ENERGY EFFICIENCY AND CONSERVATION MEASURE RESOURCE ASSESSMENT FOR THE YEARS 2008-2027

Prepared for the

Energy Trust of Oregon, Inc.

Final 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 2027 within the Energy Trust service territory. This resource assessment is designed to inform strategic planning, the project development and selection process, and for use in utility resource planning. By 2027, a technical potential of approximately 684 Average Megawatts (aMW) of electric savings and 148 million annual therms of gas savings were identified in this study[1].

Table 1: Summary of Technical Potential by Utility

Electric Utilities	**PGE aMW**	**PPL, aMW**	**Both Utilities, aMW**
Residential	32	67	99
Commercial	179	123	270
Industrial	223	82	305
Conservation Voltage Reduction	19	14	33
Total (Including cross-utility impact)			684
Natural Gas Utilities	**NNG, Mmtherm**	**CSG, Mmtherm**	**Both Utilities, Mmtherm**
Residential	76	21	97
Commercial	38	2	40
Industrial	15		15
Total (Including cross-utility impact)			153

Conservation Voltage Reduction is a potential measure applicable by the utility at the substation level. Hence, it is not a measure that would be targeted by the Energy Trust but it is included in order to give a complete picture of the demand side potential. Quantification of Conservation Voltage reduction comes from the work of the Northwest Power Planning and Conservation Council and was not explicitly developed in this project.

Stellar Processes and Ecotope, Inc., reviewed existing demographic and energy efficiency measure data sources to identify and quantify the resource potential. The

[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.

contractors created 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 and a Benefit Cost Ratio (BCR). Levelized costs are useful to compare on a comparable basis program options and conservation strategies that have different measure lives. The BCR provides a comparison to long-term benefits that include the lifetime and load shape value of the savings. In this sense, the BCR is a more thorough comparison and is the index used to screen for cost-effectiveness.

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 the society and (separately) to the utility system.

While this project was not intended to provide program design, it does identify and quantify estimates of electricity and gas use and measures of activity (such as number and energy use of households or total floor space) in the target markets for the industrial / agriculture, residential, and commercial sectors. Residential savings potential is quantified by housing type for new and existing single family, multifamily, and manufactured homes. Commercial savings are quantified 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 specific segments or subsectors of the commercial and industrial building stock can be difficult. For these segments, 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 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 2027. In providing summary statistics for this section, we screened measures to a BCR of 1 or better. 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 list of cost-effective measures does not include the highest cost measures, the supply curves and detailed tables of measures in the Technical Appendix lists all measures considered in this study. Both supply curves show some additional potential just beyond the current cost-effectiveness screen. Should higher avoided costs occur, there would be more additional measures available for conservation programs.

Figure 1: Electricity Supply Curve

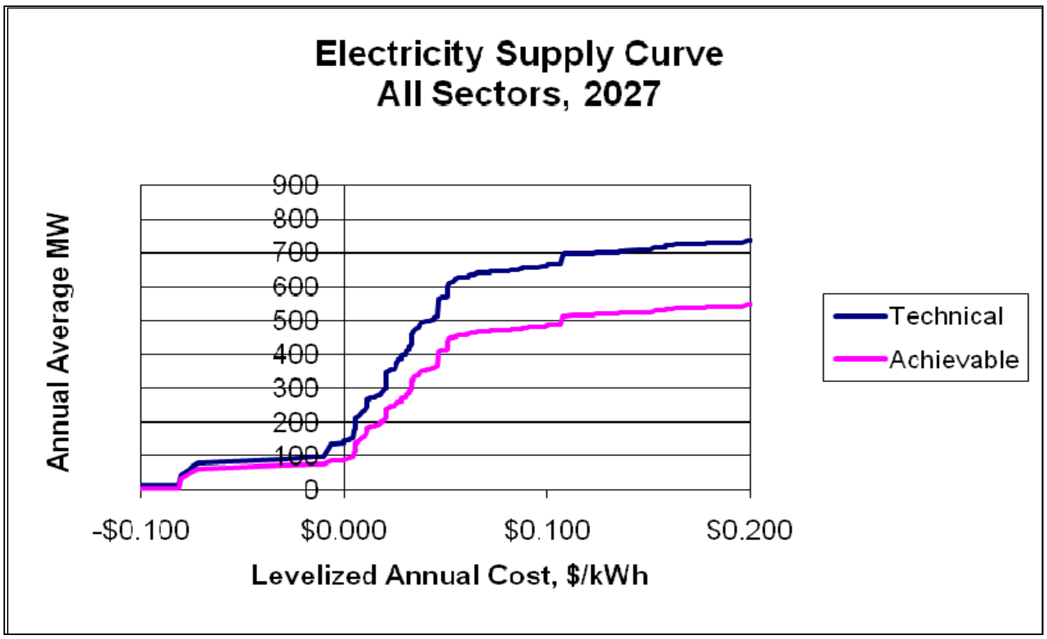


Figure 2: Electricity Technical Potential

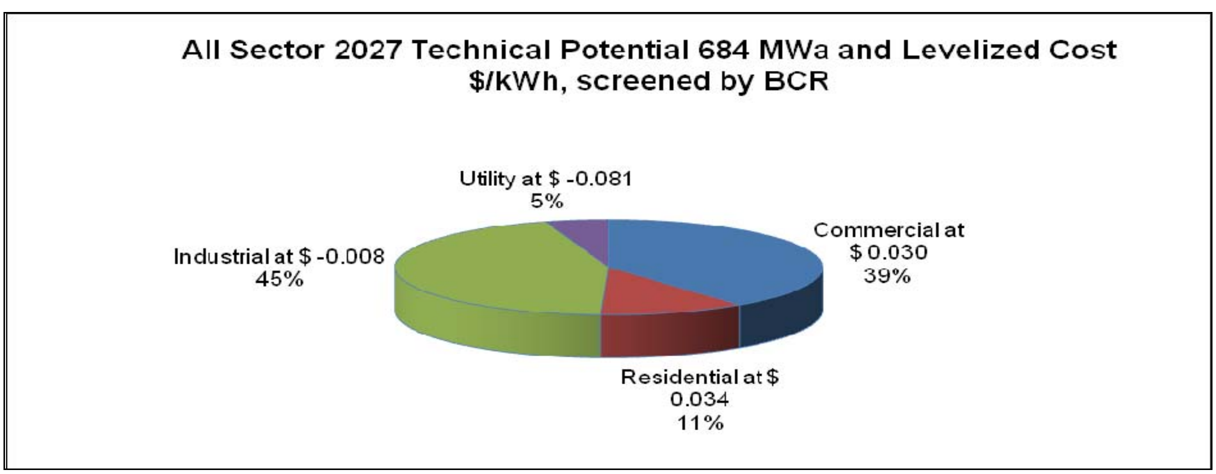


Figure 1 shows that the estimated savings from all electricity measures would reduce electricity use by 715 aMW of technical potential for cost-effective measures. Figure 2 shows the distribution of potential electric savings across market segments.

Figure 3 shows that natural gas conservation measures could reduce consumption by an estimated 153 million therms. Note that only small industrial customers are included in this gas supply curve. The larger industrial natural gas customers are not included within the Energy Trust mission. Figure 4 shows the distribution of potential natural gas savings across market segments.

Figure 3: Natural Gas Supply Curve

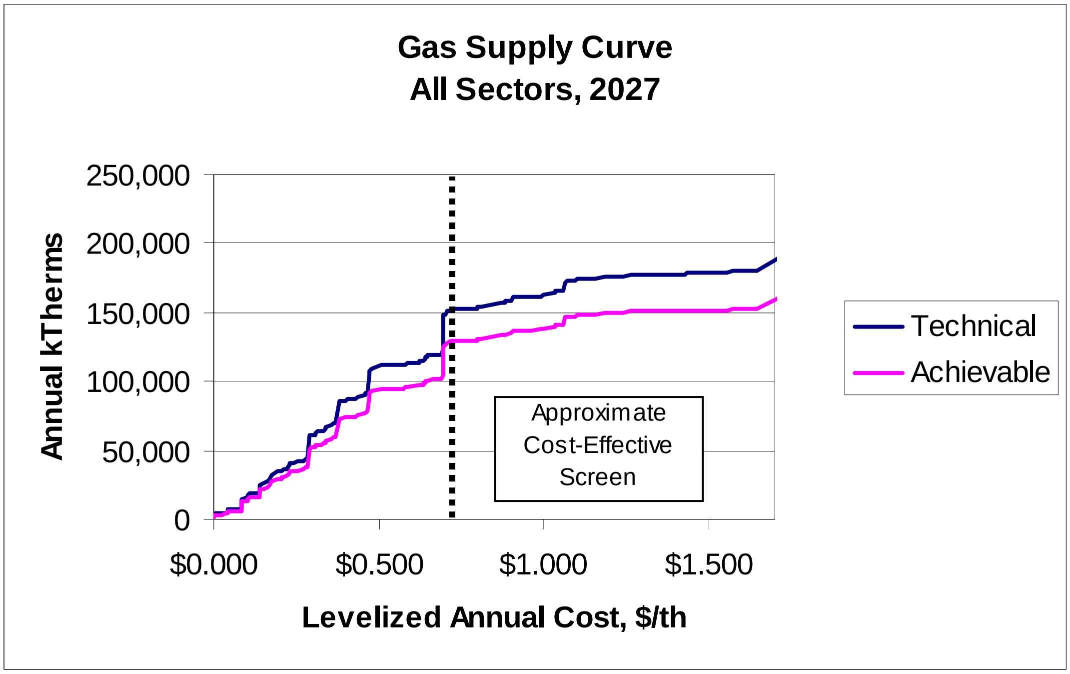
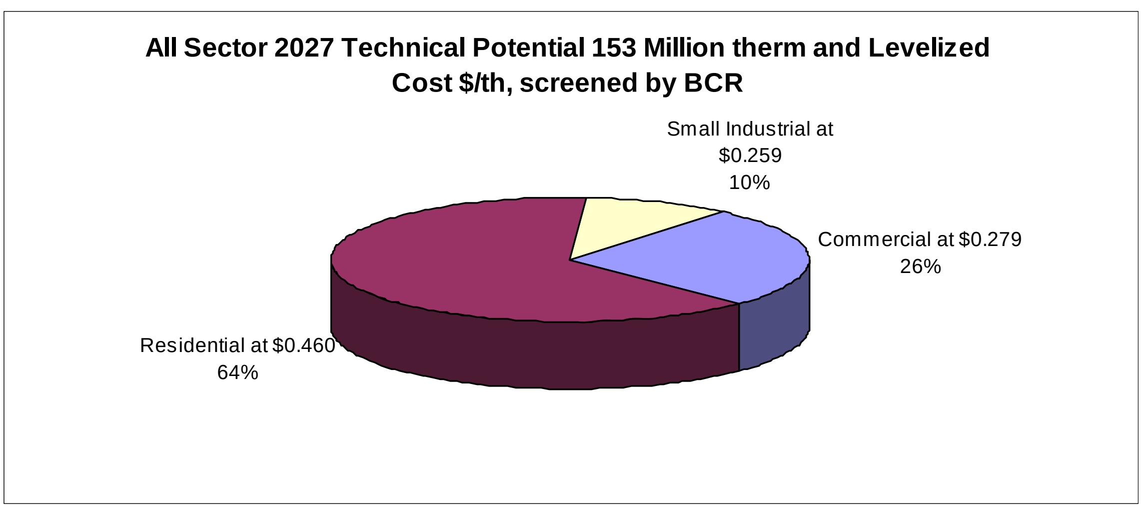


Figure 4: Natural Gas Technical Potential



Significant Efficiency Measures

Utility Sector

As mentioned previously, Conservation Voltage Reduction (CRV) is a set of measures that would be implemented at the utility level. The estimate of conservation potential was developed by the Northwest Power Planning and Conservation Council (NWPPC). The savings estimate amounts to saving 1.2% of current utility sales across all customer classes. In general, these measures could be negative in cost after credit for deferred utility investment in capacity expansion. No independent analysis was conducted for that set of measures. For further information, the reader is referred to NWPPC.

Industrial Sector

Industrial customers of investor owned utilities in Oregon with over 1 aMW 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 Trust programs.

For this sector, measures can be thought of as cutting across industries or process-specific segments. For example, motors and lighting occur in all segments; however, other measures may be specific to paper manufacturing or another process. Due to proprietary concerns, it is 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 crosscutting 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 Pacific Northwest-specific characteristics. As a result of this region specific analysis, additional detailed process measures for the electronics, paper and wood products segments are included.

Figure 5: Major Industrial Measures

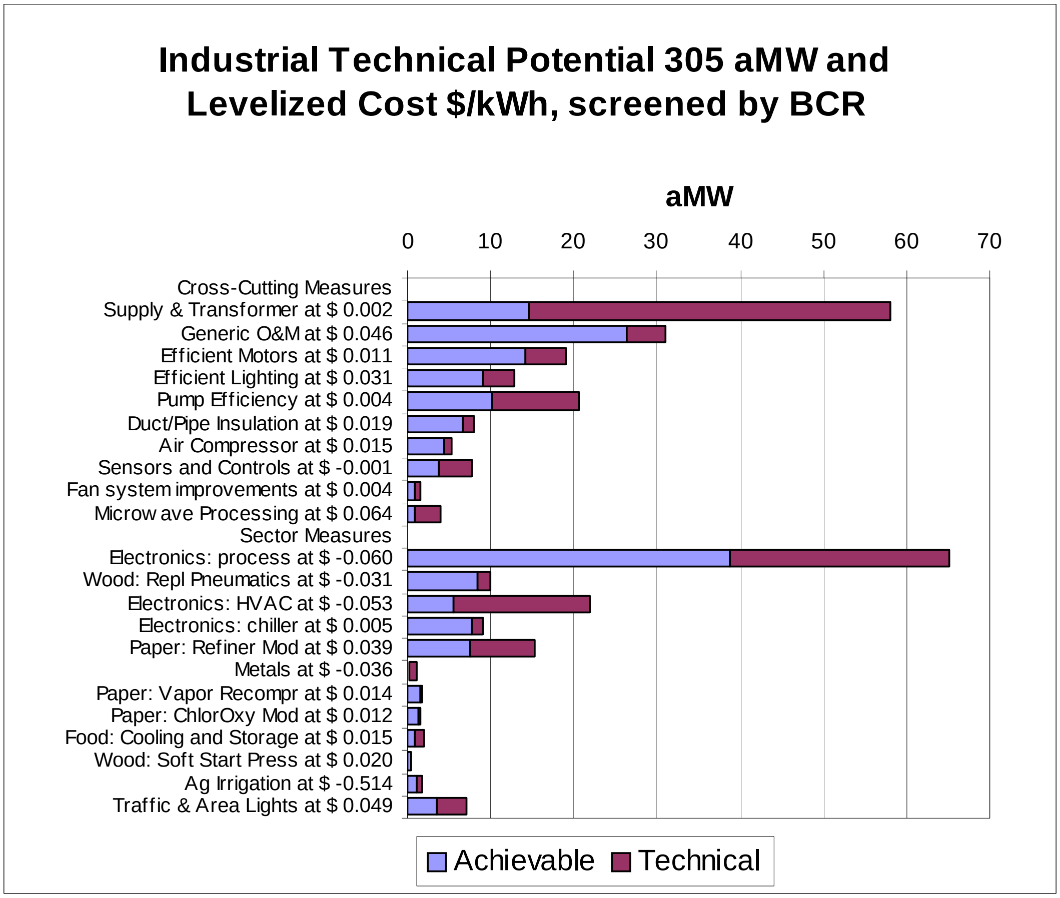


Table 2: Industrial Sector Technical Potential Saving in 2027 by Segment Screened by BCR

Segment	Consumption, aMW	Potential Savings, aMW	Savings Fraction
Electronics	465	153	33%
Wood Products	112	48	43%
Paper	239	16	7%
Food	62	4	6%
Other	242	10	4%
Primary Metal	145	26	18%
Fabricated Metal	31	2	6%
Agriculture	74	39	53%
Street and Area Lighting	36	7	20%
Total	1405	305	22%

As Table 3 shows, industrial sector measures appear low in cost from a societal perspective because there are non-energy benefits in terms of increased production and reduced use of raw materials.

Table 3: Industrial Sector Technical Potential Saving in 2027, Screened by BCR

Measure Category	aMW Savings	Level Cost, $/kWh
Cross-Cutting Measures		
Supply & Transformer	58.0	$0.002
Generic O&M	31.1	$0.046
Efficient Motors	19.0	$0.011
Efficient Lighting	12.8	$0.031
Pump Efficiency	20.5	$0.004
Duct/Pipe Insulation	7.9	$0.019
Air Compressor	5.3	$0.015
Sensors and Controls	7.7	-$0.001
Fan system improvements	1.6	$0.004
Microwave Processing	3.9	$0.064
Segment Measures		
Electronics: process	65.2	-$0.060
Wood: Repl Pneumatics	10.0	-$0.031
Electronics: chiller	22.0	-$0.053
Paper: Refiner Mod	9.1	$0.005
Electronics: HVAC	15.3	$0.039
Metals	1.2	-$0.036
Food: Cooling and Storage	2.0	$0.015
Paper: Vapor Recompr	1.7	$0.014
Paper: ChlorOxy Mod	1.5	$0.012
Wood: Soft Start Press	0.5	$0.020
Ag Irrigation	1.7	-$0.514
Traffic & Area Lights	7.2	$0.049
Total	305.3	-$0.008

Only firm industrial gas customers are included in this analysis, which is only a small fraction of gas company sales. That is because large gas customers are outside the Energy Trust mission. The firm industrial customers tend to be small facilities that are similar to commercial sector. Figure 6 and Table 4 show the potential for gas conservation measures.

Figure 6: Small Industrial Natural Gas Measures

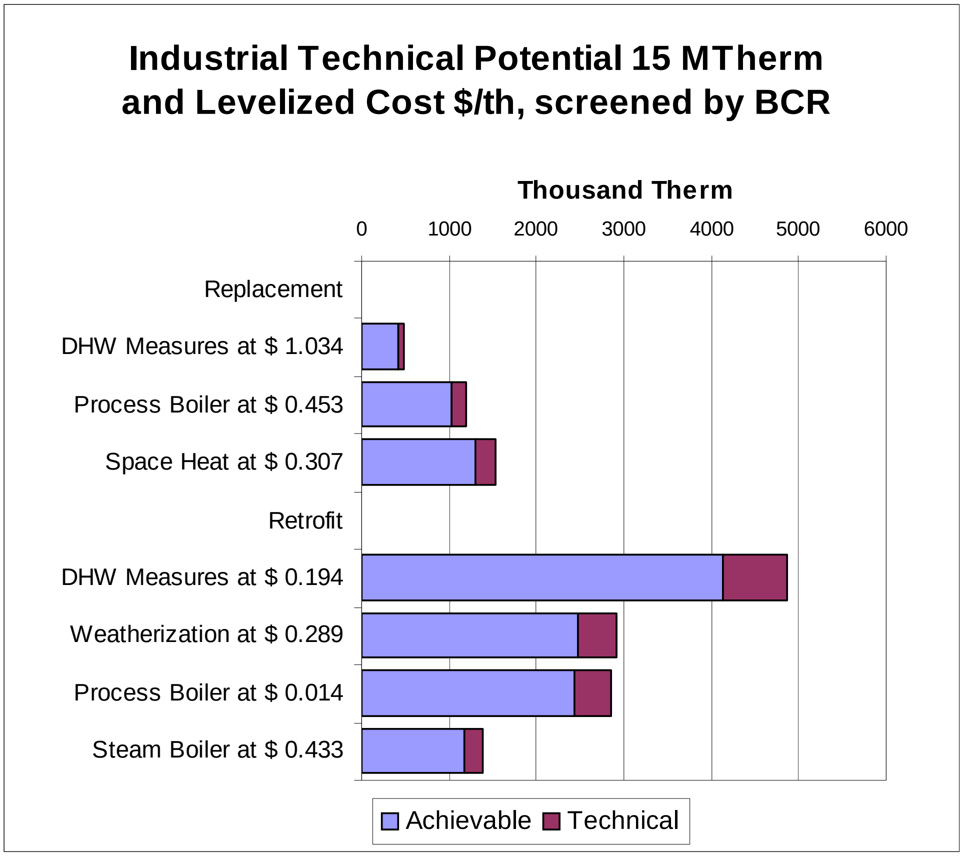


Table 4 Small Industrial Gas 2027 Technical Potential Savings, Screened by BCR

Measure Category	Technical Potential, ktherm	Levelized Cost, $/th
Replacement		
Process Boiler	1,205	$0.453
DHW Measures	493	$1.034
Space Heat	1,534	$0.307
Retrofit		
DHW Measures	4,865	$0.194
Process Boiler	2,861	$0.014
Weatherization	2,917	$0.289
Steam Boiler	1,379	$0.433
Total	15,254	$0.259

Commercial Sector.

Figure 7 and Table 5 show the potential for groups of measures in the commercial sector with most significant savings. These measure groups are broken out according market segments that affect program design. These groups are as repair and replacement of existing stock as well as measures specific to new construction. In both cases, lighting opportunities dominate. In most cases, achievable potential is estimated as 85% of technical potential. Details are shown in Table 5.

Figure 7: Major Commercial Segment Measures, Electricity

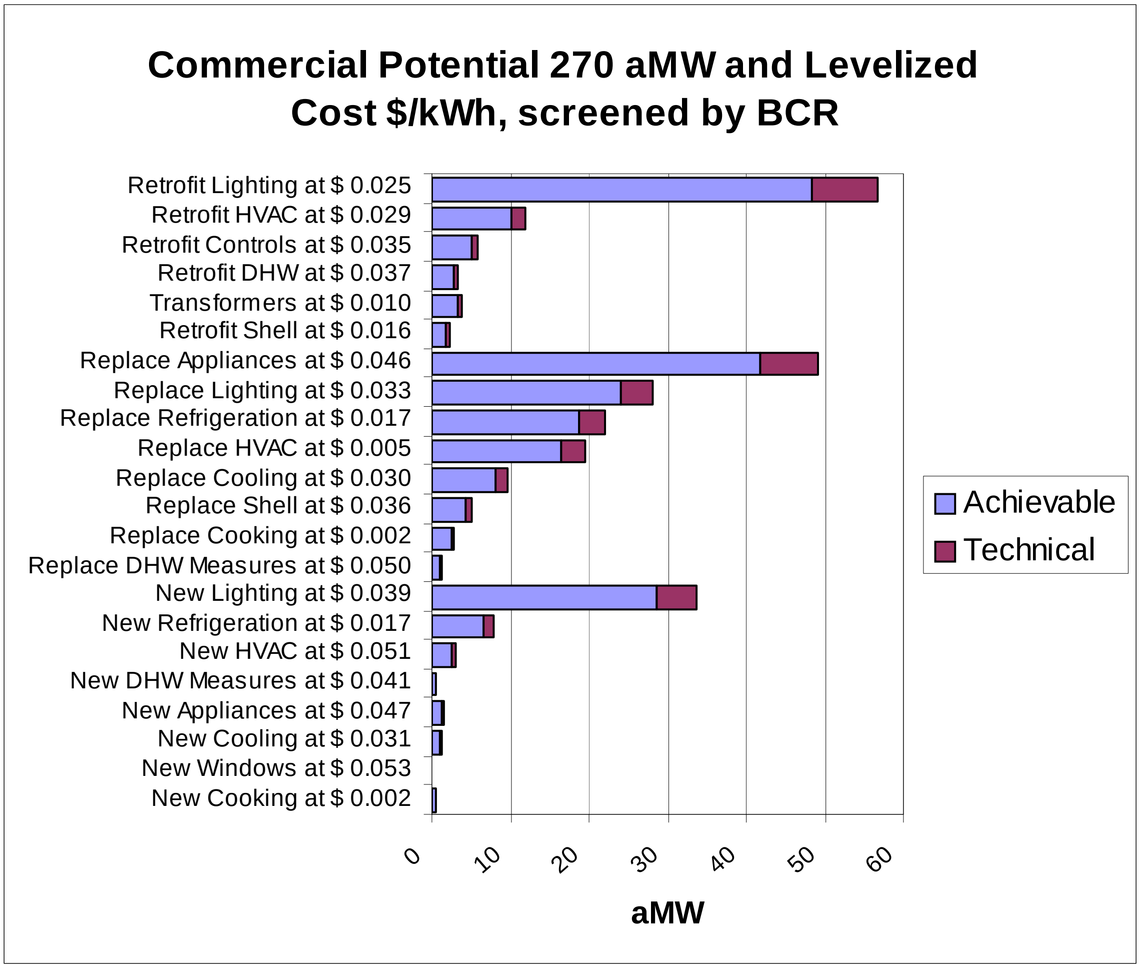


Table 5: Commercial Sector 2027 Technical Potential Savings, Screened by BCR

Measure Category	aMW Savings	Winter Peak Savings, MW	Summer Peak Savings, MW	Level Cost, $/kWh
New Cooling	1	3	2	$0.031
New Cooking	1	1	1	$0.002
New Windows	0	1	0	$0.053
New HVAC	3	7	6	$0.051
New Lighting	34	34	44	$0.039
New Appliances	2	2	2	$0.047
New Refrigeration	8	9	12	$0.017
New DHW Measures	1	1	1	$0.041
Replace Cooling	10	19	17	$0.030
Replace Cooking	3	3	3	$0.002
Replace Shell	5	15	1	$0.036
Replace HVAC	19	42	37	$0.005
Replace Lighting	28	34	44	$0.033
Replace Appliances	49	51	51	$0.046
Replace Refrigeration	22	27	35	$0.017
Replace DHW Measures	1	1	1	$0.050
Retrofit Shell	2	7	1	$0.016
Retrofit HVAC	12	24	21	$0.029
Retrofit Lighting	57	68	88	$0.025
Transformers	4	4	4	$0.010
Retrofit Controls	6	6	6	$0.035
Retrofit DHW	3	3	3	$0.037
Total	**270**	**360**	**379**	**$0.030**

Figure 8 and Table 6 show the conservation potential for natural gas in the commercial sector. These measures are also grouped by retrofit or replacement versus new construction. Equipment upgrades are the primary measures. Heat reclamation from refrigeration has emerged as a significant resource due to recent regional market research. In new construction, the predominant savings measure is from roof insulation required to be better than code minimum.

Figure 8: Major Commercial Sector Measures, Gas

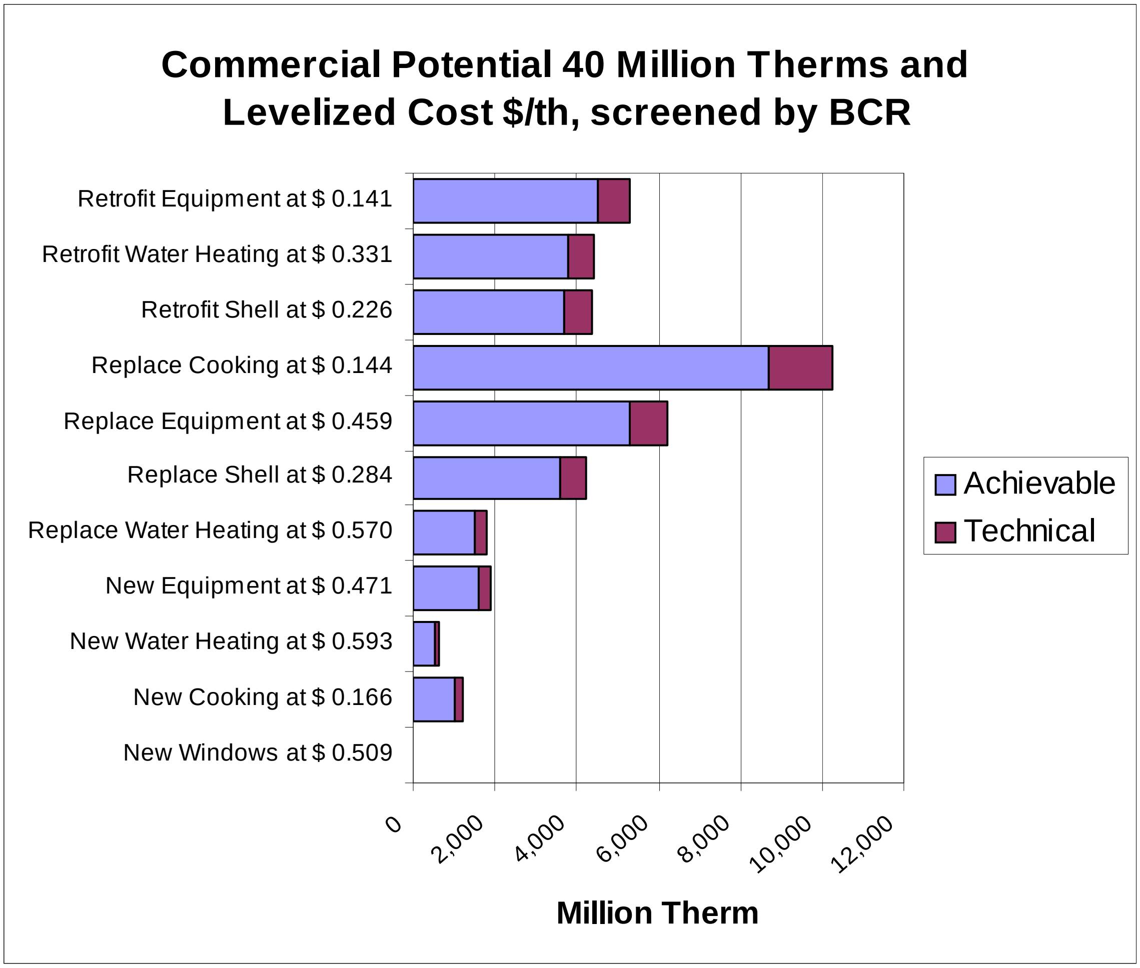


Table 6: Commercial Sector Gas Technical Potential Savings for 2027, Screened by BCR

Measure Category	Thousand therm	$/therm
New Cooking	1,209	$0.166
New Windows	72	$0.509
New Equipment	1,891	$0.471
New Water Heating	628	$0.593
Replace Cooking	10,239	$0.144
Replace Shell	4,222	$0.284
Replace Equipment	6,221	$0.459
Replace Water Heating	1,792	$0.570
Retrofit Shell	4,352	$0.226
Retrofit Equipment	5,302	$0.141
Retrofit Water Heating	4,440	$0.331
Total	**40,368**	**$0.279**

Residential Sector

Figure 9 and Table 7 show residential electricity potential in 2027 grouped by existing and new construction opportunities. There is also significant potential for weatherization, replacement of heating systems and appliances. In new construction, emerging heat pump water heaters are expected to be a major resource. Otherwise, lighting in new buildings provides the most savings potential. In addition to these known opportunities, there is an expanding array of new technology to be discussed later.

Figure 9: Major Residential Segment Measures, Electricity

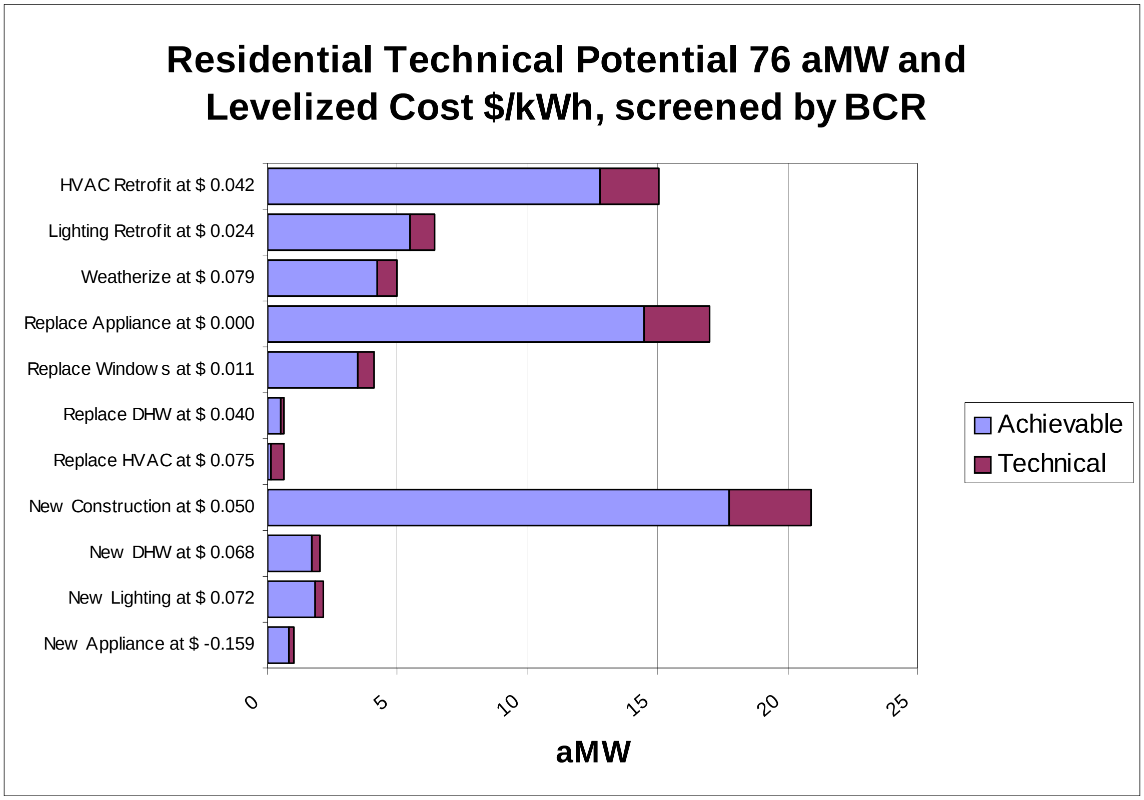


Table 7: Residential Sector Electric Technical Potential Savings for 2027, Screened by BCR

Measure	aMW Savings	Winter Peak Savings, MW	Summer Peak Savings, MW	Level Cost, $/kWh
New Construction	21	33	7	$0.050
New DHW	2	3	2	$0.068
New Lighting	2	2	2	$0.072
New Appliance	1	1	1	-$0.159
New HVAC	1	2	0	$0.071
Replace Appliance	17	20	18	$0.000
Replace Windows	4	9	0	$0.011
Replace DHW	1	1	1	$0.040
Replace HVAC	1	1	0	$0.075
DHW Measures	0	0	0	$0.009
HVAC Retrofit	15	27	4	$0.042
Lighting Retrofit	6	7	7	$0.024
Weatherize	5	10	1	$0.079
Total	**76**	**115**	**43**	**$0.034**

Figure 10 and Table 8 show residential potential for natural gas savings in 2027 grouped by existing and new construction. For natural gas, the greatest opportunity lies in weatherization of existing buildings, retrofit of existing heating equipment, and increased efficiency for new construction. Opportunities during new construction include better insulation and windows, duct sealing, high efficiency furnaces, and heat recovery ventilation. The fact that some appliances are negative in cost reflects the fact that there are non-energy benefits, such as water savings, that offset cost for some appliances.

Figure 10: Major Residential Sector Measures, Gas

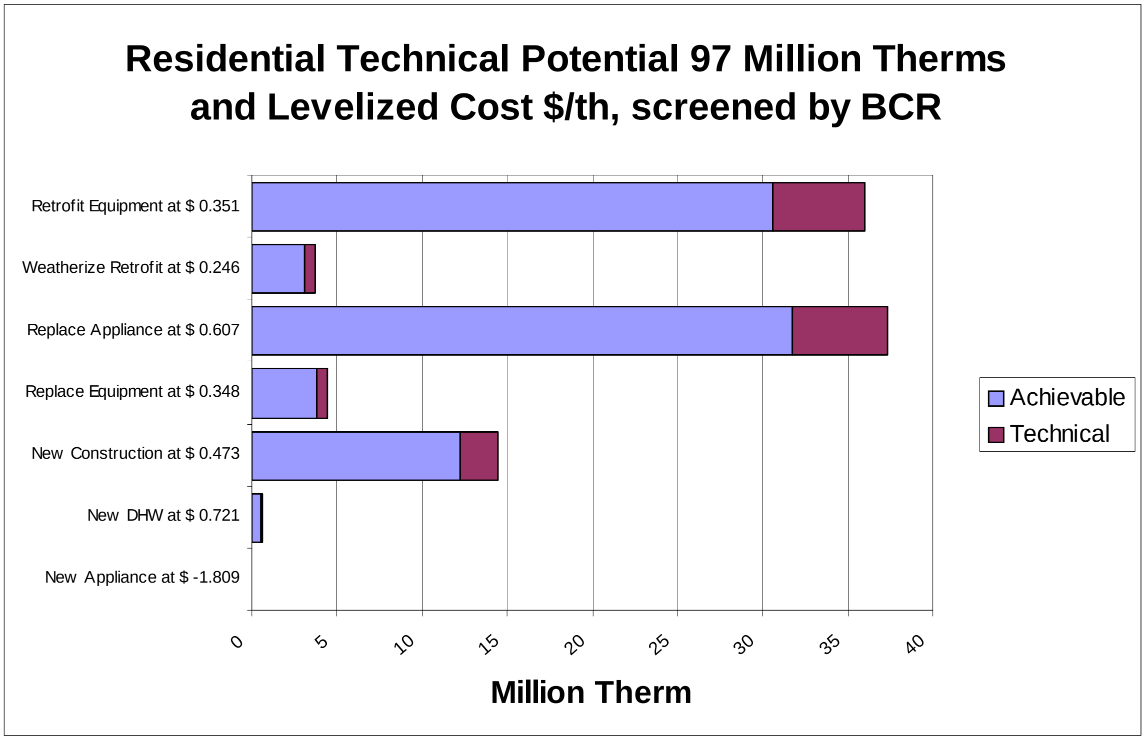


Table 8: Residential Sector Gas Technical Potential Savings for 2027, Screened by BCR

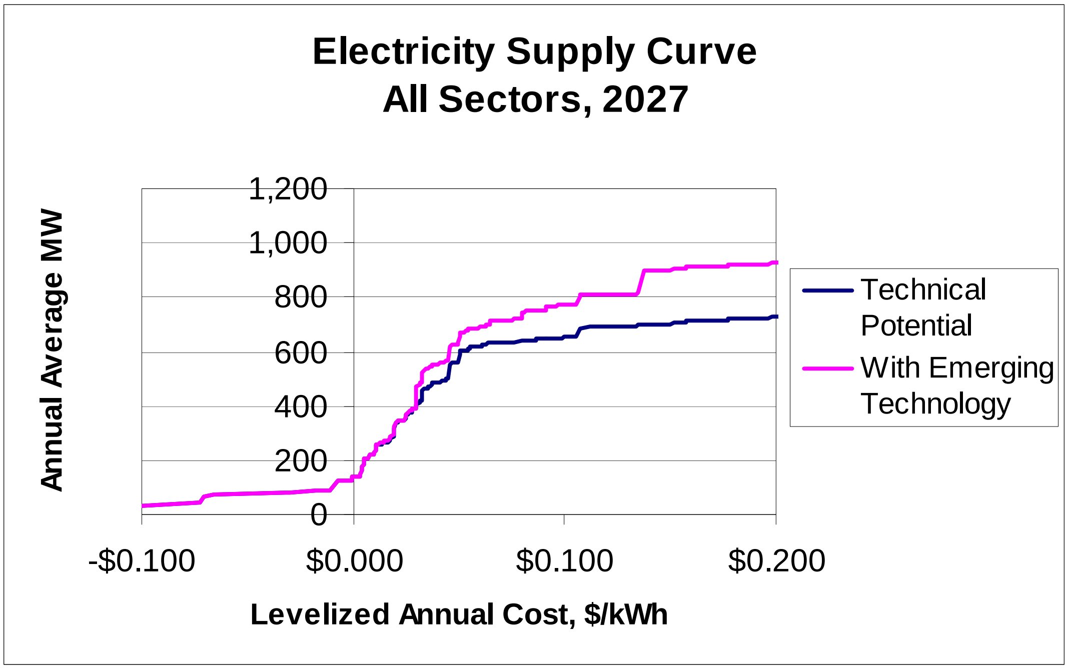
Measure Category	Thousand Therm	$/therm
New Appliance	59	-$1.809
New Construction	14,450	$0.473
New DHW	613	$0.721
Replace Appliance	37,360	$0.607
Replace Equipment	4,454	$0.348
Retrofit Equipment	35,976	$0.351
Weatherize Retrofit	3,681	$0.246
Total	**96,592**	**$0.465**

Emerging Technology

Distinction should be noted between those measures that are new -- that is, available but not yet in wide spread practice -- and those that are emerging but not yet available in the market. These measures are expected to become widespread in the future even if they are not yet considered mainstream. Measures in this category deserve discussion and possible support for demonstration because they are quite likely to become important opportunities. Unfortunately, the methodology of resource assessment is not well suited to exploring hypothetical new options (see Fred Gordon, et al., "Beyond Supply Curves", ACEEE Conference Proceedings, 2008).

Given that our ability to predict future inventions is limited, one can still develop some sensitivity estimates for products that are known or expected to be almost market ready. Figure 11 shows emerging technology increases the supply curve by almost 20%.

Figure 11. With Emerging Technology



The specific measures treated as emerging are discussed in more detail titled "New Measure Development" on page 20. In general, most of these measures we could identify as "emerging" are in the residential sector.

Residential consumer electronics are a rapidly changing market. One anticipates that many new products will start to use "smart" capabilities including internet controls. If done properly, this could lead to energy savings during "sleep" mode. California has identified large savings opportunities and is pursuing a program for Low Power Mode Appliances. Such savings would occur through new standards to be implemented at the manufacturing level and would not be immediate program opportunities. Within programs, there are opportunities for new lighting products, for heat pump water heaters and new ductless heat pumps for space heating.

The importance of these new technologies is illustrated in Table 9. Assuming that the new products occur, they would then be responsible for 61% of the new and increased technical potential for residential sector.

Table 9: Residential Emerging Technology

Measure	aMW Savings	Emerging Technology as Percent of Total
New Appliance	20	95%
New DHW	4	64%
New Lighting	2	47%
Replace Appliance	56	77%
Lighting Retrofit	23	78%
Heat Pump HW	2	100%
HVAC Retrofit	10	41%
Total	**117**	**61%**

Resource Assessment Methodology

This section describes the methodology used in this report. More detailed description is provided in the detailed appendix and many of the specifics 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 segment unit (residential household, commercial square footage, and industrial by typical facility) and customer type within each segment (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 in order for the eventual savings estimates to 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 the actual utility sales data.

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

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

- 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 depends 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, and then results were 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 & Conservation Council's (NPCC) Regional Technical Forum (RTF) data was utilized in the residential sector to collect costs and energy benefits. In addition, the NPCC 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.

Selection of Potential Measures

In residential sector, we utilized 107 measures. Each measure is developed separately for three building types. In the commercial sector, we utilized 106 measures. Each measure is then developed separately for 12 building types.

The measures identified in the initial list 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 &

Conservation 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 "Replacement." "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 was 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[2]. 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

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

based on utility projections. For replacement and new measures, it is important to specify a target year sufficiently into the future that significant new resources will be counted. We utilized the year 2027 as the target year for assessment.

Retrofit and replacement can be in conflict; if one does a retrofit, the 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 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, yet 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.

New Measure Development

In preparing this version of the planning tools, the primary focus was on updating costs and savings for previously developed measures. However, we considered a number of new measures as the request of reviewers.

Heat reclamation from commercial refrigeration has been identified as a new measure due to recent regional market research. Although still not widely practiced, it is recognized as a significant category for gas savings in this study. Heat recovery to hot water heating 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. Similarly, Heat Recovery Ventilation (HRV) has a large technical potential in both the residential and the commercial sector. In both cases, there are products currently available but local builders have been reluctant to adopt them.

Heat pump water heaters are identified as having a large technical potential in both the residential and the commercial sector. In this case, new products are expected but are not yet on the market. We consider this measure to be emerging technology.

Similarly, we expect a new generation of gas water heaters within a year. High efficiency gas water heaters have been available previously but these new products will be less expensive.

The Home Energy Monitor connects a digital readout to the customer's utility meter so that the customer has direct feedback as to their consumption level. We project this product as currently available but as emerging technology.

Lighting measures are an unusual case. New federal standards will require efficient lighting starting in about 2015. As a result, the lifetime for installing lighting measures in the current stock of buildings has been reduced. We expect that a new generation of LED lighting products will be available by year 2015 and even more efficient lighting products will emerge in about year 2020.

Prototype units of condensing natural gas packaged heaters have been demonstrated in Canada. However, the condensing feature of theses units was not the primary source of their savings – rather it was the fact that exposed ductwork was better insulated. Furthermore, manufacturers have not indicated willingness to bring these units into production due to the higher cost of the hardware.

One area of interest was the application of residential gas water heating systems for combined space heat and water heat. We considered various combinations of available technology. Although there would be cost savings by eliminating the furnace, the added cost of a hydronic heating system would be comparable. And although a tankless water heater would be higher efficiency, it would be competing against an already-efficient gas furnace for space heating. Only one combination option appears to be currently cost-effective – that would be a combination involving a low-cost hydrocoil applied to an air distribution system. We also include a high efficiency combination system based on the Polaris water heater. However, the basecase assumes that a conventional gas boiler and hydronic slab heating system would otherwise be installed and the efficiency improvement is small relative to the incremental cost.

A similar niche on the electricity side would be new ductless heat pump systems. These systems are designed for fool-proof installation that may eliminate some of the installer errors that have plagued large heat pumps. Current models are small in capacity, which limits their retrofit potential. They are suggested for homes with electric baseboard heating – which makes them one of the few retrofit equipment measures possible for older homes with baseboard heating. Energy savings will depend on the extent to which customers operate these units to offset baseboard heat and the addition of summertime cooling might offset winter savings. In multi-family housing where they would provide the equivalent of an efficient through-the-wall heat pump. These are included as an emerging technology measure. The cost estimate gives credit for the fact that a window air conditioner would otherwise have to be included to provide a similar cooling benefit.

A new set of high efficiency gas water heaters is becoming available. We include a low-cost gas water heater with 0.70 EF rating that will shortly be available as emerging technology. Tankless gas water heaters have an EF rating of 0.85. There is an incremental upgrade possible to the Navien tankless heater at 0.89 EF rating that would be cost effective even for the high cost system.

Waste heat recovery from wastewater has been previously reviewed as a potential measure. It is not well suited for residential applications, as it is a relatively expensive retrofit limited to full basements. As a result, this measure is limited to commercial facilities.

Other commercial measures that were changed include high performance lighting systems. More efficient T8 systems can replace the previous generation of older T8s. T5 systems are somewhat more expensive but can be a worthwhile replacement for metal halide lights. One advantage is the new fluorescent system is that it can be switched off or dimmed, allowing application of occupancy sensors.

Low flow spray valves are a low cost commercial application that is rapidly being deployed within the current program.

Tool Selection and Use

One of the primary goals of this project was to continue use of, and improve upon the method of analyzing measures across segments and technology types that would provide a means of comparing anticipated costs and benefits associated with a variety of program options.

The Assessment Tool used 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, and 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, segment 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 did not provide optimum flexibility to analyze measures by segment or across segments 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.

Benefit Cost Ratio (BCR)

In previous studies, we used the levelized cost as a screening criterion to determine cost effectiveness. One problem is that the levelized cost fails to take into account Time-Of-Use (TOU), that fact that savings during a peak period may have higher value and, hence, be more cost-effective. In order to better account for this feature, we computed the total benefit, net present value of lifetime savings and Non Energy Benefits (NEB), evaluated at each measure’s load shape. This lifetime benefit can then be compared to the total resource cost. If the benefits are greater than cost, the benefit-cost ratio is greater than one. This ratio offers a simple comparison.

$$BCR = \frac{Net\ Present\ Value\ of\ Benefits\ (including\ TOU, NEB, hedge\ and\ externality\ value)}{Total\ Resource\ Cost}$$

In general, screening by BCR rarely results in a different cost-effectiveness determination than that afforded by the levelized cost. The exception occurs with some residential sector end uses that occur during peak periods.

In cases where the total resource cost is actually negative, due to non-energy benefits that offset cost, the calculation for BCR returns a negative value. While this is technically correct, it could be confusing. For this reason, we defined the BCR to be 100 whenever total cost is negative. This facilitates sorting the measures in order of declining BCR.

One complication with computing BCR lies in obtaining realistic estimates of the utility system avoided cost at different times of the day. For this purpose, we used values estimated by the Northwest Power and Conservation Council (NPCC). Their methodology involved modeling the West Coast energy markets in order to forecast the market price by time of day for future years. To this estimate of market value, we add a value for future cost of CO2 mitigation. NPCC also recommends adding a “hedge value” due to the fact that DSM investments decrease financial risk. As further information is developed, the estimates of avoided cost can be further updated.

Supply Curve of Conservation Measures

The results of the assessment are provided in the form of separate spreadsheets for the industrial, commercial, and residential sectors (see appendix 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 future study period. To generate both the cost 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 5.2 percent per 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 therms) 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.

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

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 NPVs 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 the supply curves.

Technical Potential Savings Check

Since the potential savings estimate results in large numbers, it is useful to apply a reality check to verify that the numbers are reasonable. One procedure to check the potential is to compare estimated savings to the amount of estimated consumption. Such a comparison may be presented as the expected percent 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 percentage 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 percentage that can be addressed.

Figure 12 demonstrates that our analysis focused on the segments 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 12: Savings Percentages for Industrial Segments

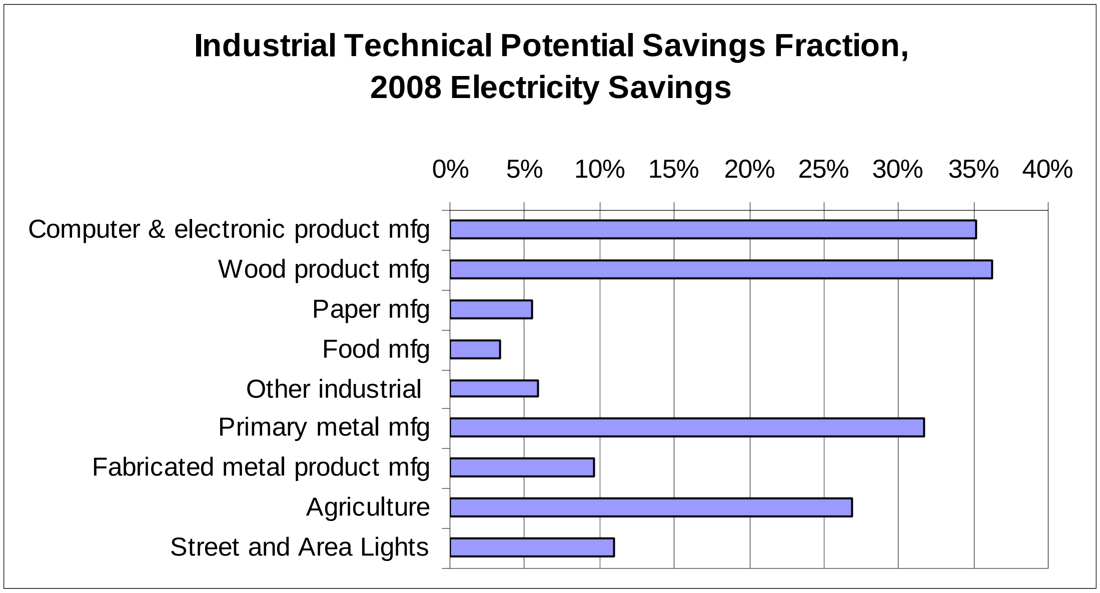


Figure 13 shows savings percentages for residential electricity consumption. Low Power Mode Appliances account for the large fraction in the appliance enduse.

Figure 13: Residential Savings Percentages by Electricity End Use

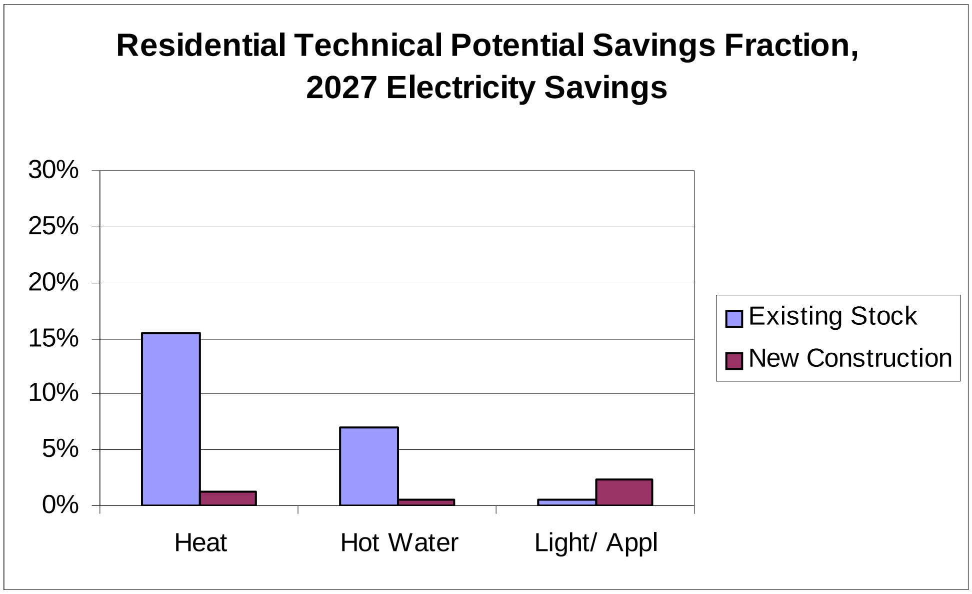


Figure 14 shows savings percentages for residential gas measures.

Figure 14: Residential Savings Percentages by Gas End Use

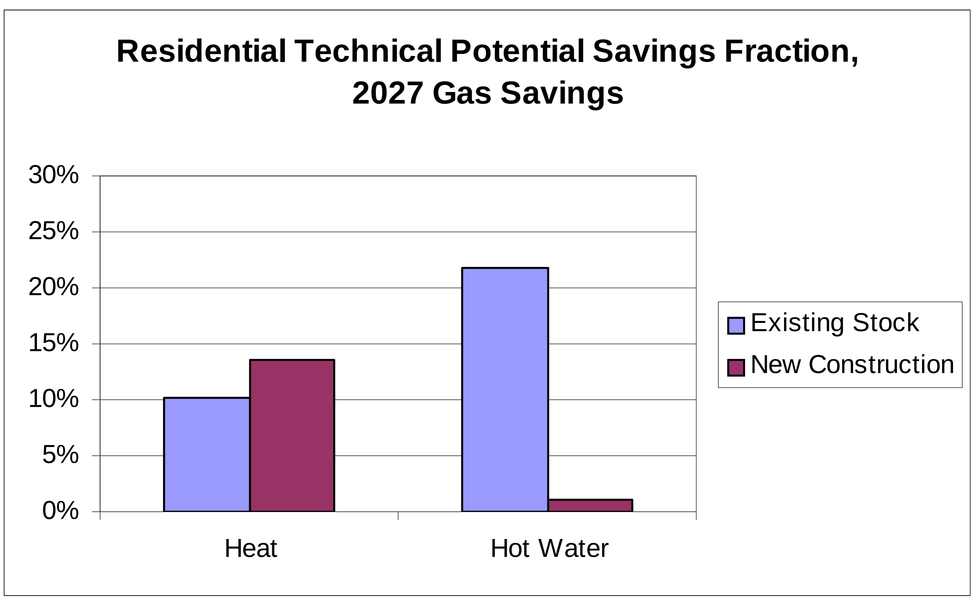


Figure 15 and Figure 16 show savings percentages for commercial sector. Refrigeration savings reflect recovered heat in addition to the refrigeration end use. Gas DHW savings are high reflecting controls, a number of boiler improvements and heat recovery for water heating.

Figure 15: Commercial Savings Percentages by Electricity End Use

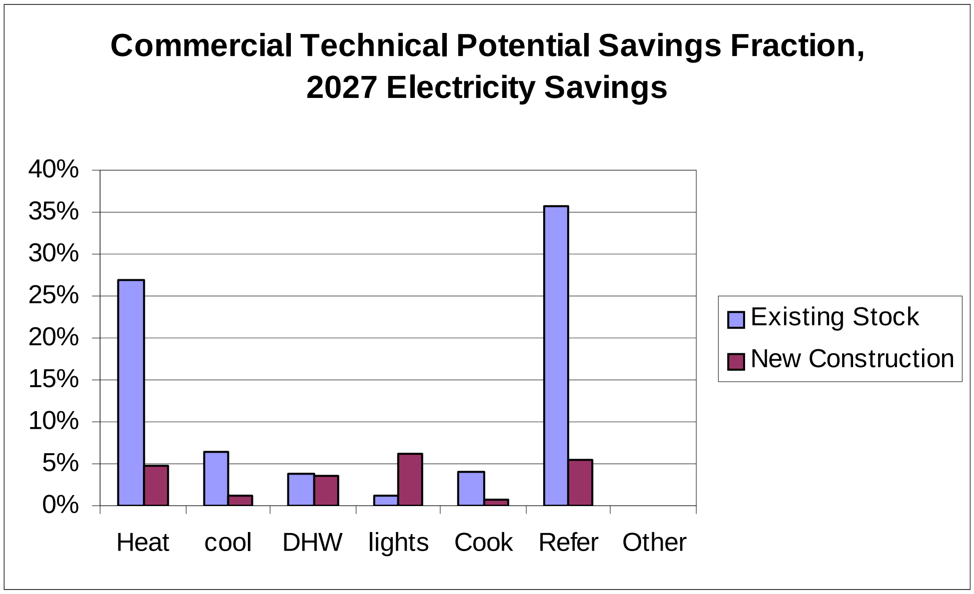
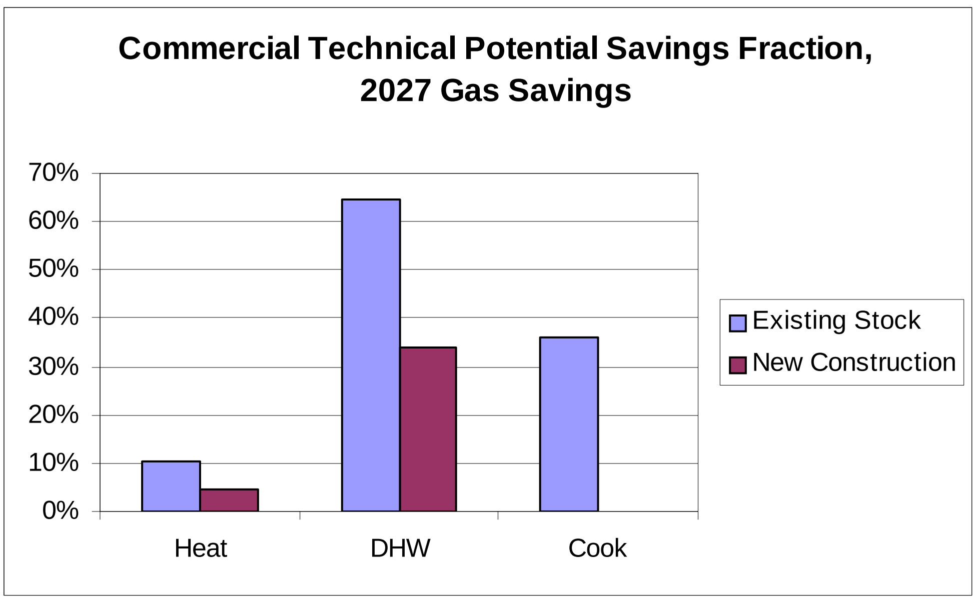


Figure 16: Commercial Savings Percentages by Gas End Use



Industrial Sector Resource Assessment

A list of the recommended industrial measures, ordered by the levelized cost, is provided in Table 11. 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.

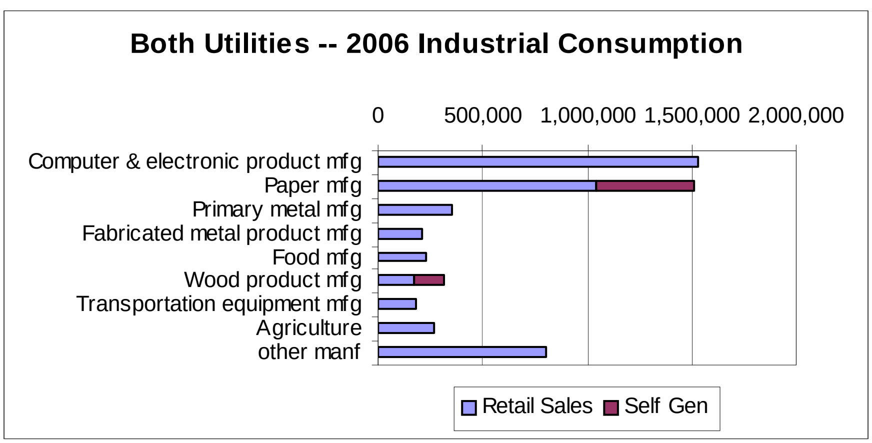
Industrial Sector Characterization

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.) In fact, economic growth has not been robust in recent years– the electronic segment in particular suffered from business reverses. We applied the same forecasted growth rates as used by the utilities in their planning to project future MWh sales.

Energy Trust serves participating industries, yet these industries 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.

The savings potential is derived from the total electrical consumption of the customer. To the extent that customers produce their own electricity, we need to include that generation as part of overall consumption. Figure 15 shows our estimate of current industrial consumption including self-generation where it is significant.

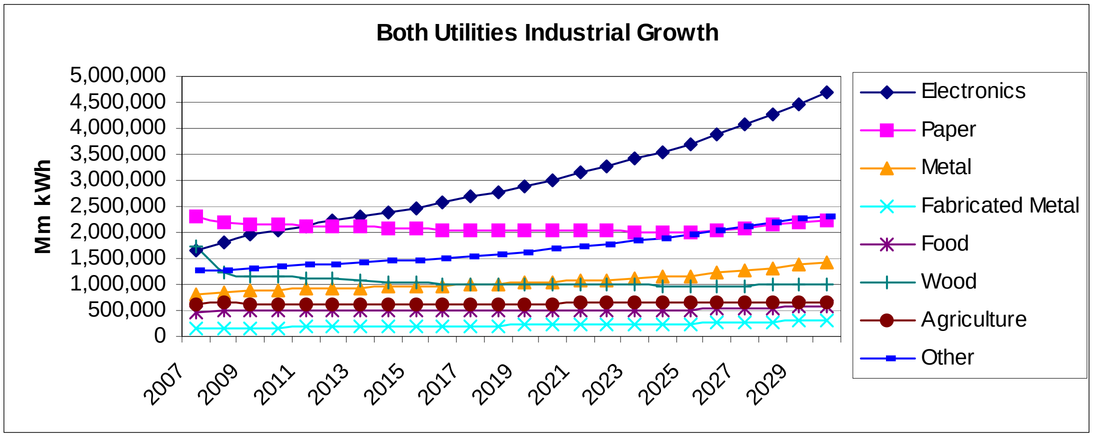
Figure 17: Industrial Electricity Consumption



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 from co-generation or Combined Heat and Power (CHP) but found it too difficult to generalize since it depends on various market factors that are not technical issues. Accordingly, CHP is an additional opportunity that is not included in this study.

Figure 18: Industrial Growth Forecast



Historically, industry has been based primarily on natural resource extraction and processing (Food and Forest Products). These industries are expected to decline or exhibit low growth rates. One notable exception is the electronics sector – this is the only industry expected to show future growth. However, past events have shown that this sector is dependent on the global business outlook and can be extremely volatile. Growth in solar photovoltaic manufacture has been proposed as a source for Oregon's future economic development. The forecast above includes solar photovoltaics as part of the electronics sector. Currently only one specific new photovoltaic plant is in operation. Other plants are projected but not yet confirmed at specific sites.

The next step is to estimate how the electricity sales are distributed to various end uses and processes within the facility. Table 10 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 technically possible industrial opportunities are achievable in the real world. We rated measures loosely as high (85% achievable), medium (50% achievable), or low (25% achievable) based on judgment.

Table 11 lists the industrial measures by increasing levelized cost. Screening by the BCR ratio is to screening by a levelized cost of about $0.09 per kWh.

Table 10: 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	67%	9%	0%	4%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	2%	13%
other manf	29%	7%	10%	1%	9%	0%	0%	1%	0%	1%	0%	2%	0%	1%	9%	30%
Total	23%	10%	6%	7%	11%	4%	1%	3%	2%	1%	1%	4%	1%	9%	5%	13%

Table 11: List of Industrial Measures

Measure Name	Incremental Cost ($/kWh)	O&M Cost ($/Yr/kWh)	Levelized cost ($/kWh)	Potential Savings (aMW)	Status
Irrigation: Ditch > Pipe	$0.080	-$1.010	-$1.000	1	available
Electronics: Wastewater preheat of OSA	$0.454	-$0.232	-$0.173	9	Available
Metal: New Arc Furnace	$0.087	-$0.173	-$0.162	0	Available
Electronics: Exhaust Injector	$0.473	-$0.135	-$0.073	35	Available
Electronics: Solidstate chiller	$0.534	-$0.123	-$0.071	21	Emerging
Metal: Net Casting	$0.634	-$0.113	-$0.030	1	Available
Wood: Replace Pneumatics	$0.298	-$0.061	-$0.031	10	Available
Metal Fab: UV Curing	-$0.085	$0.000	-$0.011	1	Available
Electrical Supply System Improvements	$0.011	-$0.010	-$0.007	39	Emerging
ASD Motors	$0.072	-$0.013	-$0.005	2	Emerging
Sensors and Controls	$0.022	-$0.003	-$0.001	8	Available
Electronics: Reduce pressure, gases	$0.001	-$0.001	-$0.001	2	Emerging
Ag: High Draft Fans for Barns	$0.001	$0.000	$0.000	0	Available
Pump Efficiency Improvement	$0.167	-$0.018	$0.004	21	Available
Motor Management (Prevent. Maint.)	$0.152	-$0.010	$0.005	1	Available
Air Compressor Sensors	$0.045	$0.000	$0.004	1	Available
Fan system improvements	$0.033	$0.000	$0.004	2	Available
Paper: Refiner Mod	$0.046	$0.000	$0.005	9	Available
Advanced Lubricants	$0.014	-$0.008	$0.007	3	Available
Motor Systems O&M Optimize	$0.062	$0.000	$0.008	15	Available
Electronics: Clean Room HVAC	$0.112	$0.000	$0.011	3	Available
Food: Cooling and Storage	$0.118	$0.000	$0.012	1	Available
Paper: ChlorOxy Mod	$0.123	$0.000	$0.012	1	Available
Transformers	$0.203	$0.000	$0.020	19	Available
Paper: Vapor Recompression	$0.008	$0.014	$0.014	2	Available
Air Compressor O&M	$0.016	$0.000	$0.017	5	Available
Wood: Soft Start Press	$0.201	$0.000	$0.020	1	Available
Duct/Pipe Insulation	$0.098	$0.002	$0.019	8	Available
Efficient Lighting Fixtures and Lamps	$0.271	$0.000	$0.026	2	Available
Food: Refrig Storage O&M	$0.055	$0.000	$0.020	1	Available
Irrigation: Pump Systems Adjust	$0.233	-$0.064	$0.021	1	Available

Measure Name	Incremental Cost ($/kWh)	O&M Cost ($/Yr/kWh)	Levelized cost ($/kWh)	Potential Savings (aMW)	Status
Electronics: CW to gas plant	$0.177	$0.000	$0.023	0	Available
Electronics: New chiller/tower, 2 loops	$0.191	$0.000	$0.025	12	Available
Electronics: Eliminate exhaust	$0.196	$0.000	$0.026	5	Emerging
High Bay Lighting	$0.174	-$0.022	$0.028	9	Available
Electronics: New air compressor	$0.198	$0.000	$0.026	2	Available
Electronics: VSD tower pumps	$0.217	$0.000	$0.028	0	Available
Electronics: Chiller optimize	$0.202	$0.011	$0.037	5	Available
Efficient Lighting Design	$0.541	$0.000	$0.053	2	Available
SR Motor	$0.416	$0.000	$0.054	2	Emerging
Electronics: Change filter strategy	$0.054	-$0.002	$0.054	7	Available
Generic O&M	$0.000	$0.050	$0.050	29	Available
Microwave Processing	$0.488	$0.000	$0.064	4	Available
Electronics: Reduce CW pressure, reset CHW	$0.535	$0.000	$0.070	0	Available
Irrigation: Nozzles	$0.240	$0.000	$0.089	0	Available
Irrigation: Water Management	$0.195	$0.067	$0.112	0	Available
Electronics: Chiller heat recovery	$1.161	$0.000	$0.152	1	Available
Advanced Industrial HVAC	$0.704	$0.050	$0.142	1	Available
Other: Wastewater Biomanagement	$0.001	$0.258	$0.258	1	Available
Irrigation: Pump Systems Repair	$1.835	-$0.010	$0.309	0	Available
Metal Fab: IR Heating	$0.488	$0.375	$0.438	0	Available
Food: RF Heat	$0.488	$0.500	$0.564	0	Emerging
Electronics: Vacuum Pump Upgrade	$0.876	$0.768	$0.972	8	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 soft-switched 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 re-strike (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 compressors result from the 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 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 “cool”. 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 segments. 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 segment 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 segments 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 has 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 Segments

Metal Segment

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

Metal Fabrication: 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 segment are the cross-cutting general measures. Given the novelty of the measure, we assume low achievable potential.

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 Segment

Refrigeration in the food segment 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 segment. 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 Segment

Agriculture is important to the rural economy but a difficult segment 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 segment 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 Segment

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 segment 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 segment 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 segment 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 segment 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 Segment

This segment is one of the largest, accounting for 40% of PGE's industrial sales. This industry segment 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. Solar photovoltaic manufacturer is included with chip plants. Table 12 shows process shares for this segment. 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 12: Electronics Segment 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

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 saves 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.

Moderately Achievable

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 a 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/sq. ft. 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.

Low Achievable

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 13: Summary of Measures -- Electronics Segment

Opportunity	Measure Name	Cost	Savings, kWh	O&M/yr	Life	LC in 2008$
Highly	Thermoelectric Chiller	$20,000	40,571	-$5000	10	($0.071)
Achievable	Exhaust Injector	$20,000	45,815	-$6170	10	($0.073)
	Reduce Gas Pressure	$0	3,260	-$46	10	($0.001)
	Vacuum pump, incremental over rebuild	$51,000	63,072		5	$0.972
Moderately	Chiller optimize	$50,000	1,736,000		10	$0.037
Achievable	Change filter strategy	$9,200	1,463,000		1	$0.054
	Clean Room HVAC	$20/sqft	144/sqft		20	$0.011
	Eliminate exhaust	$80,000	442,000		10	$0.026
	Reduce pressure, reset CHW	$40,000	81,000		10	$0.070
	VSD tower pumps	$50,000	187,000		10	$0.028
	Wastewater preheat of OSA	$325,000	776,000	-$180,000	10	($0.173)
Low	CW to gas plant	$40,000	245,000		10	$0.023
Achievable	Chiller heat recovery	$30,000	28,000		10	$0.152
	New air compressor	$50,000	273,000		10	$0.026
	New chiller/tower, 2 loops	$800,000	4,539,000		10	$0.025

Industrial Natural Gas Conservation Measures

As discussed, the gas customers included in this study are only those in the Industrial Firm tariff, corresponding to perhaps 10% of commercial and industrial customers. Those on the firm rate are generally small facilities or adjunct meters to larger facilities. As such, the end uses are more similar to other small commercial customers than to what would be expected for large industrial facilities. The primary application of gas is for boilers –either for process steam or for space heating. As a result, the opportuniy is dominated by various measures to improve boiler efficiency.

The following measures are included:

Chiller heat recovery (Electronics Segment)

Utilize heat recovery where option exists

Combo Cond Boiler (Replace and Retrofit)

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).

Combo Hieff Boiler (Replace and Retrofit)

Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.

Condensing Furnace (Replace)

Condensing / pulse package or residential-type furnace with a minimum AFUE of 92%.

Condensing Unit Heater from Nat draft or power draft (Replace)

Install condensing power draft units (90% seasonal efficiency) in place of natural draft (64% seasonal efficiency)

Heat Recovery to HW

Utilize heat recovery where option exists

DHW Condensing Boiler (Replace and Retrofit)

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).

DHW Condensing Tank (Replace and Retrofit)

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.

DHW Hieff Boiler (Replace and Retrofit)

Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.

DHW Pipe Insulation

Add 1" insulation to pipes used for steam or hydronic distribution; particularly effective when pipes run through unheated spaces.

DHW Standard Boiler (Retrofit)

Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.

DHW Wrap

Insulate the surface of the storage water heater or an unfired storage tank to R-5 to reduce standby losses.

Ducts

Duct retrofit of both insulation and air sealing

Hi Eff Unit Heater (Replace and Retrofit)

Install power draft units (80% seas. Eff) in place of natural draft (64% seasonal efficiency)

HiEff Clothes Washer (Replace and Retrofit)

Install high performance commercial clothes washers - residential sized units

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.

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.

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.

Process Boiler Controls

Process Boiler Insulation

Process Boiler Load Control

Process Boiler Maintenance

Process Boiler Steam Trap Maintenance

Process Boiler Water Treatment

Roof Insulation - Blanket R0-19

Application: Buildings with open truss unfinished interior

Roof Insulation - Blanket R0-30

Application: Buildings with open truss unfinished interior

Roof Insulation - Blanket R11-30

Application: Buildings with open truss unfinished interior

Roof Insulation - Blanket R11-41

Application: Buildings with open truss unfinished interior

Roof Insulation - Rigid R11-22 (Replace)

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

Roof Insulation - Rigid R11-33 (Replace)

Roof Insulation - Rigid R11-33: add 4' of insulation at reroof. Application: Old buildings with flat roofs, no attics, and some insulation

Solar Hot Water

Install solar water heaters on large use facility such as multifamily or lodging

SPC Condensing Boiler (Replace)

Install condensing boiler. Assumed seasonal combustion efficiency of 88% over base of 75%

SPC Condensing Boiler (Retrofit)

Install condensing boiler. Assumed seasonal combustion efficiency of 88% over base of 69.5%

SPC High Efficiency Boiler (Replace)

Install near condensing boiler. Assumed seasonal combustion efficiency of 82% over base of 75%

SPC High Efficiency Boiler (Retrofit)

Install near condensing boiler. Assumed seasonal combustion efficiency of 82% over base of 69.5%

Steam Balance (Wood Prod)

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.

Steam Trap Maint (Wood Prod)

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.

Upgrade Process Heat

Replace furnace, reheaters

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.

Wall Insulation - Blown R11

Application: Old buildings

Wall Insulation - Spray On for Metal Buildings

Wall Insulation (Cellulose) unfinished. Application: Old buildings

Waste Water Heat Exchanger

Install heat exchanger where copious warm water is discarded

Commercial Sector Resource Assessment

A list of the major commercial measures, listed by the levelized cost, is provided in Table 17 and Table 18. These lists present individual measures, with costs and benefits resulting from the applicable population.

Commercial Sector Characterization

Characterizing the commercial segment 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.

On particular problem lies with the growth of large data server "farms". Several of these facilities have located in the Northwest and their energy consumption can be prodigious. A variety of conservation measures are available for these facilities. However, quantifying the impact is difficult. Problems occur with:

- Forecasting – specific facilities are not included in the utility forecasts.
- Baseline – computer technology changes rapidly and baseline consumption is not clear
- Current practice – the extent to which HVAC and software management measures are already adopted is not clear.

As a result, although one can anticipate significant opportunities regarding data servers, we have not attempted to quantify them.

Description of Commercial Measures

Measures were previous described in the 2005 report. For this study, the detailed measure descriptions are included in Table 17 and Table 18. 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).

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 endues. 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.

Lighting measures:

CFL 9W to 39W hardwired

Cost of CFL lamp 75W> 18W

High Efficacy LED Display

Cost of ceramic metal halide lamp 72W> 39W

T8 to HP T8

Ballast change out 58W> 49W

T12 to HP T8

High Performance T8 lamp versa conventional T8 162W> 49W

T8 to HP T8

Ballast change out 58W> 49W

High Bay HID Medium to T8 (Retrofit and New)

Switched to T8 458W> 224W, 1 lamp HID to 6 Lamp HPT8

High Bay HID Large to T5 (Retrofit and New)

Assumes 2 -6 lamp T-5 fixtures to get equivalent light output, makes more sense than T8s 1080W> 701W

Daylight Control (overhead)

Assumes 5% savings

Sweep Control

Assumes 25% savings

Daylight perimeter zone

Assumes 10% savings

Occupancy Sensors

Cost of OS switch, general area. Assumes 5% savings

Exit signs

Cost vs cost of LED and CFL fixtures 20W> 1 W, switch to LED sign (not photoluminescent net incremental cost)

Ceramic Metal Halide (Retrofit and New)

100W> 44W

Daylighting Overhead (New)

Daylight control with skylite

HVAC Measures

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.

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.

Rooftop Condensing Burner

Prototype units of condensing natural gas packaged heaters have been demonstrated in Canada. However, the condensing feature of theses units was not the primary source of their savings – rather it was the fact that exposed ductwork was better insulated.

Demand Controlled Ventilation (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 CO_2 build-up modulating ventilation.

Ducts

Duct retrofit of both insulation and air sealing

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.

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.

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.

Steam Trap Maintenance

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.

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.

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.

SPC Hieff Boiler (Retro and Replace)

Boiler costs for near condensing boiler. Assumed seasonal combustion efficiency of 82% over base of 69.5%

SPC Cond Boiler (Retro and Replace)

Boiler costs for condensing boiler. Assumed seasonal combustion efficiency of 88% over base of 69.5%

Hi Eff Unit Heater (New, Retro and Replace)

Base efficiency has gone up. Install power draft units (80% seasonal eff) in place of natural draft (64% seasonal eff)

Cond Unit Heater from Natural draft (New and Replace)

Install condensing power draft units (90% seasonal eff) in place of natural draft (64% seasonal eff)

Cond Unit Heater from Power draft (New and Replace)

Install condensing power draft units (90% seasonal eff) in place of power draft (80% seasonal eff)

Cond Furnace (New and Replace)

Condensing / pulse package or residential-type furnace with a minimum AFUE of 92%.

SPC Hieff Boiler (New)

Install near condensing boiler. Assumed seasonal combustion efficiency of 82% over base of 75%

SPC Cond Boiler (New)

Install condensing boiler. Assumed seasonal combustion efficiency of 88% over base of 75%

Water Heating Measures

DHW Wrap

Insulate the surface of the storage water heater or an unfired storage tank to R-5 to reduce standby losses.

DHW Shower Heads

Install low flow shower heads (2.0 gallons per minute) to replace 3.4 GPM shower heads.

DHW Faucets

Add aerators to existing faucets to reduce flow from 3.4 gallons per minute to 2.0 GPM.

DHW Pipe Ins

Add 1" insulation to pipes used for steam or hydronic distribution; particularly effective when pipes run through unheated spaces.

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).

DHW Std. Tank (Retro)

This measure would replace existing DHW tank with equipment meeting current Oregon Energy Code requirements (thermal efficiency of 78% or better).

DHW Condensing Tank (Retro)

Replace older tanks with condensing tanks with combustion efficiency of 94% and tank insulation with an R-value of 16 or greater.

DHW Condensing Tank (Replace)

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.

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.

DHW Std. Boiler (Retro)

Replace existing boiler with unit meeting OR Code requirements of 80% combustion efficiency.

DHW Hieff Boiler (Retro)

Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.

DHW Cond Boiler (Retro)

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).

DHW Hieff Boiler (Replace and New)

Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.

DHW Cond Boiler (Replace and 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).

Combo Hieff Boiler (Retro)

Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.

Combo Cond Boiler (Retro)

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).

Combo Hieff Boiler (Replace and New)

Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.

Combo Cond Boiler (Replace and 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).

Solar Hot Water (New and Retrofit)

Install solar water heaters on large use facility such as multifamily or lodging New

Heat Pump Water Heat (New and Retrofit)

Waste Water Heat Exchanger (New and Retrofit)

Install HX on waste water

Hi Eff Clothes Washer (Replace)

Install high performance commercial clothes washers – for residential units

Computerized Water Heater Control (New and Retrofit)

Install intelligent controls on the hot water circulation loops.

Cooking Measures

Cooking measures with primarily gas savings include: Direct Fired Convection Oven, Infrared Fryer, Convection Range/Oven, Infrared Griddle, Power Range Burner. Energy Star Steam Cooker provides savings on both electricity and gas.

Shell Measures

Insulation measures:

Wall Insulation - Blown R11

Application: Old buildings

Wall Insulation - Spray On for Metal Buildings

Spray On for Metal Buildings (Cellulose) Unfinished. Application: Old buildings

Roof Insulation - Rigid R0-11

Rigid R0-11-not including re-roofing costs but including deck preparation. Application: Old buildings with flat roofs and no attics

Roof Insulation - Rigid R0-22

Rigid R0-22-- not including re-roofing costs but including deck preparation and ~4" rigid.. Application: Old buildings with flat roofs and no attics

Roof Insulation - Rigid R11-22

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

Roof Insulation - Rigid R11-33

Rigid R11-33: add 4' of insulation at time of reroofing. Application: Old buildings with flat roofs, no attics, and some insulation

Roof Insulation - Blanket R0-19

Blanket R0-19. Application: Buildings with open truss unfinished interior

Roof Insulation - Blanket R0-30

Blanket R0-30. Application: Buildings with open truss unfinished interior

Roof Insulation - Blanket R11-30

Blanket R11-30. Application: Buildings with open truss unfinished interior

Roof Insulation - Blanket R11-41

Blanket R11-41. Application: Buildings with open truss unfinished interior

Roof Insulation - Attic R0-30

Attic R0-30. Application: Buildings with uninsulated attics

Roof Insulation - Attic 11-30

Attic 11-30. Application: Buildings with partially insulated attics

Roof Insulation - Roofcut 0-22

Roofcut 0-22. Application: Buildings with uninsulated flat roofs at reroofing time

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 non-tinted. 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.

Categories of retrofit windows include: Windows – Single or Double to Class 45, 40, 36 or VEA. Details of window assumptions are listed in Table 14.

Table 14: 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

Cooling and HVAC Controls Measures

CEE Tier 2 3 ton (New and Replacement)

Install high efficiency cooling equipment complying with CEE Tier 2.

CEE Tier 2 7.5 ton (New and Replacement)

Install high efficiency cooling equipment complying with CEE Tier 2.

CEE Tier 2 15 ton (New and Replacement)

Install high efficiency cooling equipment complying with CEE Tier 2.

CEE Tier 2 25 ton (New and Replacement)

Install high efficiency cooling equipment complying with CEE Tier 2.

HVAC System Commissioning (New)

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.

HVAC controls (New)

Set up control algorithms. 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.

Lighting Scheduling/Controls (New)

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.

PCs and Monitors - Energy Management Software (New and Replacement)

There is a solution to automate the enabling of Power Management in commercial computers and monitor/displays called Surveyor by EZConserve.

LCD Monitors (New and Replacement)

Replace CRT with LCD monitor at replacement time. This measure is zeroed out as being current practice.

High Efficiency Chiller (Replace)

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 0.65 kW/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.

Chiller System Optimization (Replace)

Includes improvements in efficiency and reduction in parasitic losses in pumps, fans, and other (non-chiller) electric motor-driven systems associated with chillers.

Chiller Tower 6F approach (Replace)

Install low approach cooling tower

Transformers (Retrofit)

Savings apply at service entry for all electric usage

EMS Retrofit for Restaurants (Retrofit)

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, 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.

ECM Fan Powered Boxes (New)

Install ECM motors in VAV fan powered terminals with PSC motors

Indirect/Direct Evaporative Cooling ~20 ton (New and Replacement)

Install indirect/direct evaporative cooling in commercial building HVAC system in 20 to 60 ton range

Indirect/Direct Evaporative Cooling >60 ton (New and Replacement)

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

Ground Source Heat Pump - Air Source HP Base (Replacement)

Install GSHP in place of air source heat pumps.

Refrigeration 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.

Other refrigeration measures:

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.

Package Refrigeration - Icemakers, Vending machines (New and Replacement)

Install machines with package of measures akin to ADL low cost

Efficient Standalone Refrigeration Cases (New and Replacement)

Install efficient stand-alone cases. This measure is based upon current rebates and SAIC savings numbers

Residential Sector Resource Assessment

Sector Characterization

For this analysis, three residential segments were considered: single family, manufactured homes and multi-family units. We further divided these segments, 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, both electricity and fuel savings are considered. 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 19 and Table 20. 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 Measures

1. 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. 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. 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. Ground Source Heat Pumps (New)

Install Ground Source heat pump (GSHP) in lieu of standard air source heat pump.

5. High Efficiency AC (New/Replacement)

We examined a measure to upgrade a central forced air AC system to SEER 15 from SEER 13. Some additional savings from proper commissioning are included in the total. 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 tune-up (Retrofit)

A program based on field visits that offers minor adjustments to HVAC equipment (adjust charge, clean filters, check settings, install cutout thermostat) 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 for new and replacement models. Savings for the retrofit sector are from in lieu of a SEER 13 central AC.

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. Ductless Mini-split Heat Pump

Current models are small in capacity, which limits their retrofit potential. They are suggested for homes with electric baseboard heating – which makes them one of the few retrofit equipment measures possible for older homes with baseboard heating. In multi-family housing where they would provide the equivalent of an efficient through-the-wall heat pump. The cost estimate gives credit for the fact that a window air conditioner would otherwise have to be included to provide a similar cooling benefit.

Envelope Measures

1. Energy Star building package (New)

The Energy Star package is continuingly evolving. As new efficiency levels are implemented in codes and standards, Energy Star must develop new measures that provide a further level of energy savings. It becomes more difficult to find further measures that are cost-effective and provide sufficient savings. The current Energy Star package includes insulation, windows, duct sealing, efficient hot water and lights, as well as high efficiency heating/cooling equipment.

2. Window Upgrades (New/Replacement/Retrofit)

Improvement from U=.35 to U=.30. 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. Standalone shell measures to Energy Star levels (New).

Window and insulation as a stand-alone measures. Basecase 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 segment, 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.

4. Bring Ducts Indoors. (New)

Locating ductwork within the heated space accomplished the benefits of duct sealing at low cost. Thus, it provides an alternative path to achieve similar savings to the Energy Star package. We include an alternative package with Indoor Ducts, DHW and Lights that would be the uncertified equivalent of Energy Star.

5. Weatherization Envelope Sealing (Retrofit)

Blower-door assisted sealing has been a popular measure within the program. It applies to both electric and gas heated homes.

Lighting Measures

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

Lighting measures are difficult to categorize because new Federal standards will occur. We assume that the current Energy Star Lighting measure requires installation of 18 CFL lamps (20% reduction in LPD) or full replacement (30% reduction). However, the opportunity for this measure is short-lived. By 2015, new Federal standards will require that new lighting product meet an equivalent efficiency standard. We propose that a new set of emerging technology lighting products, based on LED lights, will become available starting in 2015 to provide efficiency beyond code minimum requirements. These proposed measures are described as:

- Add 6 LED lamps (using incandescent base) aft 2015 (65% reduction in LPD using both fixtures and lamps)
- Add 6 LED lamps (using CFL base) after 2015
- Add 16 LED lamps (using incandescent base) after 2015
- Add 16 LED lamps (using CFL base) after 2015
- All LED (from 2020 base) after 2020

Similarly for retrofit lighting measures, CFL replacements may occur up until year 2015 but then we anticipate emerging technology be based on high efficiency LED lights. These are proposed as:

- 50% LED after 2020
- 100% LED after 2020

Domestic Hot Water Measures

1. Tank wrap (Retrofit)

This measure assumes an 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 .90 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 .90 to .94.

For the gas segment, the measures includes a water tank upgrade from EF=.59 to EF=.62. an emerging efficient option to EF=.70. Tankless water heaters provide an EF= .85 and an incremental improvement to and efficient model with EF= .89.

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 .90 to 2.0).

6. Combined Space and Water Heating

We examined a variety of system that combine gas space and water heating. Although these systems have some appeal in providing radiant slab heating, there is a question about the appropriate baseline. Compared to a hydronic system that would provide similar radiant heating, there is little or no energy saving. One combination option appears to be currently cost-effective – that would be a combination involving a low-cost hydrocoil applied to an air distribution system. We also include a high efficiency combination system based on the Polaris water heater.

7. 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%. Cost estimates come from the current program.

Appliance Measures

1. Low Power Mode Appliances

Many consumer electronic products consume power in standby mode even when not active. The standby mode may include keeping a time clock, waiting for a remote signal or accessing the internet for information. If these appliances were set to reduce standby power to their minimum (sleep) level, it would save over 300 kWh per year per house.

California is engaged in a program to capture these savings through standards at the manufacturer level. While costs are not clearly defined at this time, these measures are expected to be low-cost for manufacturers to implement. These savings are for other appliances in addition to the Energy Star television.

2. EStar Refrigerator assumes a unit 15% more efficient than Federal standard.

3. Two clothes washers are considered. The MEF 2.0 Washer is only a modest improvement over the minimum standard. The high efficiency washer is MEF 2.2. It should be mentioned that units with even higher MEF ratings occur in the current program.

4. EStar Dishwasher is based on a unit rated at .68 (higher than Energy Star minimum) over a market baseline rated .52 (slightly higher than Federal minimum standard).

5. Home Energy Monitor is a device than offers direct feedback to consumers regarding their energy consumption. With the feedback, customers are expected to better control their energy usage. Estimates are based on the BC Hydro study that estimated a 6.5% reduction in electric load. To be conservative and because we are not in Canada we used 5%.

6. 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%.

6. Energy Star Television

This measure has been proposed by CEE as an emerging technology. Savings would be possible at no cost if introduced during manufacturing, due to reduced standby losses. Similar savings from other appliances are captured in the Low Power Mode measure.

Appendix: Detailed Measure Descriptions

Table 15: Detailed Measure Description, Industrial Electricity

Conservation Measure	First Cost ($/kWh)	End use App	% Savings	Measure Acceptance	Achievable Potential	Lifetime	Annual O&M Cost ($/kWh)	Levelized Cost ($/kWh)	BCR	Source
Advanced Industrial HVAC	$0.704	HVAC	15%	40%	85%	10	$0.050	$0.142	0.59	ACEEE, 2004
Advanced Lubricants	$0.014	All Motors	3%	23%	85%	1	($0.008)	$0.007	14.46	ACEEE, 2001
Ag: High Draft Fans for Barns	$0.001	Fan	4%	23%	85%	10		$0.000	1,237.67	ACEEE, 2004
Air Compressor O&M	$0.016	Fan	25%	23%	85%	1		$0.017	5.57	ACEEE, 2001
Air Compressor Sensors	$0.045	Air Comp	4%	23%	85%	15		$0.004	20.32	ACEEE, 2001
ASD Motors	$0.072	All Motors	2%	45%	25%	15	($0.013)	($0.005)	100.00	ACEEE, 2001
Duct/Pipe Insulation	$0.098	Heat, Refer, HAVC	5%	80%	85%	7	$0.002	$0.019	4.39	ACEEE, 2004
Efficient Lighting Design	$0.541	Lights	20%	70%	25%	15		$0.053	1.70	Ecotope
Efficient Lighting Fixtures and Lamps	$0.271	Lights	25%	70%	50%	15		$0.026	3.39	Ecotope
Electrical Supply System Improvements	$0.011	All Electric	3%	100%	25%	5	($0.010)	($0.007)	100.00	ACEEE, 2004
Electronics: Change filter strategy	$0.054	Fans	40%	10%	60%	1	($0.002)	$0.054	1.76	Supersymmetry, NEEA Chiller
Electronics: Chiller heat recovery	$1.161	HVAC	3%	10%	25%	10	$0.000	$0.152	0.56	Supersymmetry
Electronics: Chiller optimize	$0.202	HVAC	17%	25%	50%	10	$0.011	$0.037	2.27	Supersymmetry
Electronics: Clean Room HVAC	$0.112	HVAC	9%	30%	25%	15		$0.011	8.20	ACEEE, 2001, NEEA Chiller
Electronics: CW to gas plant	$0.177	HVAC	1%	50%	25%	10	$0.000	$0.023	3.64	Supersymmetry
Electronics: Eliminate exhaust	$0.196	HVAC	5%	80%	25%	10	$0.000	$0.026	3.29	Supersymmetry, NEEA Chiller
Electronics: Exhaust Injector	$0.473	Heat	100%	35%	85%	10	($0.135)	($0.073)	100.00	Paragon
Electronics: New air compressor	$0.198	Air Comp	17%	50%	25%	10	$0.000	$0.026	3.25	Supersymmetry
Electronics: New chiller/tower, 2 loops	$0.191	HVAC	34%	15%	25%	10	$0.000	$0.025	3.38	Supersymmetry
Electronics: Solidstate chiller	$0.534	HVAC	90%	20%	85%	15	($0.123)	($0.071)	100.00	Solid State
Electronics: Reduce pressure, gases	$0.001	Refrig, Air Comp	10%	50%	85%	3	($0.001)	($0.001)	100.00	Supersymmetry, NEEA Chiller

Conservation Measure	First Cost ($/kWh)	End use App	% Savings	Measure Acceptance	Achievable Potential	Lifetime	Annual O&M Cost ($/kWh)	Levelized Cost ($/kWh)	BCR	Source
Electronics: Reduce CW pressure, reset CHW	$0.535	HVAC	1%	50%	25%	10	$0.000	$0.070	1.20	Supersymmetry
Electronics: VSD tower pumps	$0.217	HVAC	1%	50%	25%	10	$0.000	$0.028	2.97	Supersymmetry, NEEA Chiller
Electronics: Wastewater preheat of OSA	$0.454	HVAC	15%	50%	25%	10	($0.232)	($0.173)	100.00	Supersymmetry, NEEA Chiller
Electronics: Vacuum Pump Upgrade	$0.876	Process Pump	50%	13%	85%	5	$0.768	$0.972	0.09	Phil Naughton, 2005
Fan system improvements	$0.033	Fan	6%	20%	50%	10		$0.004	19.83	ACEEE, 2001
Food: Cooling and Storage	$0.118	Refer	20%	20%	25%	15		$0.012	7.76	ACEEE, 2001
Food: Refrig Storage O&M	$0.055	Refer	4%	50%	85%	3		$0.020	4.42	DEER
Food: RF Heat	$0.488	Process Drying	1%	50%	25%	10	$0.500	$0.564	0.15	ACEEE, 2004
Generic O&M	$0.000	Process	5%	80%	85%	1	$0.050	$0.050	1.90	ACEEE, 2004
High Bay Lighting	$0.174	Lighting	25%	70%	85%	4	($0.022)	$0.028	3.18	ACEEE, 2005
Irrigation: Ditch > Pipe	$0.080	Pump	60%	3%	85%	10	($1.010)	($1.000)	100.00	PP&L
Irrigation: Nozzles	$0.240	Pump	0%	70%	50%	3		$0.089	1.01	ETO
Irrigation: Pump Systems Repair	$1.835	Pump	0%	70%	50%	7	($0.010)	$0.309	0.27	ETO
Irrigation: Pump Systems Adjust	$0.233	Pump	2%	70%	50%	3	($0.064)	$0.021	4.18	ETO
Irrigation: Water Management	$0.195	Pump	1%	70%	50%	5	$0.067	$0.112	0.76	ACEEE, 2004
Metal Fab: IR Heating	$0.488	Heat, Treating	15%	50%	25%	10	$0.375	$0.438	0.19	ACEEE, 2004
Metal Fab: UV Curing	($0.085)	Curing	60%	50%	25%	10		($0.011)	100.00	ACEEE, 2004
Metal: Net Casting	$0.634	Process Heat	90%	20%	25%	10	($0.113)	($0.030)	100.00	ACEEE, 2001
Metal: New Arc Furnace	$0.087	Process Heat	45%	10%	25%	10	($0.173)	($0.162)	100.00	ACEEE, 2001
Microwave Processing	$0.488	Process Drying	3%	50%	25%	10		$0.064	1.32	ACEEE, 2004
Motor Management (Prevent. Maint.)	$0.152	All Motors	1%	11%	85%	15	($0.010)	$0.005	18.62	ACEEE, 2001
Motor Systems O&M Optimize	$0.062	Pump, Fan	20%	11%	85%	10	$0.000	$0.008	10.46	ACEEE, 2001
Other: Wastewater Biomanagement	$0.001	Pump	25%	6%	85%	10	$0.258	$0.258	0.33	ACEEE, 2004

Conservation Measure	First Cost ($/kWh)	End use App	% Savings	Measure Acceptance	Achievable Potential	Lifetime	Annual O&M Cost ($/kWh)	Levelized Cost ($/kWh)	BCR	Source
Paper: ChlorOxy Mod	$0.123	Process	51%	10%	85%	15		$0.012	7.45	Program files
Paper: Refiner Mod	$0.046	Process	60%	53%	85%	15		$0.005	19.89	Program files
Paper: Vapor Recompression	$0.008	Process	60%	10%	85%	15	$0.014	$0.014	6.28	Program files
Pump Efficiency Improvement	$0.167	Pump, Fan	17%	23%	50%	10	($0.018)	$0.004	20.25	ACEEE, 2001
Sensors and Controls	$0.022	Process	3%	30%	50%	10	($0.003)	($0.001)	100.00	ACEEE, 2001
SR Motor	$0.416	Pump, Fan, Air, Process	3%	9%	25%	10		$0.054	1.55	ACEEE, 2001
Transformers	$0.203	All Electric	2%	100%	25%	15		$0.020	4.52	ACEEE, 2004, NEEA Chiller
Wood: Replace Pneumatics	$0.298	Pneumatic Conveyor	75%	85%	85%	15	($0.061)	($0.031)	100.00	Program files
Wood: Soft Start Press	$0.201	Process	58%	25%	85%	15		$0.020	4.58	Program files
Rural Area Lights	$0.331	Lighting	33%	10%	85%	6		$0.066	1.28	DEER
LED Traffic Lights 12" Grn	$0.366	Lighting	90%	9%	85%	7	($0.018)	$0.046	1.82	City of Ptld
LED Traffic Lights PedX	$0.161	Lighting	90%	10%	85%	3	($0.014)	$0.045	2.00	City of Ptld

Industrial Sources and References:

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

Supersymmetry USA, Proprietary report on specific site, 1998, “Report on Suggested Energy Efficiency”.
ACEEE, 2004 Resource Assessment for Energy Trust.
ACEEE, 2001, Martin, N., Worrell, E., Ruth, M., Price, L., Elliott, R.N., Shipley, A.M., and J. Thorne. 2001. Emerging Energy Efficient Technologies. Washington, D.C. Phil Naughton, Project Manger, International SEMATECH Manufacturing Initiative, Austin TX, "Fab Energy Trends and Key Areas for Equipment Improvement", 2005.
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

Results of the industrial savings estimation have already been described in Table 11 on page 31.

Table 16: Detailed Measure Description, Industrial Natural Gas

Conservation Measure	Potential Savings (th/yr)	Levelized Cost ($/th)	Initial Cost, k$	Lifetime	BCR	Program
Chiller heat recovery (Electronics)	287,614	$1.479	$3,262	10	0.48	Retrofit
Combo Cond Boiler (repl)	456,550	$0.571	$3,212	20	1.23	Replacement
Combo Cond Boiler (retro)	0	$1.536	$0	20	0.46	Retrofit
Combo Hieff Boiler (repl)	233,843	$0.311	$894	20	2.27	Replacement
Combo Hieff Boiler (retro)	0	$1.617	$0	20	0.44	Retrofit
Cond Furnace (repl)	1,290,652	$2.491	$33,052	15	0.28	Replacement
Cond Unit Heater from Nat draft(replace)	0	$0.956	$0	18	0.74	Replacement
Cond Unit Heater from power draft (replace)	398,328	$1.934	$8,906	18	0.36	Replacement
Heat Recovery to HW	942,821	$0.132	$2,538	15	5.32	Retrofit
DHW Cond Boiler (repl)	185,023	$0.141	$322	20	4.99	Replacement
DHW Cond Boiler (retro)	0	$0.443	$0	20	1.59	Retrofit
DHW Condensing Tank (repl)	150,834	$0.023	$36	15	30.40	Replacement
DHW Condensing Tank (retro)	0	$0.104	$0	15	6.76	Retrofit
DHW Hieff Boiler (repl)	110,562	$0.044	$60	20	15.94	Replacement
DHW Hieff Boiler (retro)	0	$0.346	$0	20	2.04	Retrofit
DHW Pipe Ins	44,184	$0.018	$8	15	39.57	Retrofit
DHW Std. Boiler (retro)	6,546	$0.208	$17	20	3.39	Retrofit
DHW Wrap	19,637	$0.000	$0	7	1,587.90	Retrofit
Ducts	1,936,462	$2.774	$55,229	15	0.25	Retrofit
Hi Eff Unit Heater (replace)	1,076,563	$0.307	$3,826	18	2.29	Replacement
Hi Eff Unit Heater (retro)	0	$1.871	$0	18	0.38	Retrofit
HiEff Clothes Washer (retro)	0	($0.890)	$0	15	100.00	Retrofit
HiEff Clothes Washer (repl)	0	($1.160)	$0	15	100.00	Replacement
Hot Water Temperature Reset	2,263,031	$0.174	$3,021	10	4.10	Retrofit
HW Boiler Tune	1,244,655	$0.161	$863	5	4.73	Retrofit
Power burner	1,834,621	$1.035	$16,694	12	0.68	Retrofit
Process Boiler Controls	119,927	$0.001	$2	15	513.68	Retrofit
Process Boiler Insulation	542,041	$0.008	$38	15	88.82	Retrofit
Process Boiler Load Control	271,021	$0.002	$4	15	445.19	Retrofit
Process Boiler Maintenance	135,510	$0.001	$0	15	1,407.77	Retrofit
Process Boiler Steam Trap Maintenance	440,408	$0.035	$0	15	20.11	Retrofit
Process Boiler Water Treatment	67,755	$0.001	$1	15	953.98	Replacement
Roof Insulation - Blanket R0-19	594,075	$0.313	$2,815	30	2.28	Retrofit
Roof Insulation - Blanket R0-30	623,292	$0.336	$3,166	30	2.13	Retrofit

Conservation Measure	Potential Savings (th/yr)	Levelized Cost ($/th)	Initial Cost, k$	Lifetime	BCR	Program
Roof Insulation - Blanket R11-30	216,421	$2.292	$7,506	30	0.31	Retrofit
Roof Insulation - Blanket R11-41	259,705	$2.149	$8,444	30	0.33	Retrofit
Roof Insulation - Rigid R11-22 repl	509,022	$0.812	$6,255	30	0.88	Replacement
Roof Insulation - Rigid R11-33 repl	251,048	$2.470	$9,382	30	0.29	Replacement
Solar Hot Water	47,412	$4.210	$2,458	20	0.17	Retrofit
SPC Cond Boiler Replace	275,753	$0.996	$3,381	20	0.71	Replacement
SPC Cond Boiler Retro	0	$2.113	$0	20	0.33	Retrofit
SPC Hieff Boiler Replace	159,440	$0.638	$1,253	20	1.11	Replacement
SPC Hieff Boiler Retro	0	$2.232	$0	20	0.32	Retrofit
Steam Balance (Wood Prod)	0	$0.336	$0	15	2.10	Retrofit
Steam Trap Maint (Wood Prod)	0	$0.582	$0	10	1.23	Retrofit
Upgrade Process Heat	132,576	$0.903	$1,231	15	0.78	Retrofit
Vent Damper	1,244,655	$0.433	$4,736	12	1.63	Retrofit
Wall Insulation - Blown R11	417,288	$0.227	$1,432	30	3.15	Retrofit
Wall Insulation - Spray On for Metal Buildings	458,160	$0.253	$1,751	30	2.83	Retrofit
Waste Water Heat Exchanger	67,731	$0.628	$524	20	1.12	Retrofit

Table 17: Detailed Measure Table, Commercial Sector, Electricity Savings, 2027 Technical Potential

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
Co116	EStar Steam Cooker	Install Energy Star Steam Cooker	New	Cooking	10	75,366	0	4,885	0.57	0.57	0	113,951	$0.002	41.80
Co116rep	EStar Steam Cooker	Install Energy Star Steam Cooker	Replace	Cooking	10	386,427	0	25,045	2.95	2.95	0	861,426	$0.002	41.80
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.	Replace	Refrigeration	18	995,471	0	25,929	3.55	4.66	0	9,955	$0.003	29.51
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	18	358,657	0	9,342	1.28	1.68	0	3,587	$0.003	29.51
H102	DCV	Applicable to single zone packaged systems with large make -up air fractions either because of intermittent occupancy or	Retrofit	Heating	15	3,081,308	0	32,011	7.94	6.91	3,894	14,121	$0.005	18.07

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		because of code requirements. In most cases the outdoor air is reset to 5% or less with CO2 build-up modulating ventilation.												
H128	Ground Source Heat Pump - Air Source HP Base	Install GSHP in place of air source heat pumps.	Replace	Heating	18	9,777,685	-225,064	170,060	42.17	36.73	0	1,504	$0.005	19.24
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.	Replace	Cooling	15	964,191	0	15,490	3.84	3.35	0	132,408	$0.006	14.91
E111	Roof Insulation - Attic R0-30	Roof Insulation - Attic R0-30. Application: Buildings with uninsulated attics	Retrofit	Heating	30	176,743	0	1,782	0.61	0.06	0	635	$0.007	15.62
W127r	Waste Water Heat Exchanger	Install HX on waste water	Retrofit	Water Heat	15	186,226	0	2,225	0.26	0.26	0	1,588	$0.008	10.97
W101	DHW Wrap	Insulate the surface of the storage water heater or an unfired storage tank to R-5 to	Retrofit	Water Heat	7	115,250	0	2,102	0.25	0.25	0	31,420	$0.010	8.73

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		reduce standby losses.												
M103	Transformers	0	Retrofit	Total	20	3,910,365	0	32,772	3.86	3.86	0	145,340	$0.010	9.72
E101	Wall Insulation - Blown R11	Wall Insulation - Blown R11. Application: Old buildings	Retrofit	Heating	30	1,546,645	0	10,238	3.51	0.32	0	4,019	$0.010	10.25
W102	DHW Shower Heads	Install low flow shower heads (2.0 gallons per minute) to replace 3.4 GPM shower heads.	Retrofit	Water Heat	8	235,466	0	3,612	0.42	0.42	0	4,420	$0.010	8.19
R103	Efficient Refrigeration systems	Large Grocery - Efficient Comp, Sub-cooling, controls	New	Refrigeration	18	6,283,666	0	50,516	6.92	9.08	0	7,173	$0.011	9.11
R103rep	Efficient Refrigeration systems	Large Grocery - Efficient Comp, Sub-cooling, controls	Replace	Refrigeration	18	17,440,647	0	140,209	19.20	25.19	0	19,909	$0.011	9.11
E102	Wall Insulation - Spray On for Metal Buildings	Wall Insulation - Spray On for Metal Buildings (Cellulose) Unfinished. Application: Old buildings	Retrofit	Heating	30	137,282	0	816	0.28	0.03	0	398	$0.011	9.21
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	Replace	Heating	30	1,049,484	0	6,097	2.09	0.19	0	1,421	$0.011	9.00
W126r	Heat Pump Water Heat		Retrofit	Water Heat	15	4,625,848	190,709	37,270	4.38	4.38	0	15,875	$0.013	7.11

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
C100	CEE Tier 2 3 ton (new)	Install high efficiency cooling equipment complying with CEE Tier 2.	New	Cooling	20	532,875	0	3,178	0.79	0.69	0	13,977	$0.014	6.99
E107	Roof Insulation - Blanket R0-19	Roof Insulation - Blanket R0-19. Application: Buildings with open truss unfinished interior	Retrofit	Heating	30	234,596	0	1,136	0.39	0.04	0	317	$0.014	7.50
C103	CEE Tier 2 3 ton (at rep)	Install high efficiency cooling equipment complying with CEE Tier 2.	Replace	Cooling	20	2,084,742	0	12,191	3.02	2.63	0	56,234	$0.014	6.85
L106	High Bay HID Medium to T8	458W> 224W, 1 lamp HID to 6 Lamp HPT8	New	Lighting	21	14,260	521,922	8,918	1.22	1.60	-114	4,365	$0.014	7.09
E108	Roof Insulation - Blanket R0-30	Roof Insulation - Blanket R0-30. Application: Buildings with open truss unfinished interior	Retrofit	Heating	30	263,921	0	1,192	0.41	0.04	0	317	$0.015	6.99
W124r	Computerized Water Heater Control	Install intelligent controls on the hot water circulation loops.	Retrofit	Water Heat	15	759,724	0	4,700	0.55	0.55	0	5,239	$0.016	5.68
R106rep	Heat Reclaim	Large Grocery - Heat recovery to space heating. Assumes floating head control exists and must be changed to allow HR.	Replace	Refrigeration	18	2,953,644	0	9,536	1.31	1.71	885	3,692	$0.016	6.20
R106	Heat Reclaim	Large Grocery - Heat recovery to	New	Refrigeration	18	926,424	0	2,801	0.38	0.50	270	1,158	$0.017	5.91

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		space heating. Assumes floating head control exists and must be changed to allow HR.												
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	Replace	Heating	30	1,812,746	0	6,971	2.39	0.22	0	1,421	$0.017	5.96
W103	DHW Faucets	Add aerators to existing faucets to reduce flow from 3.4 gallons per minute to 2.0 GPM.	Retrofit	Water Heat	8	58,605	0	482	0.06	0.06	0	2,946	$0.019	4.39
L104	T12 to HP T8	162W> 49W	Retrofit	Lighting	21	28,557,481	9,974,135	252,650	34.60	45.40	-2,582	95,335	$0.020	5.12
E114	Windows - Add Low E to Vinyl Tint	Windows - Add Low E to Vinyl Tint. Application: Old buildings	Replace	Heating	20	857,217	0	3,397	1.17	0.11	0	7,823	$0.021	4.77
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	Replace	Heating	30	3,319,778	0	10,122	3.47	0.31	0	5,085	$0.022	4.72

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
E112	Roof Insulation - Attic 11-30	Roof Insulation - Attic 11-30. Application: Buildings with partially insulated attics	Retrofit	Heating	30	1,126,680	0	3,225	1.11	0.10	0	4,477	$0.023	4.43
H125	ECM Fan Powered Boxes	Install ECM motors in VAV fan powered terminals with PSC motors	New	Ventilation	20	821,041	0	3,834	0.95	0.83	-34	5,337	$0.024	3.99
L106ret	High Bay HID Medium to T8	458W> 224W, 1 lamp HID to 6 Lamp HPT8	Retrofit	Lighting	21	12,181,626	2,847,192	75,734	10.37	13.61	-910	20,987	$0.025	4.09
E115	Windows - Add Low E and Argon to Vinyl Tint	Windows - Add Low E and Argon to Vinyl Tint. Application: Old buildings	Replace	Heating	20	1,340,609	0	4,122	1.42	0.13	0	7,823	$0.027	3.70
L112	Exit signs	20W> 1 W, switch to LED sign (not photoluminescent b/c of cost)	Retrofit	Lighting	21	5,353,939	0	21,824	2.57	2.57	-237	2,878	$0.028	3.47
E123	Windows - Add Low E to Vinyl Tint	Windows - Add Low E to Vinyl Tint. Application: New Construction	New	Heating	20	165,844	0	472	0.16	0.01	0	2,009	$0.029	3.43
C101	CEE Tier 2 7.5 ton (new)	Install high efficiency cooling equipment complying with CEE Tier 2.	New	Cooling	20	625,549	0	1,769	0.44	0.38	0	13,977	$0.029	3.31
C104	CEE Tier 2 7.5 ton (at rep)	Install high efficiency cooling equipment complying with CEE Tier 2.	Replace	Cooling	20	2,447,306	0	6,784	1.68	1.47	0	56,234	$0.029	3.25
L105ret	T8 to HP T8	58W> 49W	Retrofit	Lighting	21	28,557,481	5,819,339	122,727	16.81	22.05	-1,254	95,335	$0.030	3.39

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
L105	T8 to HP T8	58W> 49W	New	Lighting	21	11,005,355	10,632,001	70,548	9.66	12.68	-674	77,277	$0.031	3.21
W127	Waste Water Heat Exchanger	Install HX on waste water	New	Water Heat	15	787,246	0	2,425	0.29	0.29	0	5,750	$0.032	2.83
C102	CEE Tier 2 15 ton (new)	Install high efficiency cooling equipment complying with CEE Tier 2.	New	Cooling	20	1,112,087	0	2,819	0.70	0.61	0	13,977	$0.032	2.97
L101	CFL 9W to 39W hardwired	75W> 18W	New	Lighting	21	582,972	16,645,537	56,889	7.79	10.22	-663	16,493	$0.033	3.09
L105rep	T8 to HP T8	58W> 49W	Replace	Lighting	21	41,642,654	36,591,692	246,701	33.78	44.33	-2,537	312,126	$0.033	3.08
C105	CEE Tier 2 15 ton (at rep)	Install high efficiency cooling equipment complying with CEE Tier 2.	Replace	Cooling	20	4,350,766	0	10,812	2.68	2.34	0	56,234	$0.033	2.91
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, 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	Retrofit	Total	20	22,065,527	0	51,919	6.11	6.11	0	4,327	$0.035	2.73

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		more.												
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	15	786,209	0	2,208	0.26	0.26	0	23,447	$0.035	2.58
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	10	24,120,345	0	60,527	15.01	13.07	2,987	185,541	$0.036	2.34
L109	Sweep Control	25% savings	New	Lighting	21	16,225,492	0	41,492	-	-	-325	21,634	$0.037	2.44
E124	Windows - Add Low E and Argon to Vinyl Tint	Windows - Add Low E and Argon to Vinyl Tint. Application: New Construction	New	Heating	20	259,365	0	572	0.20	0.02	0	2,009	$0.037	2.65
C106	High Efficiency Chiller	Replace chillers or installing new	Replace	Cooling	24	8,023,037	0	14,976	1.76	1.76	0	82,755	$0.040	2.46

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		chillers to purchase units with efficiencies averaging 0.51kW/ton air conditioning (AC), rather than the standard new unit, which has an efficiency of 0.65 kW/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.												
L107	High Bay HID Large to T5	1080W> 701W	New	Lighting	21	863,874	252,953	2,917	0.40	0.52	-37	2,078	$0.040	2.53
C108	Chiller Tower 6F approach	Install low approach cooling tower	Replace	Cooling	15	5,348,691	0	12,020	2.98	2.60	0	132,408	$0.043	2.09
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	New	lighting	15	10,731,567	0	23,738	2.79	2.79	0	42,926	$0.044	2.03

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		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.												
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.	Replace	Misc.	4	56,751,830	0	430,120	50.60	50.60	-4,478	567,518	$0.046	1.91
L107ret	High Bay HID Large to T5	1080W> 701W	Retrofit	Lighting	21	10,325,750	1,379,909	24,771	3.39	4.45	-298	9,994	$0.046	2.17
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.	4	1,766,381	0	13,289	1.56	1.56	-159	17,664	$0.047	1.85

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
W124	Computerized Water Heater Control	Install intelligent controls on the hot water circulation loops.	New	Water Heat	15	335,888	0	690	0.08	0.08	0	1,944	$0.048	1.89
C102	CEE Tier 2 25 ton (new)	Install high efficiency cooling equipment complying with CEE Tier 2.	New	Cooling	20	1,912,680	0	3,199	0.79	0.69	0	24,039	$0.049	1.96
W126	Heat Pump Water Heat	0	New	Water Heat	15	1,319,720	54,408	2,741	0.32	0.32	0	5,270	$0.049	1.83
W123	Hi Eff Clothes Washer	Install high performance commercial clothes washers - residential sized units	New	Water Heat	10	804,949	0	2,120	0.25	0.25	0	75	$0.050	1.70
W123r	Hi Eff Clothes Washer	Install high performance commercial clothes washers - residential sized units	Replace	Water Heat	10	4,285,746	0	11,288	1.33	1.33	0	399	$0.050	1.70
E121	Windows - Tinted AL Code to Class 40	Windows - Tinted AL Code to Class 40. Application: Old buildings	Replace	Heating	20	637,089	0	1,046	0.36	0.03	0	4,964	$0.050	1.98
C105	CEE Tier 2 25 ton (at rep)	Install high efficiency cooling equipment complying with CEE Tier 2.	Replace	Cooling	20	7,482,889	0	12,271	3.04	2.65	0	96,717	$0.050	1.92
L115	Daylighting Overhead	Daylight control with skylite	New	Lighting	21	40,006,551	0	90,845	12.44	16.32	-1,928	32,900	$0.051	1.99
H103	Ducts	Duct retrofit of both insulation and air sealing	Retrofit	Heating	15	1,911,651	0	3,643	0.90	0.79	0	3,823	$0.051	1.77
E120	Windows - Tinted AL Code to Class 45	Windows - Tinted AL Code to Class 45. Application:	Replace	Heating	20	423,664	0	630	0.22	0.02	0	4,964	$0.055	1.79

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		Old buildings												
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	5	5,508,685	0	23,091	5.73	4.99	0	22,035	$0.055	1.56
E116	Windows - Add Argon to Vinyl Lowe	Windows - Add Argon to Vinyl Lowe. Application: Old buildings	Replace	Heating	20	3,064,071	0	4,206	1.44	0.13	0	34,623	$0.059	1.65
H101	Warm Up Control	This measure is designed to implement a shut down of outside air when the building is	Retrofit	Heating	10	3,628,540	0	7,846	-	-	0	19,242	$0.060	1.32

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		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												
W125r	Solar Hot Water	Install solar water heaters on large use facility such as multifamily or lodging	Retrofit	Water Heat	15	7,589,049	463,565	12,535	1.47	1.47	0	9,264	$0.063	1.43
E113	Roof Insulation - Roofcut 0-22	Roof Insulation - Roofcut 0-22. Application: Buildings with uninsulated flat roofs at reroofing time	Replace	Heating	30	8,515	0	8	0.00	0.00	0	12	$0.068	1.52
E125	Windows - Add Argon to Vinyl Lowe	Windows - Add Argon to Vinyl Lowe. Application: New Construction	New	Heating	20	666,639	0	770	0.26	0.02	0	8,372	$0.071	1.39
E130	Windows - Tinted AL Code to Class 40	Windows - Tinted AL Code to Class 40. Application: New Construction	New	Heating	20	151,104	0	169	0.06	0.01	0	1,474	$0.073	1.35
E106	Roof Insulation - Rigid R11-33	Roof Insulation - Rigid R11-33:	Replace	Heating	30	4,979,667	0	4,157	1.43	0.13	0	5,085	$0.080	1.29

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		add 4' of insulation at reroof. Application: Old buildings with flat roofs, no attics, and some insulation												
E129	Windows - Tinted AL Code to Class 45	Windows - Tinted AL Code to Class 45. Application: New Construction	New	Heating	20	100,484	0	96	0.03	0.00	0	1,474	$0.085	1.15
R102	Refrigeration Case Package	Efficient Evap Fans, case lighting, low energy anti-sweat heaters	New	Refrigeration	18	6,470,168	0	6,470	0.89	1.16	0	7,173	$0.087	1.13
R102rep	Refrigeration Case Package	Efficient Evap Fans, case lighting, low energy anti-sweat heaters	Replace	Refrigeration	18	17,958,292	0	17,958	2.46	3.23	0	19,909	$0.087	1.13
E118	Windows - Non-Tinted AL Code to Class 40	Windows - Non-Tinted AL Code to Class 40. Application: Old buildings	Replace	Heating	20	2,267,922	0	2,037	0.70	0.06	0	10,552	$0.091	1.08
E122	Windows - Tinted AL Code to Class 36	Windows - Tinted AL Code to Class 36. Application: Old buildings	Replace	Heating	20	1,592,723	0	1,428	0.49	0.04	0	4,964	$0.091	1.08
E110	Roof Insulation - Blanket R11-41	Roof Insulation - Blanket R11-41. Application: Buildings with open truss unfinished interior	Retrofit	Heating	30	659,802	0	466	0.16	0.01	0	792	$0.094	1.09
H124	Install Economizer	Economizer retrofit on unit	Retrofit	Cooling	15	3,296,668	0	3,274	0.81	0.71	0	9,277	$0.098	0.92

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		with no economizer												
E127	Windows - Non-Tinted AL Code to Class 40	Windows - Non-Tinted AL Code to Class 40. Application: New Construction	New	Heating	20	637,423	0	525	0.18	0.02	0	3,152	$0.099	0.99
E109	Roof Insulation - Blanket R11-30	Roof Insulation - Blanket R11-30. Application: Buildings with open truss unfinished interior	Retrofit	Heating	30	586,491	0	389	0.13	0.01	0	792	$0.100	1.03
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	New	Heating	15	16,368,663	0	13,195	3.27	2.85	0	25,183	$0.121	0.75

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		savings than the other documented commissioning on more complex systems.												
E131	Windows - Tinted AL Code to Class 36	Windows - Tinted AL Code to Class 36. Application: New Construction	New	Heating	20	377,760	0	231	0.08	0.01	0	1,474	$0.133	0.74
E119	Windows - Non-Tinted AL Code to Class 36	Windows - Non-Tinted AL Code to Class 36. Application: Old buildings	Replace	Heating	20	5,669,806	0	3,091	1.06	0.10	0	10,552	$0.150	0.66
L108	Daylight Control (overhead)	5% savings	New	Lighting	10	57,204,281	0	52,164	7.14	9.37	-565	20,802	$0.151	0.59
L114	Ceramic Metal Halide	100W> 44W	New	Lighting	21	17,472,353	16,162,179	17,574	2.41	3.16	-126	3,382	$0.157	0.64
L113	Ceramic Metal Halide	100W> 44W	Replace	Lighting	21	34,711,599	31,988,660	34,811	4.77	6.26	-251	6,864	$0.157	0.64
E128	Windows - Non-Tinted AL Code to Class 36	Windows - Non-Tinted AL Code to Class 36. Application: New Construction	New	Heating	20	1,593,557	0	782	0.27	0.02	0	3,152	$0.166	0.59
E117	Windows - Non-Tinted AL Code to Class 45	Windows - Non-Tinted AL Code to Class 45. Application: Old buildings	Replace	Heating	20	1,508,168	0	729	0.25	0.02	0	10,552	$0.169	0.58
E126	Windows - Non-Tinted AL Code to Class 45	Windows - Non-Tinted AL Code to Class 45. Application: New Construction	New	Heating	20	423,886	0	195	0.07	0.01	0	3,152	$0.177	0.55
H127	Indirect/Direct Evaporative Cooling >60 ton	Install indirect/direct evaporative cooling in	New	Cooling	18	12,751,201	0	5,704	1.41	1.23	0	9,615	$0.194	0.48

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
		commercial building HVAC system in large systems <60 ton range. Original ETO evaluation evaluated at 20, 150 and 300tons with all being essentially equivalent												
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	Replace	Cooling	18	55,428,808	0	24,309	6.03	5.25	0	42,985	$0.198	0.47
H128	Rooftop Condensing Burner	Install condensing burner	Retrofit	Heating	10	21,004,333	0	12,222	3.03	2.64	0	14,121	$0.225	0.36
W125	Solar Hot Water	Install solar water heaters on large use facility such as multifamily or lodging	New	Water Heat	15	3,291,761	201,072	1,512	0.18	0.18	0	3,465	$0.226	0.40
L102	High Efficacy LED Display	72W> 39W	New	Lighting	21	101,484	36,920,992	10,591	1.45	1.90	-75	2,464	$0.283	0.36
L111	Occupancy Sensors	5% savings	New	Lighting	15	7,450,794	0	2,189	-	-	-32	4,967	$0.343	0.25
L110	Daylight perimeter zone	10% savings	New	Lighting	10	15,165,482	0	5,160	0.71	0.93	-80	11,666	$0.396	0.23
H126	Indirect/Direct Evaporative Cooling	Install indirect/direct	New	Cooling	18	27,893,252	0	5,704	1.41	1.23	0	9,615	$0.425	0.22

Measure Code	Measure Name	Measure Description	Const. Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Winter MW	Summer mW	Gas Impacts kTherms	Floor Area	Levelized Cost, $/kWh	BCR
	~20 ton	evaporative cooling in commercial building HVAC system in 20 to 60 ton range												
H126rep	Indirect/Direct Evaporative Cooling ~20 ton	Install indirect/direct evaporative cooling in commercial building HVAC system in 20 to 60 ton range	Replace	Cooling	18	121,250,518	0	24,309	6.03	5.25	0	42,985	$0.433	0.22
R104	Package Refrigeration - Ice makers, Vending machines	Install machines with package of measures akin to ADL low cost	new	Misc.	9	27,077,751	0	2,282	0.27	0.27	0	143,088	$1.684	0.05
R104rep	Package Refrigeration - Ice makers, Vending machines	Install machines with package of measures akin to ADL low cost	Replace	Misc.	9	246,799,542	0	20,797	2.45	2.45	0	1,279,324	$1.684	0.05
R105	Efficient Standalone Refrigeration Cases	Install efficient stand alone cases. This measure is based upon current rebates and SAIC savings numbers	new	Misc.	9	706,781,901	0	24,635	2.90	2.90	0	143,088	$4.072	0.02
H105rep	Efficient Standalone Refrigeration Cases	Install efficient stand alone cases. This measure is based upon current rebates and SAIC savings numbers	Replace	Misc.	9	4,840,137,110	0	168,703	19.85	19.85	0	1,279,324	$4.072	0.02

Note: Includes emerging technology measures

Table 18: Detailed Measure Table, Commercial Sector, Gas Savings, 2027 Technical Potential

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
Co116	EStar Steam Cooker	Install Energy Star Steam Cooker	New	Cooking	10	66,578	0	0	196	21,506	$0.044	16.13
Co116rep	EStar Steam Cooker	Install Energy Star Steam Cooker	Replace	Cooking	10	503,392	0	0	1,485	168,077	$0.044	16.13
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	5	9,145	0	0	29	1,131	$0.073	10.92
Co112	Infrared Fryer	0	New	Cooking	8	418,172	0	0	773	19,117	$0.084	8.60

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
Co107	Infrared Fryer	0	Replace	Cooking	8	3,924,848	0	0	7,249	186,752	$0.084	8.59
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	10	779,738	0	0	1,014	31,744	$0.101	7.43
E111	Roof Insulation - Attic R0-30	Roof Insulation - Attic R0-30. Application: Buildings with uninsulated attics	Retrofit	Heating	30	755,884	0	1,265	318	2,478	$0.102	7.35
R106	Heat Reclaim	Large Grocery - Heat recovery to space heating. Assumes floating head control exists and must be changed to allow HR.	New	Refrigeration	18	866,471	0	3,518	244	1,083	$0.105	7.00
R106rep	Heat Reclaim	Large Grocery - Heat recovery to space heating. Assumes floating head control exists and must be changed to allow HR.	Replace	Refrigeration	18	3,693,658	0	14,884	1,036	4,617	$0.106	6.95
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	Retrofit	Heating	15	721,530	0	0	511	12,025	$0.138	5.35

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
		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.										
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	15	10,703,057	0	17,059	5,302	49,048	$0.141	5.29
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	Replace	Heating	30	3,720,482	0	5,083	929	5,317	$0.152	4.94
E101	Wall Insulation - Blown R11	Wall Insulation - Blown R11. Application: Old buildings	Retrofit	Heating	30	7,217,577	0	3,699	2,289	20,881	$0.172	4.38
W127r	Waste Water Heat Exchanger	Install HX on waste water	Retrofit	Water Heat	15	480,311	0	0	238	2,676	$0.197	3.58
W101	DHW Wrap	Insulate the surface of the storage water heater or an unfired storage tank to R-5 to reduce	Retrofit	Water Heat	7	78,020	0	0	67	16,288	$0.203	3.61

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
		standby losses.										
H119	Hi Eff Unit Heater (new)	Install power draft units (80% seas. Eff) in place of natural draft (64% seas. Eff)	New	Heating	18	1,022,397	0	0	427	6,735	$0.208	3.55
W102	DHW Shower Heads	Install low flow shower heads (2.0 gallons per minute) to replace 3.4 GPM shower heads.	Retrofit	Water Heat	8	608,020	0	0	425	11,424	$0.223	3.25
H114	Hi Eff Unit Heater (replace)	Install power draft units (80% seas. Eff) in place of natural draft (64% seas. Eff)	Replace	Heating	18	4,833,117	0	0	1,850	29,194	$0.227	3.26
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	Replace	Heating	30	6,426,288	0	5,772	1,057	5,317	$0.231	3.25
E102	Wall Insulation - Spray On for Metal Buildings	Wall Insulation - Spray On for Metal Buildings (Cellulose) Unfinished. Application: Old buildings	Retrofit	Heating	30	1,078,187	0	-25	306	3,123	$0.243	3.09
E107	Roof Insulation - Blanket R0-19	Roof Insulation - Blanket R0-19. Application: Buildings with open truss unfinished interior	Retrofit	Heating	30	1,842,477	0	46	421	2,490	$0.287	2.62
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	Retrofit	Heating	12	360,519	0	0	137	6,964	$0.300	2.47

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
		losses. This measure is most cost-effective when combined with the boiler tune up and power burner measures.										
E108	Roof Insulation - Blanket R0-30	Roof Insulation - Blanket R0-30. Application: Buildings with open truss unfinished interior	Retrofit	Heating	30	2,072,786	0	51	442	2,490	$0.307	2.45
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	Replace	Heating	30	13,990,243	0	5,814	1,941	18,721	$0.340	2.21
W124r	Computerized Water Heater Control	Install intelligent controls on the hot water circulation loops.	Retrofit	Water Heat	15	2,011,067	0	0	547	11,785	$0.359	1.97
W121	Combo Hieff Boiler (new)	Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.	New	Heating	20	471,049	0	0	104	3,819	$0.368	1.93
E112	Roof Insulation - Attic 11-30	Roof Insulation - Attic 11-30. Application: Buildings with partially insulated attics	Retrofit	Heating	30	4,400,560	0	1,174	576	16,442	$0.397	1.89
W119	Combo Hieff Boiler (repl)	Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.	Replace	Heating	20	2,075,826	0	0	417	15,219	$0.406	1.83
W103	DHW Faucets	Add aerators to existing faucets to reduce flow from 3.4 gallons per minute to 2.0 GPM.	Retrofit	Water Heat	8	151,329	0	0	57	7,616	$0.417	1.74

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
E123	Windows - Add Low E to Vinyl Tint	Windows - Add Low E to Vinyl Tint. Application: New Construction	New	Heating	20	442,153	0	421	30	7,494	$0.418	1.77
E114	Windows - Add Low E to Vinyl Tint	Windows - Add Low E to Vinyl Tint. Application: Old buildings	Replace	Heating	20	1,751,638	0	1,629	119	29,571	$0.427	1.74
H117	SPC Hieff Boiler (new)	Install near condensing boiler. Assumed seasonal combustion efficiency of 82% over base of 75%	New	Heating	20	891,239	0	0	167	6,332	$0.436	1.70
Co115	Power Range Burner	0	New	Cooking	12	579,230	0	0	144	21,506	$0.460	1.54
Co110	Power Range Burner	0	Replace	Cooking	12	3,649,595	0	0	904	140,064	$0.461	1.54
H111	SPC Hieff Boiler Replace	Install near condensing boiler. Assumed seasonal combustion efficiency of 82% over base of 75%	Replace	Heating	20	735,475	0	0	127	4,861	$0.471	1.57
E124	Windows - Add Low E and Argon to Vinyl Tint	Windows - Add Low E and Argon to Vinyl Tint. Application: New Construction	New	Heating	20	691,488	0	424	42	7,494	$0.576	1.28
E115	Windows - Add Low E and Argon to Vinyl Tint	Windows - Add Low E and Argon to Vinyl Tint. Application: Old buildings	Replace	Heating	20	2,739,404	0	1,589	176	29,571	$0.578	1.28
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	15	1,549,897	0	0	261	27,350	$0.579	1.22

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
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.	Replace	Water Heat	15	6,095,164	0	0	1,010	108,588	$0.589	1.20
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	12	7,703,430	0	0	1,416	48,748	$0.621	1.20
Co114	Infrared Griddle	0	New	Cooking	12	536,244	0	0	96	19,117	$0.638	1.11
Co109	Infrared Griddle	0	Replace	Cooking	12	3,364,952	0	0	601	124,501	$0.639	1.11
H120a	Cond Unit Heater from Nat Draft (new)	Install condensing power draft units (90% seas. Eff) in place of natural draft (64% seas. Eff)	New	Heating	18	5,510,548	0	0	741	8,082	$0.646	1.14
W115	DHW Hieff Boiler (new)	Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.	New	Water Heat	20	803,373	0	0	95	8,285	$0.693	1.02
W127	Waste Water Heat Exchanger	Install HX on waste water	New	Water Heat	15	1,198,545	0	0	168	6,967	$0.697	1.01
W113	DHW Hieff Boiler (repl)	Replace existing boiler with unit meeting OR Code requirements of 85% combustion efficiency.	Replace	Water Heat	20	3,136,930	0	0	364	32,634	$0.703	1.05

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
H115a	Cond Unit Heater from Nat draft (replace)	Install condensing power draft units (90% seas. Eff) in place of natural draft (64% seas. Eff)	Replace	Heating	18	26,049,679	0	0	3,207	35,032	$0.706	1.05
H118	SPC Cond Boiler (new)	Install condensing boiler. Assumed seasonal combustion efficiency of 88% over base of 75%	New	Heating	20	2,748,702	0	0	311	6,839	$0.720	1.03
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	20	1,827,533	0	0	204	3,819	$0.732	0.97
H112	SPC Cond Boiler Replace	Install condensing boiler. Assumed seasonal combustion efficiency of 88% over base of 75%	Replace	Heating	20	2,259,180	0	0	238	5,250	$0.775	0.96
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	15	936,138	0	0	117	25,878	$0.778	0.91
E129	Windows - Tinted AL Code to Class 45	Windows - Tinted AL Code to Class 45. Application: New Construction	New	Heating	20	281,389	0	216	0	4,460	$0.790	0.94
E121	Windows - Tinted AL Code to Class 40	Windows - Tinted AL Code to Class 40. Application: Old buildings	Replace	Heating	20	1,693,602	0	1,003	40	17,652	$0.800	0.93
W120	Combo Cond	Replace with boiler	Replace	Heating	20	7,989,078	0	0	814	15,219	$0.800	0.93

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
	Boiler (repl)	using condensing or pulse technology to achieve steady-state combustion efficiencies of 89% to 94% (this analysis used 90% efficiency for savings calculations).										
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	5	17,720,206	0	19,984	2,540	70,881	$0.874	0.91
E130	Windows - Tinted AL Code to Class 40	Windows - Tinted AL Code to Class 40. Application: New Construction	New	Heating	20	423,141	0	219	10	4,460	$0.881	0.84
H103	Ducts	Duct retrofit of both insulation and air sealing	Retrofit	Heating	15	7,145,695	0	2,018	543	14,291	$0.882	0.84
W105	DHW Recirc Controls	Install electronic controller to hot water boiler system that turns off the boiler and	Retrofit	Water Heat	10	2,757,806	0	0	380	15,897	$0.948	0.75

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
		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).										
E113	Roof Insulation - Roofcut 0-22	Roof Insulation - Roofcut 0-22. Application: Buildings with uninsulated flat roofs at reroofing time	Replace	Heating	30	54,363	0	9	3	84	$0.962	0.78
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	10	11,085,625	0	0	1,405	58,787	$1.032	0.72
W124	Computerized Water Heater Control	Install intelligent controls on the hot water circulation loops.	New	Water Heat	15	496,796	0	0	46	3,020	$1.045	0.68
W123	Hi Eff Clothes Washer	Install high performance commercial clothes	New	Water Heat	10	555,081	0	28	65	52	$1.059	0.68

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
		washers - residential sized units										
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	20	2,431,146	0	0	185	8,285	$1.073	0.66
W123r	Hi Eff Clothes Washer	Install high performance commercial clothes washers - residential sized units	Replace	Water Heat	10	4,207,612	0	0	504	392	$1.091	0.66
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).	Replace	Water Heat	20	9,569,032	0	0	711	32,634	$1.098	0.67
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	Replace	Heating	30	20,985,364	0	4,018	659	18,721	$1.154	0.65
H129	Steam Trap Maintenance	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	Retrofit	Heating	10	1,053,433	4,318,552	0	577	9,620	$1.217	0.61

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
		steam survey.										
E116	Windows - Add Argon to Vinyl Lowe	Windows - Add Argon to Vinyl Lowe. Application: Old buildings	Replace	Heating	20	8,988,268	0	-784	640	130,280	$1.266	0.59
H120b	Cond Unit Heater From Power Draft (new)	Install condensing power draft units (90% seas. Eff) in place of power draft (80% seas. Eff)	New	Heating	18	2,855,781	0	0	190	5,388	$1.307	0.56
H115b	Cond Unit Heater from power draft (replace)	Install condensing power draft units (90% seas. Eff) in place of power draft (80% seas. Eff)	Replace	Heating	18	13,499,959	0	0	821	23,355	$1.428	0.52
E125	Windows - Add Argon to Vinyl Lowe	Windows - Add Argon to Vinyl Lowe. Application: New Construction	New	Heating	20	2,239,214	0	-164	139	32,761	$1.435	0.52
H121	Cond Furnace (new)	Condensing / pulse package or residential-type furnace with a minimum AFUE of 92%.	New	Heating	18	7,723,377	0	0	432	11,399	$1.554	0.47
W125r	Solar Hot Water	Install solar water heaters on large use facility such as multifamily or lodging	Retrofit	Water Heat	15	18,498,211	1,129,933	0	1,218	13,246	$1.573	0.45
E122	Windows - Tinted AL Code to Class 36	Windows - Tinted AL Code to Class 36. Application: Old buildings	Replace	Heating	20	4,234,006	0	989	79	17,652	$1.645	0.45
E131	Windows - Tinted AL Code to Class 36	Windows - Tinted AL Code to Class 36. Application: New Construction	New	Heating	20	1,057,853	0	225	18	4,460	$1.794	0.41
H122	HVAC System Commissioning	HVAC system commissioning. Includes testing and balancing, damper	New	Heating	15	52,654,326	0	11,419	1,451	81,007	$1.801	0.41

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
		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.										
H116	Cond Furnace (repl)	Condensing / pulse package or residential-type furnace with a minimum AFUE of 92%.	Replace	Heating	18	39,904,813	0	0	1,902	50,436	$1.823	0.41
E118	Windows - Non-Tinted AL Code to Class 40	Windows - Non-Tinted AL Code to Class 40. Application: Old buildings	Replace	Heating	20	7,743,641	0	-407	352	41,791	$1.910	0.39
E127	Windows - Non-Tinted AL Code to Class 40	Windows - Non-Tinted AL Code to Class 40. Application: New Construction	New	Heating	20	1,942,094	0	-71	85	10,535	$1.946	0.38
E110	Roof Insulation - Blanket R11-41	Roof Insulation - Blanket R11-41. Application: Buildings with open truss unfinished interior	Retrofit	Heating	30	5,181,965	0	23	173	6,224	$1.960	0.38
E109	Roof Insulation - Blanket R11-30	Roof Insulation - Blanket R11-30. Application: Buildings with open	Retrofit	Heating	30	4,606,192	0	23	144	6,224	$2.084	0.36

Measure Code	Measure Name	Measure Description	Construction Type	Measure End Use	Average Lifetime	Total Incremental Cost	Total O&M	Total MWh Savings	Gas Impacts kTherms	Floor Area	Levelized Cost, $/th	BCR
		truss unfinished interior										
E119	Windows - Non-Tinted AL Code to Class 36	Windows - Non-Tinted AL Code to Class 36. Application: Old buildings	Replace	Heating	20	19,359,103	0	-724	531	41,791	$3.107	0.24
E128	Windows - Non-Tinted AL Code to Class 36	Windows - Non-Tinted AL Code to Class 36. Application: New Construction	New	Heating	20	4,855,236	0	-143	128	10,535	$3.196	0.23
E117	Windows - Non-Tinted AL Code to Class 45	Windows - Non-Tinted AL Code to Class 45. Application: Old buildings	Replace	Heating	20	5,149,521	0	-183	133	41,791	$3.307	0.22
E126	Windows - Non-Tinted AL Code to Class 45	Windows - Non-Tinted AL Code to Class 45. Application: New Construction	New	Heating	20	1,291,493	0	-33	32	10,535	$3.397	0.22
H128	Rooftop Condensing Burner	Install condensing burner	Retrofit	Heating	10	72,959,466	0	10,477	1,391	49,048	$3.689	0.20
W125	Solar Hot Water	Install solar water heaters on large use facility such as multifamily or lodging	New	Water Heat	15	4,585,397	280,092	0	96	3,439	$4.956	0.14

Table 19: Detailed Measure Table, Residential Sector, Electricity Savings, 2027 Technical Potential

Measure Code	Measure Description	Program	Average Life time	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	BCR	No. Units
N-A102	MEF 2.0 Washer	New	12	3,440,567	-11,747,241	4,833,801	700	586	57,115	-$0.180	-$1.349	100.00	103,632
N-A105	Hi-eff Washer	New	12	1,935,319	-6,765,152	3,526,419	510	427	1,580	-$0.156	-$1.167	100.00	38,862
R-A105	Hi-eff Washer	Replace	12	25,878,741	-41,262,215	26,681,914	3,861	3,234	0	-$0.066	na	100.00	168,044
R-A102	MEF 2.0 Washer	Replace	12	58,317,215	-66,337,147	41,460,480	6,000	5,025	1,504,550	-$0.017	-$0.130	100.00	516,082
N-A107	Energy Star Televsion	Replace	12	375	0	33,405,211	3,930	3,930	-202,252	$0.004	na	63960.14	374,784
R-D107	Hot water pipe wrap	Replace	10	27,460	0	1,169,772	138	138	-9,073	$0.009	na	25.67	1,248
R-W105	Window replace (U=.35), ER Z 1	Replace	45	3,594,296	0	21,746,562	5,472	152	0	$0.010	na	11.92	12,705
R-W108	Window replace (U=.35), HP Z 2	Replace	45	176,075	0	1,064,226	178	45	0	$0.010	na	12.39	505
R-D106	Tank wrap (in accordance with EWEB guidelines or equivalent)	Replace	10	10,485	0	216,752	25	25	-1,681	$0.012	na	12.46	3,745
R-W106	Window replace (U=.35), HP Z 1	Replace	45	1,010,976	0	4,067,251	680	170	0	$0.014	na	8.25	2,956
R-W107	Window replace (U=.35), ER Z 2	Replace	45	2,283,698	0	8,870,382	2,232	62	0	$0.015	na	7.65	10,043
R-L102	Common Area Lighting (MF Only)	Retro	7	2,045,657	0	28,625,138	3,367	3,367	-192,782	$0.017	na	6.30	127,854
N-H115	Ducts Indoor, DHW, Lights (HP, Z2)	New	45	9,392,125	0	30,628,819	5,120	1,284	0	$0.018	na	6.69	15,243
N-H111	E* Insulation, Ducts, DHW, Lights (HP, Z 2)	New	45	12,031,313	0	32,989,680	5,515	1,382	0	$0.021	na	5.62	7,590
R-H107	Duct Sealing, Elect Resis, Z 2	Retro	20	1,646,355	0	5,725,260	1,441	40	0	$0.023	na	4.53	2,755
R-A108	LowPowerMode Appliances	Replace	12	94,812,300	0	393,660,688	46,310	46,310	-1,176,285	$0.030	na	3.06	1,096,928

R-A104	Refrigerator Recycle	Replace	6	4,044,629	0	26,845,205	3,158	3,158	0	$0.030	na	2.81	40,446
N-A104	LowPowerMode Appliances	New	12	39,757,772	0	163,912,681	19,282	19,282	-497,746	$0.030	na	3.04	455,666
R-W135	Wx (ceiling,floor) ER, Z 2	Retro	45	937,669	0	1,810,308	456	13	0	$0.030	na	3.80	532
R-L101	Retail Lights (2 lamps)	Retro	7	4,122,926	0	27,862,743	3,278	3,278	-208,406	$0.031	na	3.02	687,154
N-H116	E* HP HSPF 7.7>9.5 (Z 2) w. cx	New	15	5,450,782	0	16,635,383	2,781	697	0	$0.032	na	3.32	7,464
R-H102	Duct Sealing, Elect Resis, Z 1	Retro	20	20,506,840	0	49,519,116	12,460	346	0	$0.034	na	3.15	36,485
R-H106	Duct Sealing, Heat Pump, Z 2	Retro	20	1,719,444	0	4,017,269	672	168	0	$0.035	na	3.18	2,881
R-W137	Wx (ceiling,floor) HP, Z 2	Retro	45	266,941	0	440,075	74	18	0	$0.035	na	3.38	127
N-H114	Window U=.3 (ER, Z 2)	New	45	2,217,753	0	3,619,387	911	25	0	$0.035	na	3.21	15,243
R-H110	Commissioning (HP), Z 2	Retro	5	552,613	0	3,481,156	582	146	0	$0.037	na	2.77	2,535
R-D100	Tank upgrade (50 gal)-10 yr warranty	Replace	10	965,502	0	3,350,983	485	406	-15,772	$0.038	na	2.44	27,586
N-H121	E* Insulation, Ducts, DHW, Lights (HP, Z 3)	New	45	4,637,793	0	6,609,115	1,105	277	0	$0.041	na	2.92	3,099
N-GH133	Ducts Indoor, DHW, Lights (Gas Z 3)	New Gas	45	1,648,548	0	8,331	2	0	346,946	$0.041	$0.274	2.76	2,127
R-H105	Commissioning (HP), Z 1	Retro	5	7,108,348	0	39,252,573	6,562	1,645	0	$0.042	na	2.43	33,138
R-D101	Tank upgrade (50 gal)-20 yr warranty	Replace	20	1,034,467	0	1,952,469	283	237	-9,687	$0.043	na	2.37	13,793
R-W127	Wx (ceiling,floor) ER, Z 1	Retro	45	7,841,071	0	10,479,523	2,637	73	0	$0.043	na	2.63	4,134
N-H126	E* HP HSPF 7.7>9.5 (Z 3) w. cx	New	15	2,054,779	0	4,285,409	716	180	0	$0.047	na	2.27	2,936
N-GH138	Ducts Indoor, DHW, Lights (Gas Z 4)	New Gas	45	1,957,651	0	15,899	4	0	340,895	$0.050	$0.330	2.29	2,526
N-L103	Add 6 LED lamps (using incandesent base) aft 2015	New	10	2,026,923	0	6,326,560	744	744	-77,987	$0.051	na	1.79	42,228

N-H125	Ducts Indoor, DHW, Lights (HP, Z 3)	New	45	5,648,974	0	6,332,705	1,059	265	0	$0.052	na	2.30	10,413
R-H108	Heat Pump, (HP Upgrade), Z 2	Replace	18	691,473	0	1,157,387	193	49	0	$0.052	na	2.11	384
N-L105	Add 16 LED lamps (using incand base) after 2015	New	10	3,341,723	0	10,143,187	1,193	1,193	-138,093	$0.053	na	1.72	26,107
R-D102	Heat pump water heater (50 gal)	Replace	15	7,002,868	2,184,202	16,649,860	2,410	2,018	0	$0.054	na	1.81	7,110
N-GH128	Ducts Indoor, DHW, Lights (Gas Z 1-2)	New Gas	45	11,155,703	0	1,439,923	362	10	1,570,419	$0.054	$0.361	2.09	14,394
N-H113	Window U=.3 (HP, Z 2)	New	45	1,414,978	0	1,487,341	249	62	0	$0.055	na	2.15	7,929
R-D103	Heat pump water heater (80 gal)	Replace	15	688,987	163,328	1,481,350	214	180	0	$0.056	na	1.73	532
N-H104	Window U=.3 (ER, Z 1)	New	45	3,282,608	0	3,338,060	840	23	0	$0.057	na	2.00	24,095
N-H106	E* HP HSPF 7.7>9.5 (Z 1) w. cx	New	15	6,852,498	0	11,204,620	1,873	470	0	$0.060	na	1.78	9,775
N-D102	Tank upgrade (50 gal)-20 yr warranty	New	20	8,120,452	0	11,240,441	1,627	1,362	-25,244	$0.061	na	1.71	108,273
R-H101	Duct Sealing, Heat Pump, Z 1	Retro	20	21,059,271	0	28,076,492	4,694	1,177	0	$0.061	na	1.81	37,657
R-W138	Wx (ceiling, floor, wall) HP, Z2	Retro	45	619,277	0	574,643	96	24	0	$0.062	na	1.90	182
N-H101	E* Insulation, Ducts, DHW, Lights (HP, Z 1)	New	45	17,800,992	0	16,051,575	2,683	673	0	$0.064	na	1.85	12,341
R-L103	50% LED after 2020	Retro	10	40,605,568	0	89,508,031	10,530	10,530	-668,357	$0.065	na	1.33	135,352
N-L102	Full lighting (all high efficacy)	New	7	5,630,634	0	15,244,198	1,793	1,793	-141,417	$0.071	na	1.19	50,274
N-GH129	E* Insulation, Ducts, DHW, Lights (Gas Z 3)	New Gas	45	25,108,237	0	711,311	179	5	2,956,271	$0.072	$0.475	1.60	18,078
N-GH125	Heating upgrade (AFUE 90) (Z 1-2)	New Gas	15	180,024	0	772	0	0	33,765	$0.072	$0.519	1.42	1,200
N-L108	Common Area Lighting (MF Only)	New	7	1,487,156	0	3,514,634	413	413	-3,334	$0.074	na	1.12	92,947
R-H109	Heat Pump, (ER Base), Z 2	Retro	18	855,404	49,982	1,042,505	174	44	0	$0.075	na	1.45	132

N-A106	Home Energy Monitor	New	3	2,985,524	0	14,524,921	1,709	1,709	0	$0.076	na	1.19	28,434
N-GH134	E* Insulation, Ducts, DHW, Lights (Gas Z 4)	New Gas	45	25,108,237	0	5,047,893	1,270	35	2,114,843	$0.076	$0.506	1.50	18,078
N-D103	Heat pump water heater (50 gal)	New	15	14,349,942	4,475,762	23,328,562	3,376	2,827	0	$0.079	na	1.23	14,568
R-L104	100% LED after 2020	Retro	10	62,705,855	0	110,042,035	12,945	12,945	-831,081	$0.080	na	1.06	104,510
R-A106	Home Energy Monitor	Replace	3	20,199,830	0	93,005,179	10,941	10,941	0	$0.080	na	1.12	192,379
R-H103	Heat Pump, (HP Upgrade), Z 1	Replace	18	4,247,620	0	4,596,482	768	193	0	$0.080	na	1.36	2,360
N-D101	Tank upgrade (50 gal)-10 yr warranty	New	10	3,789,544	0	6,282,337	909	761	-19,137	$0.081	na	1.14	108,273
R-W129	Wx (ceiling,floor) HP, Z 1	Retro	45	2,693,242	0	1,921,171	321	81	0	$0.081	na	1.46	1,295
N-H102	E* Insulation, Ducts, DHW, Lights (ER, Z 1)	New	45	16,220,010	0	11,524,845	3,957	358	0	$0.082	na	1.30	18,374
N-H118	HRV E* (HP Z 2)	New	15	19,330,301	0	21,966,456	3,672	921	0	$0.086	na	1.24	7,929
N-C108	Room AC (Z 1)	New	18	386,931	0	377,327	0	172	0	$0.089	na	1.17	9,673
R-H112	ER> Mini-split ductless heat pump Z2-3	Retro	15	84,434,715	0	90,317,000	15,098	3,785	0	$0.091	na	1.16	28,145
R-A103	Estar Dishwasher	Replace	12	27,139,027	-6,572,160	20,752,498	3,003	2,515	613,245	$0.092	$0.721	1.02	714,185
N-D104	Heat pump water heater (80 gal)	New	15	6,151,515	1,458,244	7,774,831	1,125	942	0	$0.096	na	1.02	4,747
R-W128	Wx (ceiling, floor, wall) ER, Z1	Retro	45	36,454,018	0	21,789,695	5,483	152	0	$0.097	na	1.18	15,095
N-H122	E* Insulation, Ducts, DHW, Lights (ER, Z 3)	New	45	3,313,366	0	1,952,586	491	14	0	$0.098	na	1.16	3,510
R-A101	Estar Refrigerator	Replace	12	27,734,007	0	33,277,016	3,915	3,915	-190,554	$0.099	na	0.86	374,784
N-H105	Ducts Indoor, DHW, Lights (HP, Z 1)	New	15	13,901,753	0	13,616,234	2,276	571	0	$0.100	na	1.07	24,095
R-C108	Room AC (Z 2)	Retro	18	688,446	0	594,576	0	271	0	$0.101	na	1.04	17,211
R-W130	Wx (ceiling, floor, wall) HP, Z1	Retro	45	5,812,695	0	3,324,835	556	139	0	$0.101	na	1.17	1,727
N-H103	Window U=.3 (HP, Z 1)	New	45	1,776,622	0	975,923	163	41	0	$0.105	na	1.13	10,364

R-H104	Heat Pump, (ER Base), Z 1	Retro	18	281,241,849	16,433,136	242,160,994	60,934	1,693	0	$0.107	na	0.98	43,268
N-H119	HRV E* (ER Z 2)	New	15	30,297,176	0	27,538,675	4,604	1,154	0	$0.107	na	0.99	15,243
R-W131	Windows U=.30, ER, Z 1	Retro	45	57,765,478	0	27,183,202	6,840	190	0	$0.123	na	0.93	15,881
R-W140	Windows U-.30, HP, Z 2	Retro	45	1,566,283	0	736,320	123	31	0	$0.123	na	0.96	349
R-C104	Room AC (Z 1)	Retro	18	1,169,444	0	758,423	0	346	0	$0.134	na	0.78	29,236
N-H109	HRV, E* (ER Z 1)	New	15	44,844,365	0	32,561,619	8,193	228	0	$0.134	na	0.76	24,095
R-H111	ER> Mini-split ductless heat pump Z1	Retro	15	983,347,469	0	697,848,920	116,660	29,244	0	$0.138	na	0.77	327,782
N-H128	HRV E* (HP Z 3)	New	15	7,255,621	0	4,924,131	823	206	0	$0.144	na	0.74	3,099
N-L107	All LED (from 2020 base) after 2020	New	10	4,024,795	0	3,579,924	421	421	-48,739	$0.157	na	0.50	15,480
N-H112	E* Insulation, Ducts, DHW, Lights (ER, Z 2)	New	45	6,000,154	0	2,163,268	544	15	0	$0.161	na	0.71	5,579
N-L101	E* lighting (18 lamps)	New	7	10,533,302	19,803,371	34,091,056	4,010	4,010	-338,156	$0.163	na	0.49	191,515
R-W133	HRV ER, Z 1	Retro	18	48,779,737	0	23,922,959	6,020	167	0	$0.177	na	0.59	30,174
R-C103	Evaporative Cooling (Direct/indirect) (Z 1)	Retro	18	15,277,903	0	7,215,842	0	3,291	0	$0.184	na	0.57	19,097
R-W132	Windows U-.30, HP, Z 1	Retro	45	16,247,823	0	5,084,064	850	213	0	$0.185	na	0.64	3,695
N-A103	Estar Dishwasher	New	12	886,050	-214,571	326,800	47	40	11,016	$0.185	$1.460	0.51	23,317
N-H120	ER> Mini-split ductless heat pump Z2	New	15	13,552,047	0	6,992,615	1,169	293	0	$0.189	na	0.56	6,588
N-A101	Estar Refrigerator	New	12	30,868,038	0	18,123,563	2,132	2,132	-52,552	$0.196	na	0.43	218,922
R-W139	Windows U=.30, ER, Z 2	Retro	45	21,072,610	0	6,135,475	1,544	43	0	$0.199	na	0.57	7,229
N-H129	HRV E* (ER Z 3)	New	15	18,222,496	0	8,861,677	1,481	371	0	$0.201	na	0.53	10,413
N-H108	HRV, E* (HP Z 1)	New	15	25,647,495	0	12,422,501	2,077	521	0	$0.202	na	0.53	11,282
N-C110	Evaporative Cooling (Direct/indirect) (Z 1)	New	18	9,983,302	0	4,185,202	0	1,909	0	$0.207	na	0.50	12,479

N-H130	ER> Mini-split ductless heat pump Z3	New	15	4,714,985	0	2,141,225	358	90	0	$0.215	na	0.49	2,289
R-D104	Solar hot water heater (50 gal) - Solar Z 2. With electric backup.	Replace	20	192,291,028	0	69,360,243	9,388	29,467	0	$0.226	na	0.43	29,904
R-C105	AC Tune - up (Z 2)	Retro	18	2,634,183	0	977,609	0	446	0	$0.234	na	0.45	17,561
R-W136	Wx (ceiling, floor, wall) ER, Z2	Retro	45	23,856,078	0	5,836,585	1,469	41	0	$0.237	na	0.48	11,377
R-W142	HRV HP Z 2	Retro	18	1,322,639	0	452,267	76	19	0	$0.254	na	0.43	664
R-W141	HRV ER, Z 2	Retro	18	17,794,648	0	5,817,764	1,464	41	0	$0.266	na	0.39	13,736
N-GH124	E* Insulation, Ducts, DHW, Lights (Gas Z 1-2)	New Gas	45	193,996,390	0	9,179,789	2,310	64	4,894,710	$0.270	$1.790	0.42	154,507
N-L104	Add 6 LED lamps (using CFL base) after 2015	New	10	1,253,146	0	603,761	71	71	-8,220	$0.282	na	0.27	26,107
N-L106	Add 16 LED lamps (using CFL base) after 2015	New	10	3,341,723	0	1,569,779	185	185	-21,372	$0.289	na	0.27	26,107
R-C107	Evaporative Cooling (Direct/indirect) (Z 2)	Retro	18	13,768,925	12,875,477	7,762,518	0	3,540	0	$0.298	na	0.35	17,211
N-H117	E* GSHP HSPF 12 (Z 2)	New	15	6,733,956	0	2,126,072	355	89	0	$0.309	na	0.34	464
N-H110	ER> Mini-split ductless heat pump Z1	New	15	13,464,373	0	4,237,870	1,066	30	0	$0.310	na	0.33	6,280
N-D105	Solar hot water heater (50 gal) - With electric backup.	New	20	451,975,148	0	118,822,290	16,083	50,481	0	$0.310	na	0.32	70,289
N-H124	Window U=.3 (ER, Z 3)	New	45	5,102,299	0	941,054	237	7	0	$0.314	na	0.36	10,413
N-H123	Window U=.3 (HP, Z 3)	New	45	2,031,574	0	349,308	58	15	0	$0.337	na	0.35	3,099
R-C101	AC Tune - up (Z 1)	Retro	18	10,461,617	0	2,659,155	0	1,213	0	$0.342	na	0.31	69,744
R-W134	HRV HP Z 1	Retro	18	13,720,384	0	3,457,378	578	145	0	$0.345	na	0.32	7,021
N-C111	Room AC (Z 2)	New	18	2,444,134	0	588,210	0	268	0	$0.361	na	0.29	61,103

N-H127	E* GSHP HSPF 12 (Z 3)	New	15	2,356,885	0	542,083	91	23	0	$0.425	na	0.25	163
N-C113	Evaporative Cooling (Direct/indirect) (Z 2)	New	18	6,346,195	0	1,021,778	0	466	0	$0.540	na	0.19	7,933
N-H107	E* GSHP HSPF 12 (Z 1)	New	15	7,746,628	0	1,363,941	228	57	0	$0.555	na	0.19	534
N-C109	High SEER CAC, (SEER 15) (Z 1)	New	18	100,306,197	0	15,594,389	0	7,112	0	$0.559	na	0.19	143,295
R-C106	High SEER CAC, (SEER 15) (Z 2)	Retro	18	17,780,736	0	2,733,566	0	1,247	0	$0.565	na	0.18	19,756
R-C102	High SEER CAC, (SEER 15) (Z 1)	Retro	18	70,615,915	0	7,247,485	0	3,305	0	$0.847	na	0.12	78,462
N-C112	High SEER CAC, (SEER 15) (Z 2)	New	18	72,547,782	0	4,193,713	0	1,913	0	$1.503	na	0.07	103,640

Note: Includes emerging technology measures

Table 20: Detailed Measure Table, Residential Sector, Gas Savings, and 2027 Technical Potential

Measure Code	Measure Description	Program	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	BCR	No. Units
N-A102	MEF 2.0 Washer	New	12	17,461,607	-59,619,738	19,232,240	2,783	2,331	57,115	-$0.245	-$1.833	100.00	525,952
N-A105	Hi-eff Washer	New	12	9,822,154	-34,334,581	22,067,504	3,194	2,675	1,580	-$0.127	-$0.949	100.00	197,232
R-A102	MEF 2.0 Washer	Replace	12	58,317,215	-66,337,147	41,460,480	6,000	5,025	1,504,550	-$0.017	-$0.130	100.00	516,082
R-GH115	AFUE 90 to hydrocoil combo, Z 3	Retro Gas	45	867,078	0	0	0	0	495,985	na	$0.101	7.46	2,890
R-GH118	AFUE 90 to hydrocoil combo, Z 4	Retro Gas	45	867,078	0	0	0	0	487,244	na	$0.103	7.33	2,890
R-GH112	AFUE 92 to hydrocoil combo, Z 1-2	Retro Gas	45	7,727,005	0	0	0	0	2,292,345	na	$0.195	3.87	25,757
R-GW128	Wx insulation (add walls), Z 4	Retro Gas	45	5,553,700	0	0	0	0	1,535,860	na	$0.209	3.61	4,609
R-GW123	Wx insulation (add walls), Z 3	Retro Gas	45	893,565	0	0	0	0	232,351	na	$0.223	3.39	823
N-GH133	Ducts Indoor, DHW, Lights (Gas Z 3)	New Gas	45	1,648,548	0	8,331	2	0	346,946	$0.041	$0.274	2.76	2,127
R-GW127	Wx insulation (ceiling, floor), Z 4	Retro Gas	45	7,932,359	0	0	0	0	1,659,335	na	$0.277	2.73	3,981
R-GW122	Wx insulation (ceiling, floor), Z 3	Retro Gas	45	1,243,977	0	0	0	0	253,196	na	$0.285	2.65	672
R-GW118	Wx insulation (add walls), Z 1-2	Retro Gas	45	81,407,568	0	0	0	0	16,138,694	na	$0.292	2.59	63,370
R-GH114	Duct Sealing, Z 3	Retro Gas	20	482,224	0	0	0	0	131,969	na	$0.298	2.47	797
N-GH130	Heating upgrade (AFUE 90) (Z 3)	New Gas	15	31,912	0	0	0	0	9,505	na	$0.328	2.25	225
N-GH138	Ducts Indoor, DHW, Lights (Gas Z 4)	New Gas	45	1,957,651	0	15,899	4	0	340,895	$0.050	$0.330	2.29	2,526
R-GH117	Duct Sealing, Z	Retro	20	482,224	0	0	0	0	118,706	na	$0.332	2.23	797

Measure Code	Measure Description	Program	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	BCR	No. Units
	4	Gas											
N-GH128	Ducts Indoor, DHW, Lights (Gas Z 1-2)	New Gas	45	11,155,703	0	1,439,923	362	10	1,570,419	$0.054	$0.361	2.09	14,394
R-GW117	Wx insulation (ceiling, floor), Z 1-2	Retro Gas	45	108,147,695	0	0	0	0	16,349,617	na	$0.383	1.97	53,805
N-GH135	Heating upgrade (AFUE 90) (Z 4)	New Gas	15	31,912	0	0	0	0	7,166	na	$0.435	1.70	225
R-GH124	AFUE 90+ Furnace, Z 4	Replace Gas	18	5,826,518	2,501,729	0	0	0	1,583,456	na	$0.457	1.61	20,768
N-GH132	HRV, E* (Gas Z 3)	New Gas	15	1,858,661	0	0	0	0	388,169	na	$0.468	1.58	6,267
R-GH120	AFUE 90+ Furnace, Z 1-2	Replace Gas	18	49,695,619	20,584,151	0	0	0	12,981,801	na	$0.470	1.56	170,881
N-GH129	E* Insulation, Ducts, DHW, Lights (Gas Z 3)	New Gas	45	25,108,237	0	711,311	179	5	2,956,271	$0.072	$0.475	1.60	18,078
R-GH122	AFUE 90+ Furnace, Z 3	Replace Gas	18	5,826,518	2,501,729	0	0	0	1,517,613	na	$0.477	1.54	20,768
N-GH134	E* Insulation, Ducts, DHW, Lights (Gas Z 4)	New Gas	45	25,108,237	0	5,047,893	1,270	35	2,114,843	$0.076	$0.506	1.50	18,078
N-GH125	Heating upgrade (AFUE 90) (Z 1-2)	New Gas	15	180,024	0	772	0	0	33,765	$0.072	$0.519	1.42	1,200
N-GH137	HRV, E* (Gas Z 4)	New Gas	15	1,858,661	0	0	0	0	292,620	na	$0.620	1.19	6,267
R-GH116	Boiler to Polaris Combo radiant, Z 3	Retro Gas	45	12,717,149	0	0	0	0	1,151,966	na	$0.639	1.18	2,890
R-GH111	Duct Sealing, Z 1-2	Retro Gas	20	4,195,831	0	0	0	0	531,435	na	$0.644	1.15	6,779
R-GH119	Boiler to Polaris Combo radiant, Z 4	Retro Gas	45	12,717,149	0	0	0	0	1,102,216	na	$0.668	1.13	2,890
N-GH139	Tank upgrade (50 gal gas)	New Gas	15	22,590,923	0	0	0	0	3,184,322	na	$0.693	1.01	115,256

Measure Code	Measure Description	Program	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	BCR	No. Units
R-GD110	Tankless Gas heater replace	Replace Gas	20	194,227,189	0	0	0	0	22,860,178	na	$0.693	1.01	246,680
N-GH127	HRV, E* (Gas Z 1-2)	New Gas	15	12,146,439	0	0	0	0	1,700,492	na	$0.697	1.06	40,489
R-A103	Estar Dishwasher	Replace	12	27,139,027	-6,572,160	20,752,498	3,003	2,515	613,245	$0.092	$0.721	1.02	714,185
R-GW130	Window replace (U=.35), Z 4	Replace Gas	45	595,209	0	0	0	0	46,455	na	$0.742	1.02	1,833
N-GD106	Tank upgrade (50 gal gas) Hi Eff Alternative	New Gas	15	33,990,055	0	0	0	0	4,466,269	na	$0.743	0.94	60,838
R-GD111	Tank upgrade (50 gal gas) Hi Eff Alternative	Replace Gas	15	47,731,073	0	0	0	0	6,271,237	na	$0.743	0.94	82,309
R-GW125	Window replace (U=.35), Z 3	Replace Gas	45	96,187	0	0	0	0	7,184	na	$0.775	0.97	331
R-GD112	Upgrade to Navien Tankless Gas heater	Replace Gas	20	34,539,148	0	0	0	0	3,339,127	na	$0.844	0.83	246,680
R-GH123	Duct Sealing and AFUE 90+ , Z 3	Replace Gas	20	6,291,314	994,013	0	0	0	679,479	na	$0.875	0.84	4,056
N-GD109	Upgrade to Navien Tankless Gas heater	New Gas	20	4,045,220	0	0	0	0	371,382	na	$0.889	0.79	27,173
N-GD108	Tankless Gas heater	New Gas	20	29,505,869	0	0	0	0	2,649,341	na	$0.909	0.77	28,315
R-GH125	Duct Sealing and AFUE 90+ , Z 4	Replace Gas	20	6,291,314	994,013	0	0	0	600,793	na	$0.990	0.75	4,056
R-GH113	Boiler to Polaris Combo radiant, Z 1-2	Retro Gas	45	113,329,411	0	0	0	0	6,155,848	na	$1.066	0.71	25,757
R-GW120	Window replace (U=.35), Z 1-2	Replace Gas	45	8,148,680	0	0	0	0	439,749	na	$1.073	0.70	24,970
N-GH131	Window U=.3 (Gas Z 3)	New Gas	45	12,598	0	0	0	0	665	na	$1.097	0.69	70
N-A103	Estar Dishwasher	New	12	4,496,890	-1,088,996	2,582,221	374	313	11,016	$0.146	$1.148	0.64	118,339

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R-GW129	Window, retro (U=.35), Z 4	Retro Gas	45	24,473,983	0	0	0	0	1,192,924	na	$1.188	0.64	5,806
R-GW124	Window, retro (U=.35), Z 3	Retro Gas	45	4,334,273	0	0	0	0	202,650	na	$1.239	0.61	1,144
N-GH136	Window U=.3 (Gas Z 4)	New Gas	45	12,598	0	0	0	0	501	na	$1.456	0.52	70
N-GH126	Window U=.3 (Gas Z 1-2)	New Gas	45	82,326	0	0	0	0	2,924	na	$1.631	0.46	450
R-GW119	Window, retro (U=.35), Z 1-2	Retro Gas	45	312,594,809	0	0	0	0	10,545,249	na	$1.717	0.44	73,577
N-GH124	E* Insulation, Ducts, DHW, Lights (Gas Z 1-2)	New Gas	45	193,996,390	0	9,179,789	2,310	64	4,894,710	$0.270	$1.790	0.42	154,507
R-GD116	Wx Air Sealing, Z 4	Retro Gas	10	1,265,914	0	0	0	0	81,628	na	$2.028	0.37	2,985
R-GH121	Duct Sealing and AFUE 90+ , Z 1-2	Replace Gas	18	54,228,260	7,801,961	0	0	0	2,657,346	na	$2.028	0.39	33,895
R-GD115	Wx Air Sealing, Z 3	Retro Gas	10	118,225	0	0	0	0	7,613	na	$2.031	0.37	278
R-GW131	HRV, Z 4	Retro Gas	18	7,528,368	2,264,546	0	0	0	337,565	na	$2.521	0.29	3,952
R-GW126	HRV, Z 3	Retro Gas	18	1,180,842	382,594	0	0	0	51,845	na	$2.620	0.28	668
R-GW121	HRV, Z 1-2	Retro Gas	36	103,043,753	43,205,669	0	0	0	2,990,284	na	$3.032	0.25	53,801
R-GD114	Wx Air Sealing, Z 1-2	Retro Gas	10	10,898,941	0	0	0	0	452,080	na	$3.153	0.24	25,117
R-GD113	Solar hot water heater (50 gal) - With gas backup.	Replace Gas	20	333,979,814	0	0	0	0	6,065,607	na	$4.493	0.15	51,939
N-GD107	Solar hot water heater (50 gal) - With gas backup.	New Gas	20	65,958,203	0	0	0	0	1,197,906	na	$4.493	0.15	10,272