C112	E* Insulation (ER, Zone 2)	ResPkgNewElec	45	2,128,850	0	3,057,161	769	21		$0.028	na
N-C113	E* HP HSPF 7.7>9.5 (Zone 2) w. cx	ResPkgNewElec	18	969,525	0	1,725,748	288	72		$0.041	na
N-C114	E* GSHP HSPF 12 (Zone 2)	ResPkgNewElec	18	383,124	0	87,276	15	4		$0.319	na
N-C115	HRV * E* (HP Zone 2)	ResPkgNewElec	18	1,275,761	0	1,909,628	319	80		$0.049	na
N-C116	HRV (only, Zone 2)	ResPkgNewElec	18	3,991,594	0	789,680	199	6		$0.368	na
R-W127	Wx (two measures) ER, Zone 1	ResWxRetrofit	45	73,119,487	0	80,903,825	20,358	566	0	$0.037	na
R-W128	Wx (three measures) ER, Zone1 (one added)	ResWxRetrofit	45	62,995,855	0	63,812,977	16,057	446	0	$0.040	na
R-W129	Wx (two measures) HP, Zone 1	ResWxRetrofit	45	15,676,353	0	11,432,225	1,911	479	0	$0.056	na
R-W130	Wx (three measures) HP, Zone1 (one added)	ResWxRetrofit	45	5,481,104	0	4,156,192	695	174	0	$0.054	na
R-W131	Windows ER, Zone 1	ResWxRetrofit	45	278,008,810	0	123,377,852	31,045	862	0	$0.092	na
R-W132	Windows HP, Zone 1	ResWxRetrofit	45	83,175,253	0	31,448,599	5,257	1,318	0	$0.108	na

Measure Code	Measure Description	Measure Group	Average Lifetime	Total Incremental Cost	Total O&M Impact ($)	Total kWh Savings	Winter Peak Savings, kW	Summer Peak Savings, kW	Gas Savings Therms	Level Cost, $/kWh	Level Cost, $/th
R-W133	HRV ER, Zone 1	ResWxRetrofit	18	194,299,597	0	119,294,610	30,018	834	0	$0.118	na
R-W134	HRV HP Zone 1	ResWxRetrofit	18	57,856,094	0	34,640,664	5,791	1,452	0	$0.121	na
R-W135	Wx (two measures) ER, Zone 2	ResWxRetrofit	45	5,899,564	0	9,249,864	2,328	65	0	$0.026	na
R-W136	Wx (three measures) ER, Zone2 (one added)	ResWxRetrofit	45	10,558,264	0	7,439,812	1,872	52	0	$0.058	na
R-W137	Wx (two measures) HP, Zone 2	ResWxRetrofit	45	574,543	0	1,399,284	234	59	0	$0.017	na
R-W138	Wx (three measures) HP, Zone2 (one added)	ResWxRetrofit	45	4,027,253	0	547,932	92	23	0	$0.300	na
R-W139	Windows ER, Zone2	ResWxRetrofit	45	10,195,235	0	6,960,573	1,751	49	0	$0.060	na
R-W140	Windows HP, Zone2	ResWxRetrofit	45	18,019,816	0	3,795,597	635	159	0	$0.194	na
R-W141	HRV ER, Zone 2	ResWxRetrofit	18	7,841,942	0	8,249,957	2,076	58	0	$0.069	na
R-W142	HRV HP Zone 2	ResWxRetrofit	18	4,088,478	0	3,962,288	662	166	0	$0.075	na

Table 16 Detailed Measure Table, Residential Sector, Gas Savings, 2017 Technical Potential

Measure Code	Measure Description	Measure Group	Average Lifetime	Total Incremental Cost	Total O&M Impact ($)	Total kWh Savings	Winter Peak Savings, kW	Summer Peak Savings, kW	Gas Savings Therms	Level Cost, $/kWh	Level Cost, $/th
R-A102	Estar Washer	ResApplianceReplace	15	9,692,744	-15,018,542	13,286,478	1,923	1,610	196,511	-$0.029	-$0.311
R-A103	Estar Dishwasher	ResApplianceReplace	13	20,055,938	-11,226,000	14,931,229	2,161	1,810	354,754	$0.044	$0.501
R-A106	Hi-eff Washer	ResApplianceReplace	15	6,604,790	-14,344,633	16,031,159	2,320	1,943	244,267	-$0.035	-$0.373
R-H111	Duct Sealing, Zone 1	ResHVACRetrofitgas	20	13,890,055	0				1,225,083	na	$0.762
R-H112	AFUE 90+ Furnace, Zone 1	ResHVACRetrofitgas	18	79,495,735	0				5,918,202	na	$0.977
R-H113	AFUE 85 DHW combo, Zone 1	ResHVACRetrofitgas	18	39,453,339	0				697,518	na	4.113
R-H114	Combo with Hot Water delivery, Zone1	ResHVACRetrofitgas	30	32,556,607	5,743,115				1,115,177	na	$1.752
R-H115	Duct Sealing and AFUE 90+ , Zone 1	ResHVACRetrofitgas	20	23,044,022	3,865,261				2,368,148	na	$0.764
R-WG110	Tankless Gas heater	ResDHWGasReplace	20	61,294,872	0				7,724,670	na	$0.533
R-WG117	Wx insulation 2 measures, Zone 1	ResWxRetrofitgas	45	30,314,978	0	0	0	0	3,256,095	na	$0.380
R-WG118	Wx insulation 1 added measure, Zone 1	ResWxRetrofitgas	45	41,232,264	0	0	0	0	10,226,847	na	$0.164
R-WG119	Window, replacement (U=.35), Zone 1	ResWxRetrofitgas	45	190,599,296	0	0	0	0	5,214,639	na	$1.491
R-WG120	Window upgrade (U=.35), Zone 1	ResWxRetrofitgas	45	1,853,049	0	0	0	0	81,479	na	$0.928
R-WG121	HRV, Zone 1	ResWxRetrofitgas	18	25,425,838	11,389,414	0	0	0	612,139	na	$4.373
N-C117	E* Insulation, Ducts (Zone1)	ResPkgNewGas	45	56,961,403	0	0	0	0	4,849,422	na	$0.479
N-C118	Heating upgrade (AFUE 90) (Zone1)	ResPkgNewGas	18	25,621,664	25,467,367	0	0	0	2,297,964	na	$1.616
N-C119	Window U=.3 (Zone1)	ResPkgNewGas	45	54,892,298	0	0	0	0	1,340,088	na	$1.671
N-C120	HRV, E* (Zone 1)	ResPkgNewGas	45	108,340,061	0	0	0	0	4,051,794	na	$1.091
N-C121	E* Plus (FTC) Insulation (Zone1)	ResPkgNewGas	45	266,681,259	0	0	0	0	5,537,529	na	$1.964
RN-A102	Estar Washer	ResApplianceNew	12	11,608,214	-2,143,423	10,129,825	1,466	1,228	48,207	$0.089	$0.962
RN-A106	Hi-eff Washer	ResApplianceNew	12	7,910,022	-2,047,244	12,207,561	1,767	1,480	70,475	$0.045	$0.490
R-WG106	Tank upgrade (50 gal gas)	ResDHWNewgas	15	26,279,286	0	0	0	0	960,470	na	$2.292
R-WG107	Tank upgrade (50 gal gas) condensing	ResDHWNewgas	15	40,135,205	0	0	0	0	1,036,370	na	$3.244
R-WG108	Solar hot water heater (50 gal) - Solar Zone 2. With gas backup.	ResDHWNewgas	20	42,193,924	0	0	0	0	1,173,520	na	$2.417

Measure Code	Measure Description	Measure Group	Average Lifetime	Total Incremental Cost	Total O&M Impact ($)	Total kWh Savings	Winter Peak Savings, kW	Summer Peak Savings, kW	Gas Savings Therms	Level Cost, $/kWh	Level Cost, $/th
R-WG109	Tankless Gas heater	ResDHWNewgas	20	66,064,853	0	0	0	0	8,180,744	na	$0.543