Technical Appendix O: Cost-Effective Conservation Methodology and Results

Contents

Introduction

The methodology and input parameters defined in this section are used to calculate conservation measure cost-effectiveness relative to the findings of the Ninth Power Plan.[1] The resource strategy (see Chapters 4 and 5) determines the overall conservation target amount and avoided cost. The targets are then used to define the remaining avoided cost components for use in evaluating measure cost-effectiveness. Background material on developing the conservation measures, the supply curves, and most of the cost and benefit components can be found in Technical Appendix H – Conservation Methodology and Potential.

[1] This methodology was developed to reflect the proposed dual target approach to conservation, as proposed in the draft Ninth Power Plan. The topic of a dual versus single target for conservation is an area of ongoing discussion during the public comment process. Should the Council shift towards a single target in the final Power Plan, the methodology will be updated to reflect regional values, as needed.

Method for Determining the Cost-Effectiveness Limit for Conservation

The conservation targets represent the conservation resources needed to meet the Ninth Plan requirement for an adequate, efficient, economical, and reliable power system. The resource strategy and conservation targets are established through optimization modeling that compares both generating and demand-side resources (e.g., conservation, demand response, etc.) against the Northwest's power system needs. The modeling results and interpretation of those results determine the conservation targets consisting of amounts of energy (average megawatts, or aMW) and their associated levelized cost bins. From these target amounts, the specific components of the avoided costs are determined. The avoided costs represent the value of the next available combination of resources from which the target was derived. In this way, the cost-effectiveness for conservation measures is always measured relative to the plan findings. The avoided cost can then be used going forward to calculate benefit cost ratios for new or updated measures.

As conservation measures are reviewed and updated, conservation program managers, the Regional Technical Forum (RTF), and regulators should use the benefit/cost ratio method outlined below to determine cost-effectiveness for measures relative to the Ninth Plan. The RTF will provide clear guidance on cost effectiveness at the measure application level following this methodology and these parameters for the measures it maintains. These should be adopted by Bonneville to meet its cost-effective conservation resource obligations as outlined in Chapter 5.

This method assures that all the costs and benefits are captured, that the time-dependent shape of the savings is accounted for, and that the capacity contribution of the measures is fully considered. This method is also consistent with the approach outlined in the Methodology for Quantifiable Environmental Costs and Benefits appendix (see Technical Appendix C). Individual entities may have differing input values than the ones presented below, given specific needs, but the methodology to estimate these parameters should be consistent. If a measure's benefit-to-cost ratio from this perspective is one or greater, the measure is considered cost-effective relative to the alternative resources defined in the Plan. This ratio is calculated as follows, where all parameters are in constant dollar value:

$$\text{Benefit Cost Ratio} = \frac{\text{NPV(energy + capacity + annual O\&M}_{\text{avoided}} \text{ + other fuel + NEI)}}{\text{NPV(capital cost * (1 + admin) + annual O\&M + other fuel + NEI)}}$$

where NPV is the net present value and

$$\text{energy} = \text{kWh}_{i,bb} * ((\text{MP} + \text{CO2}_{\text{avoided}})_i + \text{RMC}) * (1 + \text{RAC})$$

$$\text{capacity} = \text{kW}_{\text{peak},bb} * (\text{T}_{\text{avoided}} + \text{D}_{\text{avoided}} + \text{R}_{\text{avoided}}) * (1 + \text{RAC})$$

For the energy and capacity formulas above, *i* represents the time segment (e.g., heavy/light load hours, monthly) and *bb* represents busbar. Loss factors of 2.8% for transmission (T) and 4.4% for distribution (D) are included for calculating busbar savings (See Technical Appendix A – Global Assumptions). Note that these values are average losses on the system and are used as inputs to calculate cost effectiveness using the Council's conservation cost-effectiveness calculator, ProCost. However, ProCost uses these values to calculate the marginal line losses[2], which can be much significantly than the average.

The inputs in the benefit cost ratio formula are further defined in Table O - 1 below. In addition to term definitions, the table also outlines whether the inputs are benefits and/or costs, and where the specific values are derived.

Table O - 1: Summary of inputs in the Council's benefit cost calculation for conservation

Term	Definition	Benefit?	Cost?	Value
Capital cost	Incremental measure cost ($) (includes equipment and labor)		X	Measure specific
Admin	Program administration cost adder		X	Varies by sector
Annual O&M	Operations and maintenance costs ($/year)	X	X	Measure specific
NEI	Non-energy impacts ($)	X	X	Measure specific
Other fuel	Non-electric (e.g., natural gas use) impacts ($)	X	X	Measure specific
kWh	Energy saved (in kWh)	X		Measure specific
MP	Market price, from Ninth Plan forecast ($/MWh)	X		Forecast file
RMC	Risk mitigation credit ($/kWh)	X		W: $0.070/kWh E: $0.025/kWh*
kW_{peak}	Power saved during peak periods (kW)	X		Measure specific
$CO2_{avoided}$	Value of avoided carbon ($/MWh)	x		Forecast file
$T_{avoided}$	Deferred transmission capacity credit ($/kW-yr)	X		W: $14.69, E: $4.77*
$D_{avoided}$	Deferred distribution capacity credit ($/kW-yr)	X		W: $24.18, E: $11.71*

[2] Marginal line losses are the line losses incurred by an incremental increase in line loading. Conservation reduces line loading at the margin and therefore avoids these marginal line losses. The Council and RTF have developed a method for calculating time-varying, marginal T&D (line) losses which is used for calculating site-to-busbar impacts for conservation measures. Marginal line losses are independent of core ("iron") line losses and are greater than average resistive line losses. The full methodology can be found in the presentation titled "T&D Losses and Calculations for Energy Efficiency".

Term	Definition	Benefit?	Cost?	Value
$R_{avoided}$	Deferred resource capacity credit ($/kW-yr)	X		$77
RAC	Regional act credit for conservation	X		10%

"Measure Specific" means that the value, if applicable, is unique to each measure
"Forecast File" means that the values for this attribute can be found in the MC_and_Loadshape file.
* Different values for the western (Oregon and Washington) and eastern (Idaho and Montana) parts of the region.

Many of these parameters are included as inputs in the net levelized cost of energy for the conservation supply curves used in the portfolio analysis (See Technical Appendix H). However, several of the parameters are developed based on the results of the plan, including the risk mitigation credit and the deferred resource capacity credit. In addition, a revised market price forecast is produced based on the results of the plan.

Conservation Avoided Cost Components

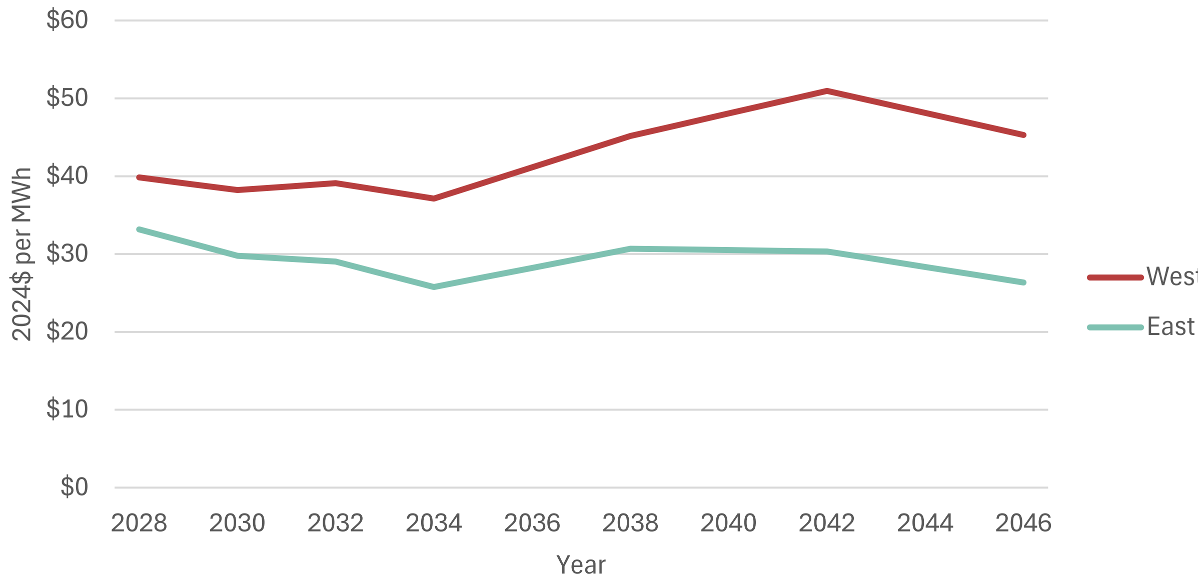
The primary components of the avoided costs of conservation include the market price forecast (MPF), the risk mitigation credit (RMC), the deferred resource capacity credit (DRCC), and the deferred transmission and distribution credits. For the Ninth Plan, these values also differ based on location, so there are two values, or sets of values for each parameter, except for the DRCC. In addition, for the West part of the region, a value for avoided carbon is included.

Market Price Forecast - Value of Avoided Energy

Even though the measure energy savings are known, the total dollar value of these energy benefits is unknown *a priori*; it is determined through the portfolio model findings. The MPF is derived from the resource strategy using the OptGen model. The MPF combined with the conservation savings represents the avoided cost of energy for a given measure. The average market prices of electricity are shown in Figure O - 1.

The figure shows separate MPF estimates for the West side of the region, defined as Oregon and Washington, and the East side, defined as Idaho and Montana. The Council decided to use separate MPF estimates as these were shown to be significantly different.

Figure O - 1: Annual Average Electricity Market Prices from OptGen



Deferred Resource Capacity Credit

The DRCC was a key factor in the 2021 Power Plan (8th Plan), as the models exhibited a high value for conservation during the shoulder hours of each day – just before sunrise and just after sunset. These were considered the "hours of greatest need" when the market prices of electricity were at their highest. The Ninth Power Plan analysis shows a much stronger need for energy at all hours but also shows value for conservation occurring during key hours. The DRCC was developed for the Ninth Plan based on the cost of a simple cycle combustion turbine (SCCT) of $122/kW-yr. The method of calculating the value associated with the annual deferment of the generation implies that the resource purchase is deferred until the end of its life. That means the cost of investing in the resource is temporarily saved. The cost savings are the cost of investing now versus the cost of investing later, which ends up being the difference in the discounted cost stream of the investment over time. The resulting value of $77/kW-yr represents this value of deferring the resource build rather than avoiding it altogether.

The hours where this credit applies is also an input to ProCost. For winter, the hours ending 8, 9, 18, and 19, and for summer hours ending 17, 18, 19, and 20 represent the hours for the DRCC.

Transmission and Distribution System Deferral Credit

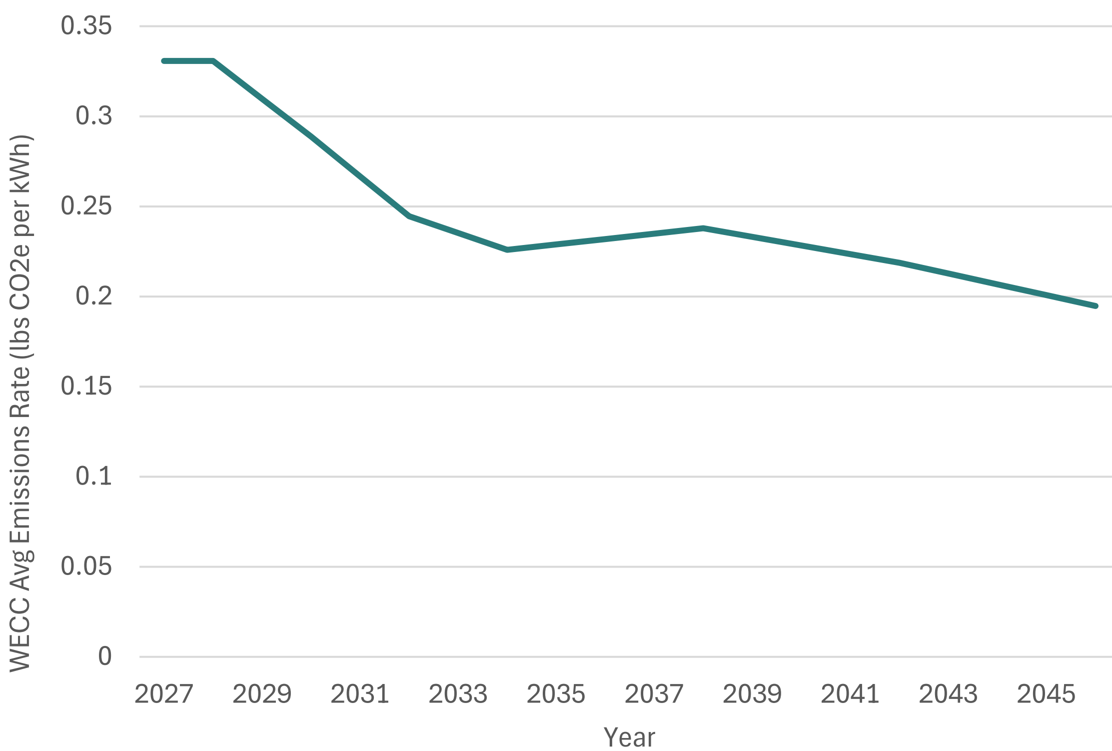
As indicated in Table O - 1, the deferred transmission capacity credit values are $14.69/kW-yr for the West and $4.77/kW-yr for the East portion of the region. The deferred distribution system capacity credit values are $24.18/kW-yr for the West and $11.71/kW-yr for the East. See Technical Appendix A – Global Assumptions for more information on these values.

Value of Avoided Carbon

As discussed in Technical Appendix B – Existing System Parameters and Policies, both Washington and Oregon have policies aimed at decarbonization. This includes the Clean Energy Transformation Act and Climate Commitment Act in Washington, as well as the Clean Energy Targets Bill in Oregon. These policies either directly or indirectly place a high value on avoiding the production of carbon dioxide.

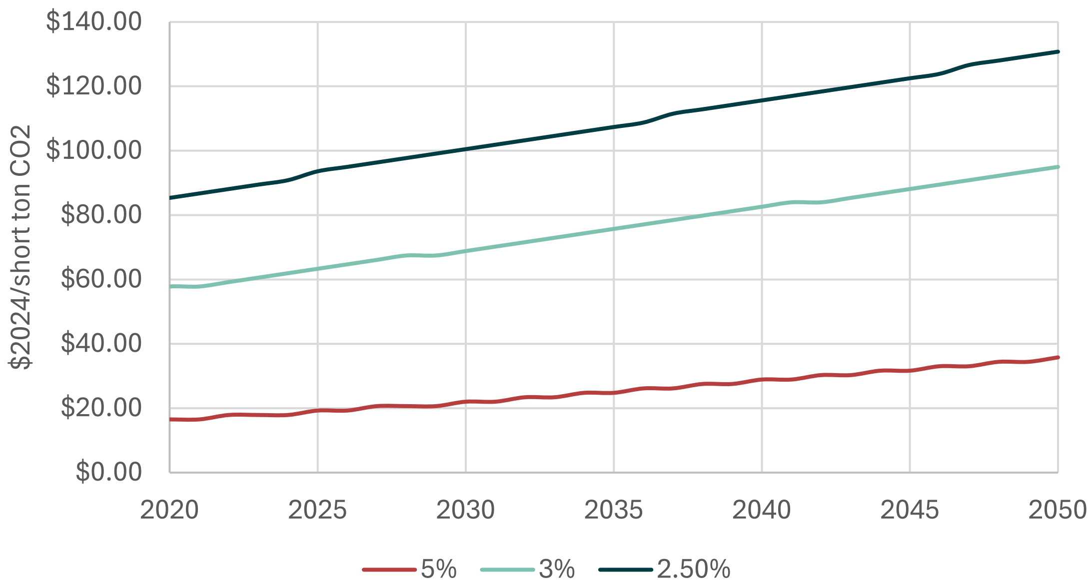
For this reason, the avoided cost of carbon is included in the cost effectiveness framework, but only for the West modeling zones in Oregon and Washington. An avoided cost of carbon for conservation requires two elements: the marginal CO2 emissions rate (lbs/kWh) the conservation is avoiding, and the price ($/lb, or $/ton) of the avoided carbon. Figure O - 2 shows the first element – the estimated marginal CO2 emissions rate. For simplicity, the Council used the overall WECC modeled emissions rate as a proxy of the marginal Northwest emissions rate, as a market purchase is often on the margin.

Figure O - 2: Marginal Carbon Dioxide Emission Rates (lbs/kWh)



For the carbon prices, the Council used the Social Cost of Carbon with the three percent discount rate (see Figure O - 3).[3] These prices, along with the avoided emission rates, were applied to the West portion of the region.

Figure O - 3: Social Cost of CO2 (SC-CO2): 2020 - 2050 (Short Tons)



Risk Mitigation Credit

The RMC is the value of efficiency to avoid a variety of risks. Because the Council assesses a wide range of futures (varying loads, hydro conditions, renewable profiles, temperatures) and multiple scenario analyses, the Council uses the risk mitigation parameter to approximate the value of conservation in reducing risk across all the future unknowns. The Ninth Power Plan clearly indicated that when the system is constrained, the value of conservation increases. The risk mitigation parameter is then estimated to define that added value of conservation. The process for determining this credit value involved the following steps:

1) Calculate the benefit cost ratios (BCRs) of all conservation measures using the above parameters (including the MPF) except the RMC.
2) Sum all the potential for measures with BCRs greater than or equal to 1.0 and compare that potential to the target.
3) If the total is less than the target, then estimate the amount of extra RMC value needed to reach the target.

[3] https://www.epa.gov/sites/default/files/2016-12/documents/sc_co2_tsd_august_2016.pdf.

4) Rerun ProCost with this new RMC value and check the total potential with BCRs ≥ 1.0.

5) Repeat steps 3 and 4 until the new total equals the targets.

For the Ninth Power Plan, the Council found that RMC values of $70 per megawatt-hour ($0.070 per kilowatt-hour) for Washington and Oregon, and $25/MWh ($0.025 per kilowatt-hour) for Idaho and Montana are needed to achieve the targets provided in Chapter 5, the Conservation Program.

Multiple iterations were needed to arrive at the final RMC values. The West value in particular required additional iterations, as there are versions of the supply curves that have additional potential available in Oregon and Washington in futures with higher electrification assumed. Since there is more potential available in the higher electrification futures, it would take a lower RMC to meet the target amount of 860 aMW in a high electrification future and a higher RMC to meet the target amount in a lower electrification future. To account for this, the Council selected an RMC value ($70/MWh) that reached approximately 860 aMW on average across the higher and lower electrification futures.

Cost-Effective Conservation Results

The total cost-effective conservation potential in the region is 1,060 aMW by 2032. This value is the result of two separate targets of 860 aMW for Oregon and Washington (West) and 200 aMW for Idaho and Montana (East) (see Chapters 4 and 5). The breakdown of that potential by year, location, and sector is shown in Figure O - 4.|

Figure O - 4: Cost Effective Potential, by Location, Year, and Sector

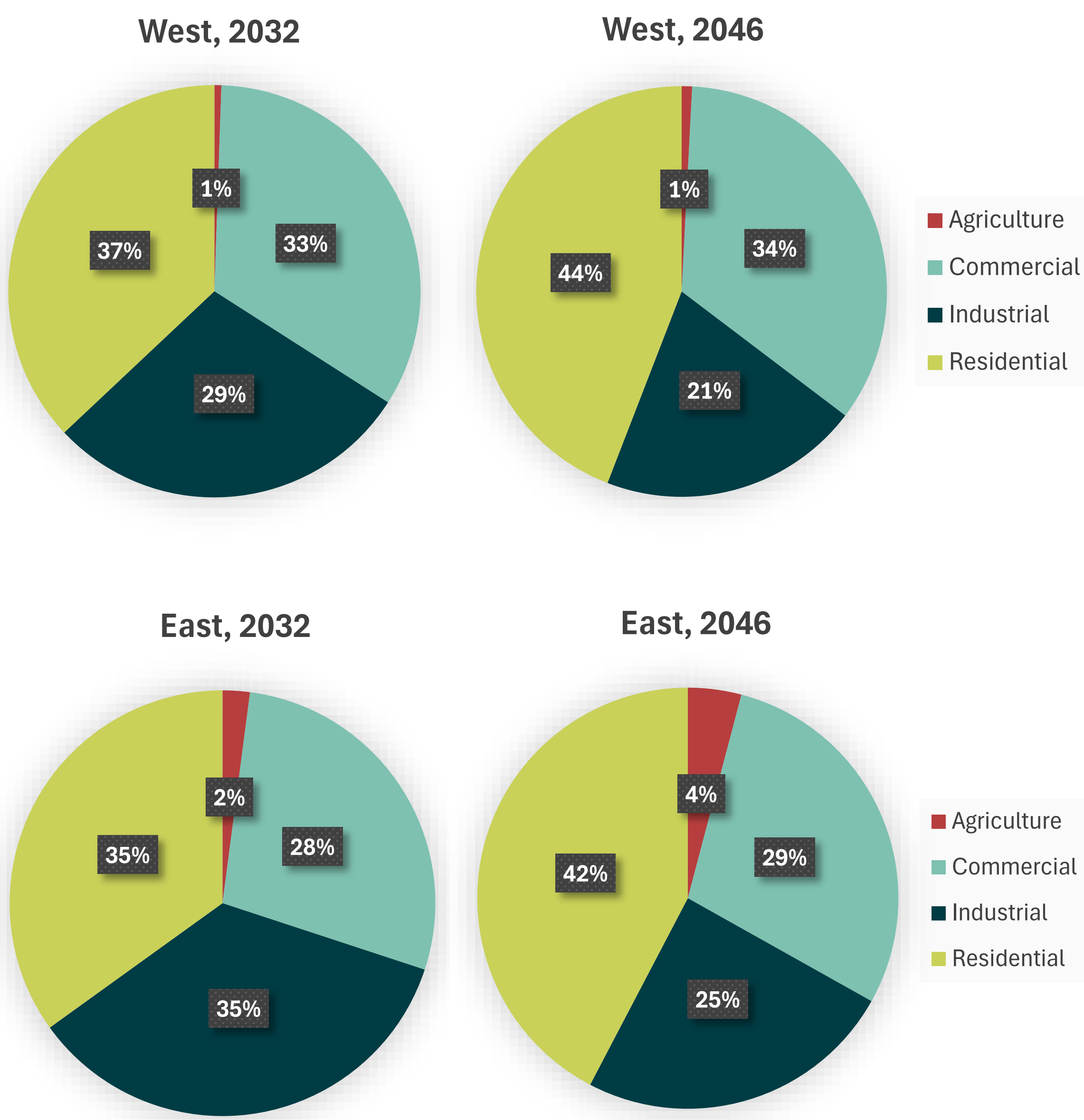


Figure O - 4 exhibits a relatively similar sector breakdown for the East and West parts of the region. For the West, the residential sector shows the largest cost-effective potential (37%) by the end of the Action Plan in 2032, followed by the commercial sector (33%), industrial sector (29%), and agricultural sector (1%). By the end of the Ninth Plan period in 2046, the residential and commercial sector shares grow to 44 and 34% respectively, followed by the industrial sector at 21% and the agricultural sector at 1%.

The East sector breakdown looks relatively similar to the West, with a couple of slight differences. Similar to the West, the East shows the residential sector having the most cost-effective potential by 2046 (42%) and is tied with the industrial sector as having the most potential by 2032 (35%). Unlike the West, the East shows slightly higher industrial cost-effective potential in 2032 (35%) as compared to commercial (28%); however, this rank order shifts by 2046 with an estimated 29% in commercial and 25% in industrial. Unsurprisingly, the East shows a higher amount of agricultural cost-effective potential than the more urban West, with a 2% share in 2032, growing to a 4% share by 2046.

The following sections break down the sector level results further to explore cost effectiveness at the end use and measure levels.

Residential Sector Results

The residential sector holds the largest cost-effective potential in the region, accounting for nearly 400 aMW by 2032 and growing to nearly 1,600 aMW by 2046.

Table O - 2 shows how the cost-effective residential sector potential breaks down by end use for the West (Oregon and Washington) by 2032 and 2046. By 2032, HVAC is the end use with the largest cost-effective potential (at 38% of the total), followed by water heating (20%), electronics (20%), and dryers (8%). By 2046, water heating grows to the largest end use at 31%, followed by HVAC at 22%, dryers at 20%, and electronics (15%).

Table O - 2: Residential Cost-Effective Potential by End Use, West (OR and WA)

End Use	2032	2046
HVAC	38%	22%
Water Heating	30%	31%
Electronics	20%	15%
Dryer	8%	20%
Refrigeration	3%	4%
Vehicle	2%	8%
Food Preparation	0%	0%
Grand Total	**100%**	**100%**

In 2032, various weatherization measures, including envelope insulation, efficient storm windows, and air sealing make up the majority of HVAC savings (60% of the total), followed by heat pump retro-commissioning and upgrades (27%), and duct sealing (12%). By 2046, the largest HVAC cost-effective savings shift to heat pump retro-commissioning and upgrades (46%), followed by weatherization measures (38%), and duct sealing (11%). For water heating, the vast majority of energy savings (~90%) in both 2032 and 2046 are attributable to heat pump water heaters, with the remainder coming from thermostatic shower restriction valves and efficient portable spas. For electronics, most savings come from efficient TVs (~50%), followed by efficient clothes washers (~30%), and efficient computers.

Similarly, Table O - 3 shows how the cost-effective residential sector potential breaks down by end use for the East (Idaho and Montana) by 2032 and 2046. While the top three end uses categories for the East – water heating, electronics, and HVAC – are the same as those of the West, some differences can be observed. For example, the share of HVAC savings in the East is significantly lower than that of the West; however, water heating and electronics (appliance) savings are higher.

Table O - 3: Residential Cost-Effective Potential by End Use, East (ID and MT)

End Use	2032	2046
Water Heating	31%	36%
Electronics	23%	19%
HVAC	21%	10%
Vehicle	15%	11%
Dryer	8%	22%
Refrigeration	1%	2%
Food Preparation	0%	0%
Grand Total	**100%**	**100%**

In terms of measure savings, the make-up of the underlying measures for the East within end use categories is relatively similar to that of the West. For example, the majority of cost-effective HVAC savings in 2032 is made up by weatherization measures (63%), followed by heat pump retro-commissioning (14%), and duct sealing (21%). Heat pump water heaters significantly dominate water heating cost-effective potential (at approximately 90%), and electronics savings again are predominantly televisions (~40%), clothes washers (~25%), and computers.

Commercial Sector Results

The commercial sector accounts for the next largest cost-effective potential in the region, totaling nearly 350 aMW of potential by 2032 and growing to just over 1,200 aMW of potential by 2046.

Table O - 4 shows how the cost-effective commercial sector potential breaks down by end use for the West by 2032 and 2046. Similar to the residential sector, HVAC represents the end use with the largest cost-effective potential by 2032 (49%) and 2046 (62%). The largest portion of this cost-effective HVAC savings is associated with variable refrigerant systems with very high efficiency dedicated outside air (VRF with VHE DOAS), followed by window upgrades, heat recovery ventilation (HRV), and high efficiency fans. Refrigeration represents the end use with the next largest potential, at least in the nearer term, accounting for 12% of cost-effective savings by 2032 and 7% of savings by 2046. This end use is entirely made up of efficient upgrades to refrigeration equipment in grocery applications. Beyond HVAC and refrigeration, other significant end uses include:

- whole building, primarily representing strategic energy management (SEM);

- electronics, including efficient servers, computers, and televisions;
- lighting, primarily representing the addition of advanced controls;
- water heating, dominated mostly by heat pump water heaters and circulator pumps; and
- vehicles, represented by engine block heater controls.

Table O - 4: Commercial Cost-Effective Potential by End Use, West (OR and WA)

End Use	2032	2046
HVAC	49%	62%
Refrigeration	12%	7%
Whole Building	10%	5%
Electronics	9%	3%
Lighting	9%	8%
Water Heating	4%	5%
Vehicles	4%	3%
Motors/Drives	2%	3%
Food Preparation	1%	2%
Appliances	1%	2%
Compressed Air	0%	1%
Other	0%	0%
Grand Total	**100%**	**100%**

Similarly, Table O - 5 shows how the cost-effective commercial sector potential breaks down by end use for the East by 2032 and 2046. The East end use breakdown is largely similar to the West breakdown, with cost-effective HVAC savings dominating the total, with 45% of the total savings by 2032 and 57% by 2046. The measures underlying these savings are also similar, with VHE-DOAS, windows, and HRV accounting for the top three individual measures. Aside from HVAC, the top end uses for the East side are largely similar to the West, with the next largest end uses being a mix of electronics, whole building, lighting, and refrigeration. Refrigeration savings are not quite as significant in the East (9% versus 12% for the West), but still within the top five end uses. The measures underlying the end use categories are also similar to the West, with some cost-effective applications of SEM, heat pump water heaters, efficient servers and computers, advanced lighting controls, and engine block heater controls.

Table O - 5: Commercial Cost-Effective Potential by End Use, East (ID and MT)

End Use	2032	2046
HVAC	45%	57%
Electronics	12%	5%
Whole Building	10%	5%
Lighting	10%	10%
Refrigeration	9%	5%
Vehicles	7%	5%
Water Heating	3%	4%
Food Preparation	2%	3%
Motors/Drives	2%	3%
Appliances	1%	2%
Other	0%	0%
Compressed Air	0%	0%
Grand Total	**100%**	**100%**

In comparing the differences between the East and West cost-effectiveness, it is often the case that if a given measure category is cost-effective in the West it is also cost-effective in the East; however, the difference is often how many applications of the measure are cost-effective. For example, of the approximately 600 individual applications of VHE-DOAS, about 85% are cost-effective in the West versus about 33% in the East. Therefore, both locations have cost-effective applications of VHE-DOAS, but the West has more applications crossing the cost-effectiveness threshold.

Industrial Sector Results

The sector accounting for the next largest cost-effective potential in the region is the industrial sector, totaling just over 300 aMW by 2032 and growing to nearly 800 aMW by 2046.

Table O - 6 shows how the cost-effective industrial sector potential breaks down by end use for the West by 2032 and 2046. Unlike the residential and commercial sectors, HVAC is not the end use with the largest potential, largely driven by the fact that heating and cooling tends to be a smaller fraction of energy use in industrial facilities than commercial buildings and residences. For industrial, the largest cost-effective savings potential is found in whole building measures, which is predominantly strategic energy management (SEM). SEM, a method of continuously tracking and reducing overall facility energy usage over time, accounts for approximately half of industrial energy savings potential by 2032 and nearly a third by 2046. HVAC accounts for the next largest end use, accounting for about 10% of the cost-effective industrial potential. This potential is made up by more efficient heating via heat pumps and higher efficiency mechanical cooling.

Table O - 6: Industrial Cost-Effective Potential by End Use, West (OR and WA)

End Use	2032	2046
Whole Building	49%	31%
HVAC	10%	7%
Pumps	9%	15%
Compressed Air	9%	12%
Fans and Blowers	7%	11%
Refrigeration	7%	7%
Material Processing	5%	11%
Lighting	3%	4%
Other Motors	1%	1%
Material Handling	0%	1%
Grand Total	**100%**	**100%**

The next highest potential end uses in industrial are generally considered end uses centered around "motors and drives" – pumps, compressed air, and fans are all highly tied to motor and motor system efficiency. Collectively, these motor and drive system measures account for over a third of the total cost-effective potential.

The cost-effective industrial breakdown by end use for the East is show in Table O - 7, and again, the overall distribution is very similar to that of the West. Whole building measures, such as SEM, account for the highest share of savings, by a wide margin, followed by HVAC, motor and drive end uses, and refrigeration. A couple of individual industrial measures are found to be cost-effective in the West but not in the East. These include fast-acting doors in refrigerated warehouses and "industrial heat pumps," or heat pumps used for process loads rather than space conditioning.

Table O - 7: Industrial Cost-Effective Potential by End Use, East (ID and MT)

End Use	2032	2046
Whole Building	55%	38%
HVAC	11%	8%
Pumps	8%	15%
Fans and Blowers	7%	11%
Compressed Air	7%	10%
Refrigeration	6%	7%
Lighting	3%	4%
Material Processing	2%	5%

End Use	2032	2046
Material Handling	0%	1%
Other Motors	0%	0%
Grand Total	**100%**	**100%**

Agricultural Sector Results

The final sector, agriculture, has the smallest savings potential primarily due to its locational nature. While there are homes and business scattered in every corner of the region, the bulk of the agricultural area in the region is located primarily in eastern Oregon/ Washington and Idaho. In total, the Ninth Plan includes about 10 aMW of cost-effective agriculture potential by 2032 and just over 50 aMW of potential by 2046.

The end use breakdown for cost-effective agriculture potential for the West and East parts of the region is shown in Table O - 8 and Table O - 9 below. In both cases, irrigation accounts for the vast majority of energy savings potential, accounting for between 75 and 90% of all savings across the region and over the Plan period. Cost-effective irrigation measures include hardware upgrades for various types of irrigation systems, such as pivots, linear systems, and wheel and hand-lines. Other cost-effective irrigation measures include efficient irrigation pump motor replacements and advanced irrigation management – a suite of tools to optimize crop irrigation levels.

Table O - 8: Agricultural Cost-Effective Potential by End Use, West (OR and WA)

End Use	2032	2046
Irrigation	87%	75%
Lighting	5%	3%
Refrigeration	4%	4%
HVAC	2%	17%
Motors/Drives	1%	1%
Process Loads	1%	1%
Grand Total	**100%**	**100%**

Aside from irrigation, the next largest end uses for savings potential include lighting, refrigeration, motors and drives, and HVAC. Most of the refrigeration, HVAC, and non-irrigation pump motor savings are tied to the dairy industry, including measures for refrigeration heat recovery, variable-speed drives on milk transfer pumps, and more efficient ventilation fans in dairy operations.

Table O - 9: Agricultural Cost-Effective Potential by End Use, East (ID and MT)

End Use	2032	2046
Irrigation	83%	81%
Refrigeration	9%	8%
Motors/Drives	3%	3%
Lighting	3%	1%
HVAC	2%	5%
Process Loads	0%	1%
Grand Total	**100%**	**100%**

Distribution System Results

The distribution system efficiency, specifically conservation voltage reduction (CVR), was modeled differently in the Ninth Plan than in previous plans. The Council developed measures for the conservation supply curves and separately developed a demand response product (demand voltage reduction, or DVR) that was included in the DR supply curve. However, including both CVR and DVR could potentially double-count the same resource; therefore, the Council decided to input the resource only as DVR, and allow it to run whenever the model preferred. This way, the model could choose the optimum mode of operation; either CVR (running all the time) or DVR (running intermittently). While the model generally showed a preference for CVR in the Action Plan period, the Council recognizes that utilities may have their own unique needs, and therefore recommends utilities pursue this resource in whatever form provides the most value for their system (see Chapter 4 – Action Plan for more details).