APPENDIX G: CONSERVATION RESOURCES AND DIRECT APPLICATION RENEWABLES

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List of Figures and Tables

OVERVIEW

This appendix provides an overview of the general methodology used by the Council for estimating the conservation resource potential in the region and describes the major sources of information used to prepare that analysis. It also provides a description of the spreadsheet workbooks containing the detailed input assumptions and specific source data used for each of the measures in the Council's conservation supply curves. The workbooks are available on the Council's Seventh Power Plan web site http://www.nwcouncil.org/energy/powerplan/7/technical.

The Council structures this work by examining many conservation measures. A conservation "measure" is any device or method that results in electricity savings compared with its baseline. The Council estimates costs and savings for over 1,600 measure permutations.[1] These costs and savings, coupled with savings shape over time, capacity impacts, and estimates of the possible pace of deployment, are used to develop supply curves of conservation potential available by year. The supply curves represent the amount, daily and seasonal shape, and capacity characteristics of conservation available at different cost levels by year. Costs are expressed as TRC (Total Resource Cost) net levelized costs, in 2012 dollars, so they can be compared to the costs of power purchases and the costs of new resource development.[2] The Council uses an in-house model called ProCost to calculate measure-level TRC net levelized cost, estimate the hourly, daily and seasonal savings, and identify capacity impact of efficiency measures. The levelized cost and savings potential amount, by season and year, and the capacity impacts are inputs to the Regional Portfolio Model.

The Regional Portfolio Model determines the amount of energy efficiency to be developed to achieve least-cost and least-risk adequate electric system for the region. Findings from the Regional Portfolio Model include year-by-year conservation development goals, expressed in average megawatts of energy, to achieve a least-cost and least-risk system. Regional Portfolio Model findings are also used to establish conservation cost-effectiveness methodologies to guide conservation program development. The methodology for cost-effectiveness is based on a benefit-to-cost ratio rather than a levelized cost. The benefit-to-cost ratio provides a means to assure that both the shaped energy and capacity savings of the measures are taken into account.

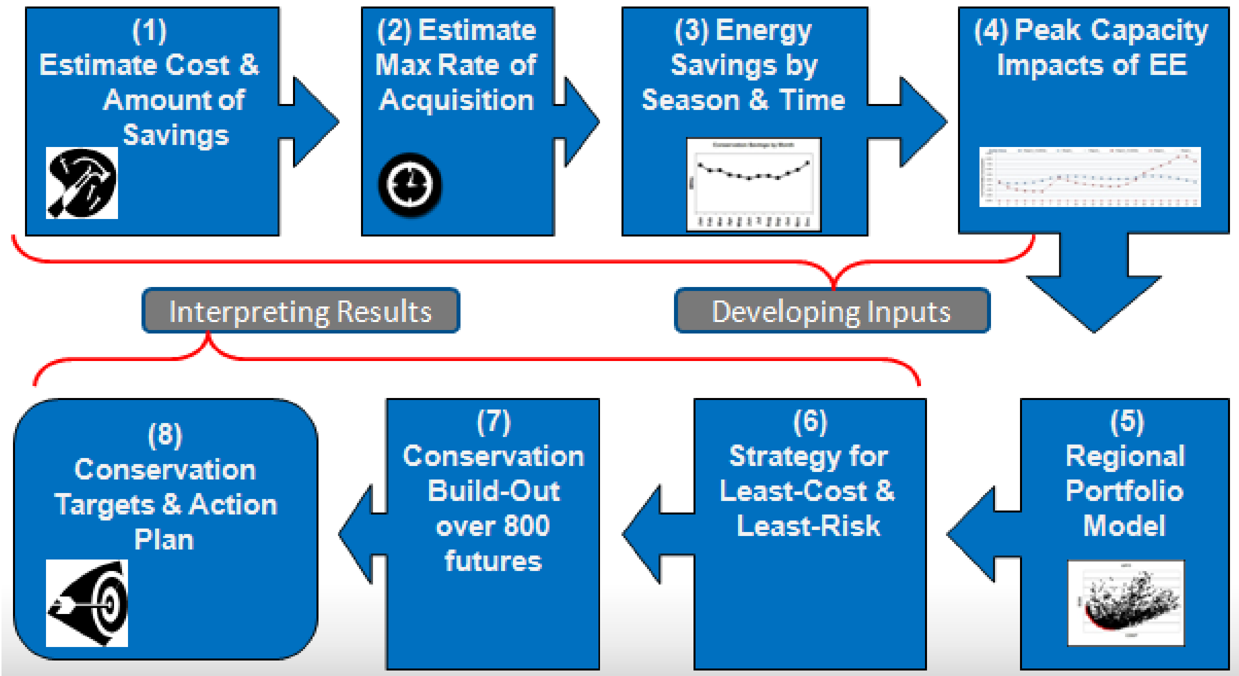
Figure G - 1 describes the overall process. The first tier of Figure G - 1 includes the development of inputs for the conservation assessment which is the subject of this appendix.

[1] A measure permutation includes different applications and different efficiencies for a given measure. For example, a 1.5 GPM showerhead in single family homes with electric water heating is a unique permutation for the low-flow showerhead measure. Other measure permutations would change the segment (multifamily, manufactured), the flow-rate of the showerhead (1.0 GPM), or the water heater type (heat pump water heater).

[2] "TRC Net Levelized Cost" is computed based on all costs minus all benefits regardless of which sponsor incurs the cost or accrues the benefits. TRC Net Levelized Cost includes all applicable costs and all benefits. In addition to energy system costs and benefits, TRC Net Levelized Cost includes non-energy, other-fuel, O&M, periodic-replacement and risk-mitigation benefits and costs. TRC Net Levelized Cost corresponds to TRC B/C ratios with regard to the costs and benefits included. Benefits are subtracted from costs, and then levelized over the life of the program.

The second tier of Figure G - 1 describes the analysis and process to set the conservation targets for the region. That analysis is described in Chapter 15 and Appendix L.

Figure G - 1: Overview of Council Conservation Analysis and Methodology

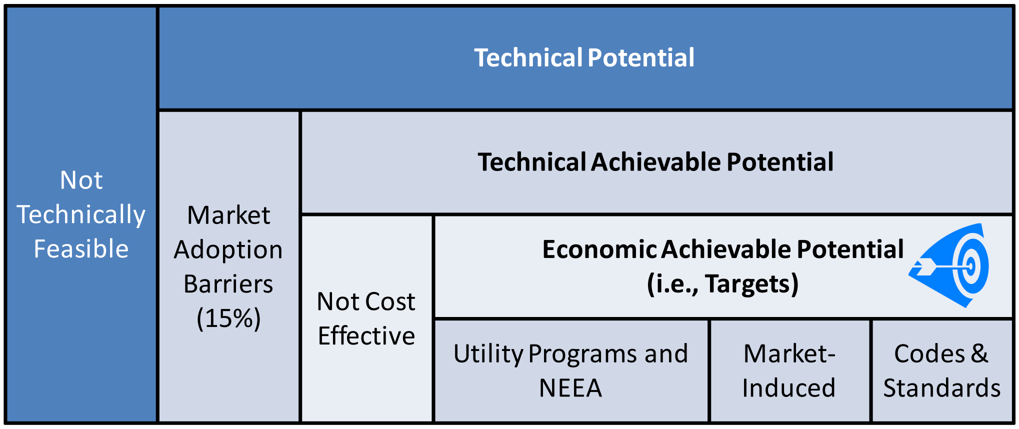


The following sections describe the "global" inputs and methodology used by the Council in its assessment of regional conservation resource potential. Later the appendix describes the conservation cost-effectiveness methodology.

GENERAL CONSERVATION RESOURCE METHODOLOGY

The three types of conservation resource potential considered are Technical Potential, Technical Achievable Potential, and Economic Achievable Potential. An illustrative description of what each represents and their interrelationship is provided in Figure G - 2.

Figure G - 2: Types of Conservation Potential

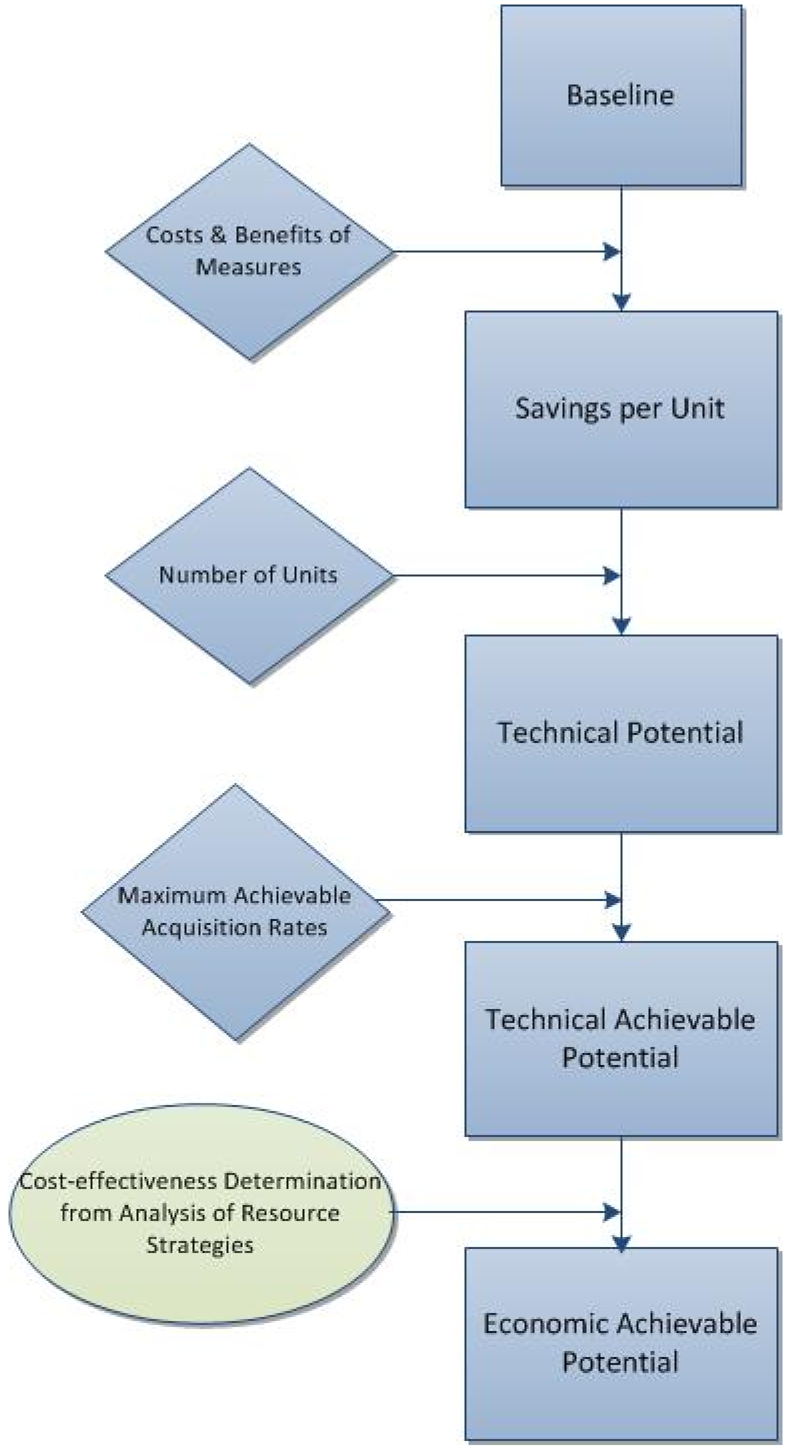


Adapted from the National Action Plan for Energy Efficiency[3]

The general methodology for developing the potential is considered a bottom-up method. This means that the total regional potential estimates are built up from individual conservation measures (e.g., efficient light bulbs, motors, refrigerators) multiplied by the number of applicable units in the region. These are then summed by bundle, category, and sector to reach the total regional conservation potential. The overall steps for estimating the different types of potential are illustrated in Figure G - 3. Note that the industrial sector uses a different (top-down) method; see the Industrial Sector section for more information.

[3] National Action Plan for Energy Efficiency (2007). *Guide for Conducting Energy Efficiency Potential Studies*. Prepared by Philip Mosenthal and Jeffrey Loiter, Optimal Energy, Inc. <www.epa.gov/eeactionplan>

Figure G - 3: General Methodology to Estimating Potential



Each of these components will be discussed further below.

Baseline

The “baseline” refers to the conditions of the electricity-using buildings, systems, and devices at the start of the plan. For conservation, the baseline is what the energy efficiency is measured against. The baseline estimate is a critical factor in determining both energy savings and forecast energy demand. The Council uses a frozen efficiency baseline forecast described in Chapter 7. Estimates of current market conditions and characteristics of the building stock come from several sources. Key among these are the residential, commercial, and industrial stock assessments completed by the Northwest Energy Efficiency Alliance (NEEA), selected studies from utilities, Bonneville, Energy Trust of Oregon, and other sources.

For new and replacement equipment, baseline conditions are the more efficient of either (1) minimum applicable code or standard or (2) market conditions at the start of the planning period. State building codes and federal and state standards for equipment are continually being upgraded. The baseline assumptions codes and standards used in the Seventh Power Plan are those that were adopted at the end of 2014, with few exceptions. Some of these include standards that were adopted before the end of 2014, but with effective dates that occur in the future. For such codes or standards, both savings estimates and the demand forecast reflect the effective dates of adopted standards. If current market practice is more efficient than code, baselines are generally estimated using the average efficiency as typically taken from available sales data. Lacking sales data, other sources are used such as retail stocking data (such as the California Energy Commission appliance database), ENERGY STAR market share data, distributor sales data, and store shelf surveys. The Council estimates current market practice as of the beginning of 2016. Cost data are from utility program data, US DOE National Impact Assessment workbooks, or on-line retail stores. There is a baseline assumption for each measure in the Council analysis. These baseline assumptions are described in the measure workbooks.

Units

Coupled with the baseline efficiencies are the counts of buildings/systems/devices. In all cases, the number of units is tied to the demand forecast. In development of the forecast (see Chapter 7), the Council projects the total number of units (e.g. households, by state and segment, or commercial square feet, by state and segment) over the 20-year planning horizon. These quantities, multiplied by the saturations and electric fuel shares, give the total number of units available. For example, the number of refrigerators is equal to the number of households times the average number of refrigerators per home. Within the sector-specific sections below, more details are provided on the sources for number of units.

Technical Potential

Technical potential is the amount of conservation that is technically feasible. It considers conservation measures and the number of these measures that could physically be installed, without regard to achievability or cost. It can be viewed as the upper limit of what conservation potential is available.

A conservation “measure” is any device or method that results in electricity savings compared with its baseline. The Power Act defines conservation as “any reduction in electric power consumption as a result of increases in the efficiency of energy use, production, or distribution”.[4] For a measure to constitute conservation under the Act, it has to meet both parts of the definition. That is, the measure must reduce electric power consumption and the reduced consumption must result from an increase in the efficiency of energy use, production, or distribution. A measure that does just one or the other – for example, reduce electricity consumption but not through an efficiency increase – does not qualify as “conservation” under the Act.

Measures are identified from the range of measures currently in utility programs, as well as a broad search of utility potential assessments, emerging technology research, and input from local, regional, and national experts. Once the measures are identified, Council staff seeks to identify adequate and reliable savings and cost data. Costs and savings are based both on engineering estimates, as well as estimates based on results from the operation of existing programs. Note that although the Council included a wide-ranging list of measures, no conservation assessment can include *all* efficiency measures that could be installed. Some measures were passed over due to lack of data or resources at the time of the supply curve development. The Council believes these omissions do not significantly impact results. A list of known missing measures is provided as part of the discussion about each sector. Also, as described in Chapter 12, there are additional measures only included in the emerging technology scenario, as the Council does not yet consider them currently available and reliable. If a measure is not in the Seventh Power Plan, this does not preclude program administrators from providing incentives for such a measure.

The efficiency measures are grouped into three bundles: new, natural replacement, and retrofit applications. There are three reasons to distinguish these application modes. First, costs and savings can be different by application mode. Second, in the case of new and natural replacement, the available stock for the measure depends on the forecast of new additions and replacement rate for equipment. These opportunities are tracked separately over course of the forecast period and limit the annual availability of conservation opportunities. Third, the Council’s portfolio model treats new and natural replacement applications as lost-opportunity measures that can only be captured at the time of construction or natural replacement.

Measure costs, savings, applicability, and achievability estimates are identified separately for each of the new, natural replacement, and retrofit application modes. The Council analyzes measure costs and savings on an incremental basis. Measure cost is the incremental cost over what would be done absent the measure or program. The same is true for savings. Incremental measure costs and savings can be different depending on the application mode. For example, incremental costs of high performance windows in a new application only include the additional cost of the windows required by code. In a retrofit application, the labor cost of removing and replacing the existing window are added to the measure cost.

[4] Northwest Power Act,§3(3), 94 Stat. 2698.

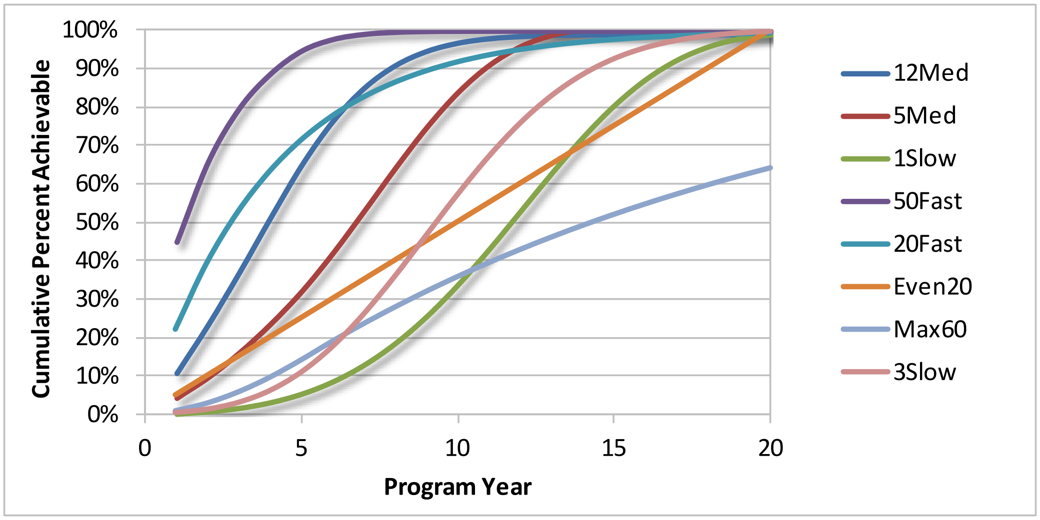
Measure applicability reflects two major components: technical applicability and measure saturation. First is the technical applicability of a measure. Technical applicability includes what fraction of the stock the measure applies to. Technical applicability can be composed of several factors. These include the fraction of stock that the measure applies to, overlap with mutually exclusive measures, and the existing saturation of the measure. Existing measure saturation reflects the fraction of the applicable stock that has already adopted the measure and for which savings estimates do not apply. When the baseline is equivalent to the average market conditions, then the measure saturation is set to zero.

Technical Achievable Potential

The Council assumes that only a portion of the technically available conservation can be achieved. Ultimate achievability factors are limited to 85 percent of the technically available conservation over the twenty-year forecast period.[5] In addition to a limit of 85 percent, the Council estimates near-term achievable penetration rates for bundles of conservation measures. For these estimates, conservation measures are bundled based on the characteristics of the measures and consideration of the likely delivery mechanisms. In the Seventh Power Plan, the Council uses a suite of typical ramp rates to reflect penetration rates, illustrated in Figure G - 4. For example, measures involving emerging technology might start out at low penetration rates and gradually increase to 85 percent penetration. Measures suitable for implementation by a building code or a federal equipment standard might increase rapidly to 85 percent penetration in new buildings and major remodels. Measures requiring new delivery mechanisms might ramp up slowly. Simple measures with well-established delivery channels, like efficient showerheads, might take only half a dozen years to fully implement. Whereas retrofit measures in complex markets might take 20 years to reach full penetration. The Council also considers region wide conservation program accomplishments when developing these ramp rates to help align early year potential with recent historic accomplishments. Assumptions for the ramp rates applied to each measure are detailed in the conservation supply curve workbooks described by sector below.

[5] See http://www.nwcouncil.org/reports/2007/2007-13/ for more information on the source of 85%.

Figure G - 4: Suite of Ramp Rates



Cost and Benefits of Conservation Resources

The Council estimates the cost and benefits of conservation by measure. The Council's analysis attempts to include all quantifiable costs of conservation measures including capital costs, labor and markup, finance costs maintenance, operations-fuel, non-energy consumables, other quantifiable non-energy costs, and program administrative costs. The net cost is the total cost of the measure less any non-electric impacts. Costs represent an increase in the required financial commitment relative to the baseline and are expressed as positive incremental effects. Benefits represent a reduction in the required financial commitment and are expressed as negative incremental effects.

Costs and non-electric impacts are tallied regardless of which sponsors incurs these costs or accrues the benefits. The details of the inputs are provided here. The following section provides an overview of the calculation methodology and ProCost, the tool used by the Council to estimate TRC net levelized cost.

Calculating Levelized Cost

The Council uses a levelized cost to compare conservation resources to supply resources. There are many definitions of levelized cost depending on what components are included. The Council uses the total resource net levelized cost (TRC net levelized cost) for its analysis of the cost of conservation measures, which is similar to the Societal Cost Test outlined in the National Action Plan for Energy Efficiency and the California Standard Practice Manual.[6] This includes all of the costs and benefits described in the following sections to reflect the full cost of the measures, regardless of who is paying the costs. ProCost is the tool the Council uses to calculate the TRC net levelized cost for conservation measures.

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[6] http://www.epa.gov/cleanenergy/documents/suca/cost-effectiveness.pdf and http://www.cpuc.ca.gov/NR/rdonlyres/004ABF9D-027C-4BE1-9AE1-CE56ADF8DADC/0/CPUC_STANDARD_PRACTICE_MANUAL.pdf

The primary components of the TRC net levelized cost are the net present value (NPV) of the measure costs divided by the annual savings of the measure. Economic costs and benefits are converted to present value costs and benefits based the financing costs, sponsor cost shares, and discount rates. ProCost uses standard capital recovery factors and present value (PV) factors to calculate PV costs and benefits. Finance costs use sponsor-specific interest rates and terms as assigned by user input to calculate PV of capital costs of measures. Annual costs and benefits that are not financed are counted in the years they occur and discounted to present values using standard present value factors and the global discount rate of 4 percent used in all Council analysis for the Seventh Plan.

ProCost sums all of the present value costs and nets out benefits. This net present value is then amortized over the life of the program (20 years) using standard capital recovery factors and the discount rate. The resulting annual "levelized" cost is divided by the discounted annual energy savings adjusted for transmission and distribution line losses to produce a levelized cost per unit energy saved in dollars per kWh.

The TRC net levelized costs are all costs minus all benefits regardless of which sponsor incurs the cost or accrues the benefits. In addition to energy system costs and benefits, TRC net levelized cost includes non-energy, program administration, other-fuel, O&M, periodic-replacement benefits and costs. The ten percent Regional Act Credit is taken into consideration in the Regional Portfolio Model and thus not included in the TRC net levelized costs uses in the supply curve inputs. The costs and benefits included in the Seventh Power Plan are summarized on Table G - 1. Each of these parameters is discussed in the following sections.

Table G - 1: TRC Net Levelized Cost Components

Costs Included	Benefits Netted Out
Capital & Labor	Deferred T & D Expansion
Annual O&M	Regional Act Credit*
Program Administration	Deferred Generation Capacity Investment**
Periodic Replacement	Avoided Periodic Replacement
Other Fuel Costs	Other Fuel Benefits
Non-Energy Impacts	Non-Energy Impacts

*The 10 percent advantage for conservation in the Northwest Power Act is accounted for when comparing conservation and other resources in the RPM rather than in the levelized cost of conservation.

** The value of deferred generation capacity is determined as part of the RPM analysis and is not included as part of the levelized cost input to the RPM analysis.

Cost of Conservation

The cost of conservation, as described above, is based on the incremental cost of the measure compared to the baseline case. The Council also includes a programmatic administration cost, approximated at 20 percent of the incremental cost. In addition to those up-front costs, a measure may have on-going operation and maintenance (O&M) costs (or benefits) compared to the baseline. For example, a heat pump water heater has maintenance costs to clean filters and discharge condensate compared to an electric resistance water heater. There may also be periodic replacement costs (or benefits) compared to the baseline. An example of the periodic replacement cost is the replacement of system component that was not present in the baseline system, like a compressor in a heat pump heating system that replaces an electric baseboard heating system. There may also be other fuel costs, such as additional gas heating required when high-efficiency lighting (that produces less waste heat) is installed. Finally, other quantifiable non-energy costs are also included in the cost calculation if they can be sufficiently quantified. For example, an evaporative cooler might require significant water consumption and associated water costs compared to a vapor-compression system.

Financial Input Assumptions

The present value cost of conservation is determined in part by who pays for it and how it is financed. The Regional Technical Forum (RTF) was asked to provide recommendations on the anticipated "cost-sharing" between utilities and consumers. Staff also developed estimates of the cost of capital and equity used to pay for conservation based on the mix of consumers in each of the major sectors. These costs shares and finance costs are applied to each cost source for each measure at the time they are incurred. .

Table G - 2 through Table G - 6 show the financial assumptions used in the economic analysis of conservation opportunities in each of the five major economic sectors. Each sector table also provides the utility financial assumptions, where the portion of the initial capital cost is shared between the customer, the wholesale electric provider, the retail electric provider, and the natural gas utility. For the Seventh Power Plan, the Council assumes the natural gas utility will not bear any portion of the cost, but is included for completeness. The analysis assumes that end use customers directly pay 35 percent of measure capital cost and all of measure operational and maintenance costs. The cost of capital varies for among residential, commercial, and industrial customers. Financial life is the term over which a sponsor's share of capital cost is financed. A financial life of one year indicates that portion is expensed, rather than financed. For the Seventh Power Plan, the Council assumed the portion of capital cost paid by Bonneville, the wholesale utility, as well as retail utilities do not finance conservation investments, but expense them each year.

Table G - 2: Residential Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	4.3%	4.39%	5.33%	5.45%
Financial Life (years)	12	1	1	1
Sponsor Share of Initial Capital Cost	35%	20%	46%	0%
Sponsor Share of Annual O&M	100%	0%	0%	0%
Sponsor Share of Periodic Replacement Cost	100%	0%	0%	0%
Sponsor Share of Administrative Cost	0%	30%	70%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

Table G - 3: Commercial Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	6.8%	4.39%	5.33%	5.45%
Financial Life (years)	12	1	1	1
Sponsor Share of Initial Capital Cost	35%	20%	46%	0%
Sponsor Share of Annual O&M	100%	0%	0%	0%
Sponsor Share of Periodic Replacement Cost	100%	0%	0%	0%
Sponsor Share of Admin Cost	0%	30%	70%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

Table G - 4: Industrial Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	8.5%	4.39%	5.33%	5.45%
Financial Life (years)	12	1	1	1
Sponsor Share of Initial Capital Cost	35%	20%	46%	0%
Sponsor Share of Annual O&M	100%	0%	0%	0%
Sponsor Share of Periodic Replacement Cost	100%	0%	0%	0%
Sponsor Share of Admin Cost	0%	30%	70%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

Table G - 5: Agriculture Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	6.8%	4.39%	5.33%	5.45%
Financial Life (years)	12	1	1	1
Sponsor Share of Initial Capital Cost	35%	20%	46%	0%
Sponsor Share of Annual O&M	100%	0%	0%	0%
Sponsor Share of Periodic Replacement Cost	100%	0%	0%	0%
Sponsor Share of Admin Cost	0%	30%	70%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

Table G - 6: Utility Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	6.3%	4.39%	5.33%	5.45%
Financial Life (years)	12	1	1	1
Sponsor Share of Initial Capital Cost	0%	30%	70%	0%
Sponsor Share of Annual O&M	0%	30%	70%	0%
Sponsor Share of Periodic Replacement Cost	0%	30%	70%	0%
Sponsor Share of Admin Cost	0%	30%	70%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

The analysis assumes three sponsors of measure cost; the end use customer, the wholesale utility, the retail utility. Gas utility sponsorship is not considered in the Council analysis. This analysis uses a discount rate of 4.0 percent, consistent with the all other resources analyzed in the Seventh Power Plan; see Appendix A for more details.

Benefits of Conservation

In addition to the energy saved by conservation, there are several benefits that reduce the cost of conservation. These contributors include: deferred transmission and distribution (T&D) capacity expansion, deferred generation capacity investment, avoided periodic replacement, other fuel benefits, value of non-power system impacts (also referred to as non-energy benefits), and the regional act credit.

The deferred T&D capacity is estimated from the contribution of conservation on winter peak loads, defined as 6 pm on a weekday in December, January, or February. As discussed in Chapter 7, absent energy efficiency, the regional peak demand is growing. By reducing the peak load with efficiency, ongoing upgrades or expansions to the T&D system and associated costs are deferred. The Council used data from eight transmission utilities and eight distribution utilities to estimate this value: $26/kW-yr for deferred transmission and $31/kW-year for deferred distribution (both in 2012$). These inputs are described in the workbooks T+D Costs on the Council's website http://www.nwcouncil.org/energy/powerplan/7/technical. The Council recognizes that potential transmission and distribution systems cost savings are dependent upon local conditions.

ProCost has a new calculation for the deferred T&D capacity benefits since the Sixth Power Plan. In the Sixth Power Plan, ProCost used average losses to calculate the conservation T&D benefits, but for the Seventh Power Plan, ProCost was updated to calculate the losses based on the hour when they occur.

There are two types of losses on the transmission and distribution system. The first are no-load/core losses, or the losses that are incurred just to energize the system – to create a voltage available to serve a load. Nearly all of these occur in step-up and step-down transformers. The second are resistive losses, which are caused by friction released as heat as electrons move on increasingly crowded lines and transformers. Typically, about 25 percent of the average annual losses are no-load or core losses, and about 75 percent are resistive losses.

Losses increase significantly during peak periods. ProCost uses the formula for the resistive losses, I^2R, where "I" is the amperage (current) on any particular transformer or distribution line, and "R" is the resistance of the wires through which that current flows. While the "R" is generally constant through the year, since utilities use the same wires and transformers all year long, the "I" is directly a function of the demand that customers place on the utility. Thus, resistive losses increase with the square of the current, meaning losses increase as load increases. Depending on the system load shape, the percentage of generation that is "lost" before it reaches loads is typically at least twice as high as the average annual losses on the system. During the highest critical peak hours (perhaps 5-25 hours per year) when the system is under stress, the losses may be four to six times higher than the average.

ProCost uses the system load shape and the conservation measure load shape to calculate the impact of the measure on system losses, accounting for both the core and resistive losses. [7]

Conservation measures also have a deferred generation capacity value, though the economic value of this is derived from analysis of resource strategies in the Regional Portfolio Model rather than fixed as an input. As such, the economic value of deferred generation capacity was set to zero for the RPM inputs. Instead, the derived economic value of deferred generation capacity is captured in the determination of the plan conservation goals and for setting cost-effectiveness levels for conservation measures and programs. Measure cost-effectiveness methodology is described in the section below titled "Determining the Cost-Effectiveness Limit for Conservation".

The other benefits of conservation included in the levelized cost calculation include the periodic replacement, other fuel, and quantifiable non-power system impacts. An example of the periodic replacement benefit is a high-efficiency LED light bulb that has a significantly longer life than a baseline halogen bulb. As such, by installing an LED that has a 12-year measure life, the user avoids replacing the halogen bulb five times (every two years).

The other fuel benefits are savings in natural gas or heating oil from, for example, increased insulation levels. The homeowner who has air conditioning and a gas furnace will save electricity in reduced cooling usage as well as saving gas from reduced heating usage by adding ceiling insulation.

In addition, the Council includes the value of quantifiable non-power system impacts. For example, by installing an efficient clothes washer, the homeowner will use less water than the baseline. The value of this water reduction is included as a benefit in the net levelized cost calculation.

Finally, the Northwest Power Act directs the Council and Bonneville to give conservation a 10 percent cost advantage over sources of electric generation.[8] The Council does this by

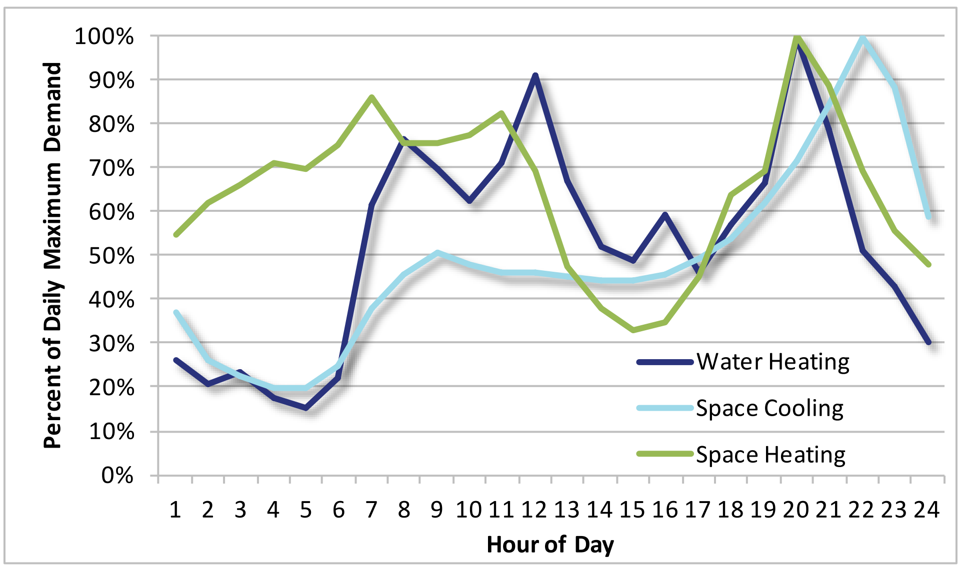
[7] Overall conservation avoids line losses that range between 7 and 8 percent depending on the load shape of each measure's savings.

calculating the Act credit as 10 percent of the value of energy saved at wholesale market prices, plus ten percent of the value of savings from deferring electric transmission and distribution system expansion, deferred generation capacity investment, and risk avoidance. This credit is applied in the RPM and is thus not included in the TRC net levelized cost input data.

Value of Conservation with Respect to Time

The energy saved from conservation is generally not constant across every hour of the year. For example, efficient street lighting only saves energy from dusk-to-dawn, the hours of which vary over the year. Figure G - 5 shows typical daily load shape of conservation savings for measures that improve the efficiency of space heating, water heating, and central air conditioning in a typical Northwest home. The vertical axis indicates the ratio (expressed as a percent) of each hour's electric demand to the maximum demand for that end use during over the course of the entire day. The horizontal axis shows the hour of the day, with hour "1" representing midnight.

Figure G - 5: Illustrative Hour Load Profile for Three Residential End Uses



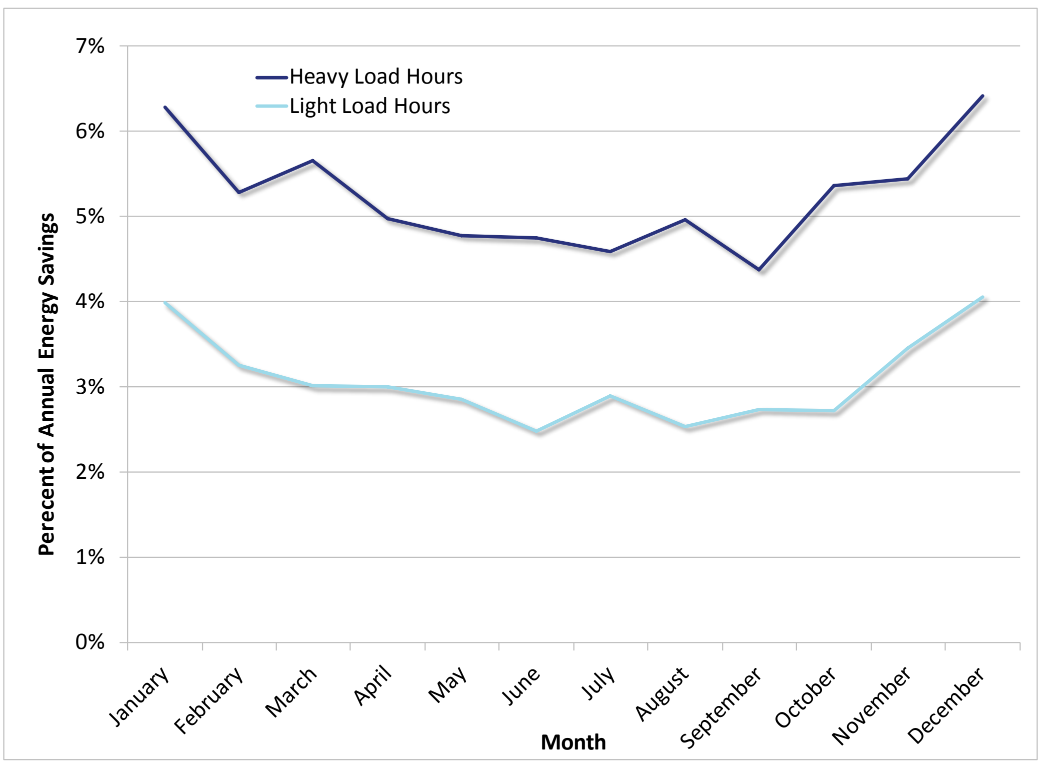
As can be seen from inspecting Figure G - 5, water heating savings increase in the morning when occupants rise to bathe and cook breakfast, then drop while they are away at work and rise again during the evening. Space heating savings also exhibit this "double-hump" pattern. In contrast, central air conditioning savings increase quickly beginning in the early afternoon,

[8] Northwest Power Act,§3(4)(D), 94 Stat. 2699.

peaking in late afternoon and decline again as the evening progresses and outside temperatures drop. Measure savings can also vary seasonally and by day of the week. As the price of electricity varies by day and by season, the value of the conservation will also vary, depending on its savings shape.

The shape of the savings for the complete set of conservation measures in the supply curve during heavy and light load hours is provided in Figure G - 6. As is shown, the energy savings are greater during the winter season than summer, in large part due to significant savings from conversion of electric resistance heating to more efficient heat pump technologies and increased use of lighting during the winter period. As such, the conservation measures have a greater impact on winter peak load requirements than summer peak requirements. Winter peak hours are defined as 6pm on a weekday in December, January, or February. Summer peak hours are defined as 6pm on a weekday in July or August. The peak capacity factor[9] varied from around 1.2 in summer to around 2.0 in winter, indicating that conservation measures have a fairly significant impact on peak loads, particularly in the winter. Of course each individual conservation measure analyzed by the Council have a unique shape, which will have an effect on its value as a resource option and on measure cost-effectiveness.

Figure G - 6: Monthly Savings Shape for All Measures during Heavy and Light Load Hours



[9] Capacity factor in this context is defined as the peak savings in megawatts divided by the annual energy savings in average megawatts.

COST-EFFECTIVENESS ANALYSIS METHODOLOGY

The Council uses a multi-step process to evaluate the cost and amount of conservation to be developed for a least-cost and least risk resource strategy. Conservation supply curves are constructed based on cost and savings available from over 1,600 conservation measure permutations across the residential, commercial, industrial, agriculture, and the electric utility system sectors. The conservation supply curves, annual deployment limitations, and the seasonal and time of day availability of conservation data are provided as inputs to the RPM. Data on the cost and availability of generating resource options are also provided to the RPM. The RPM tests plans for the development of conservation and generation resources across 800 different futures. The RPM analysis produces strategies for conservation and generation resource development that have lowest cost and lowest economic risk outcomes for the region. The Council then considers the RPM conservation strategies, along with practical considerations, to develop near-term conservation targets and actions as well as cost-effectiveness guidance for near-term conservation program decisions. The process is outlined in Figure G - 1 above.

As with all other resources, the Council uses the RPM to determine how much conservation is cost-effective to develop.[10] The RPM compares resources, including conservation on a “generic” level. That is, it does not model a specific combined cycle gas or wind project nor does it model specific conservation measures or programs. Run time constraints limit the number of conservation programs the RPM can consider. The RPM cannot consider individual programs for every measure and every specific load shape, and perform a measure-specific benefit-cost ratio for each sub-component of conservation. Therefore, the Council simplifies the set of conservation measures available to the portfolio model. In the case of conservation, the model uses two separate supply curves.

These two supply curves, one for retrofit resources and a second for lost opportunity resources, depict the amount of savings achievable at varying levelized costs. The lost opportunity measures incorporate those that are new or natural replacement applications. The estimates of costs and savings in the supply curves incorporate line loss savings, the value of deferred distribution capacity expansion, and the non-energy costs and benefits of the savings, as discussed above. The available savings are also allocated to heavy and light-load time periods to reflect the time-based value of savings and savings impact on capacity needs.

[10] A full explanation of how the RPM arrives at the cost-effective amount of conservation is described in Appendix L in the section entitled “The Sources of Increased Conservation”.

Decision Rules for Modeling Conservation Resource Acquisition in the Regional Portfolio Model

The reason the RPM uses separate lost-opportunity and retrofit supply curves is that if a lost opportunity conservation resource is not acquired when it is available, it cannot be acquired later (e.g., after the building is constructed) or cannot be cost-effectively acquired later (e.g., the cost of revisiting a home makes adding an increment of ceiling insulation non-cost effective). Thus, the maximum amount of lost opportunity resources is limited annually based on the new construction and equipment turnover. Since retrofit conservation resources do not have this restricted "window of opportunity," the maximum amount of conservation is limited by the total long-term potential. Deferring the purchase of high-cost conservation resources to periods when market costs are high reduces cost and risk. That is, a portfolio management strategy that acquires high-cost conservation resources early results in higher cost and risk than a strategy that defers their acquisition to periods in future when market prices are higher. If market prices are expected to increase over time, the value acquiring high-cost conservation resource is less in the near-term than in the long term.

The RPM models conservation resources using fourteen[11] annual supply curve bins that represent the quantity of technically achievable conservation available each year from 2016 through 2035 at levelized cost. The supply curves are differentiated by levelized cost bin and by retrofit versus lost opportunity resources. The conservation in these cost bins carry with them the shape and capacity characteristics of the combined set of measures in the cost bin. The cost bins, used for both resources are in Table G - 7, along with the average cost and total amount of conservation potential. Note, the RPM can select a portion of conservation within a bin.

Table G - 7: Levelized Cost Bins for Conservation

Bin	Cost Range (2012$/MWh)	Average Levelized Cost (2012$/MWh)		Maximum Conservation (aMW)		
		LO	Retrofit	LO	Retrofit	Total
1	<$20	**-$21**	**-$32**	959	883	1,841
2	$20-50	36	36	1,802	1,598	3,400
3	$50-80	64	65	2,220	1,857	4,078
4	$80-110	92	94	2,317	2,055	4,372
5	$110-140	126	125	2,506	2,079	4,585
6	$140-170	156	160	2,621	2,129	4,750
7	>$170	580	410	2,818	2,271	5,088

In addition to the numbers presented in the above table there are 38 aMW of potential from short-term lighting savings (pre-2020), all available at less than $20 per megawatt-hour. This potential accounts for savings between the current baseline and the 2020 lighting standard of 45

[11] Seven cost bins for the two resource types (retrofit and lost opportunity)

lumens per watt. Since these savings do not persist past 2020, they are inputted separately from the other conservation measures (they are inputted as a contract purchase).

The amount of conservation resources technically achievable each year increases based on the assumption that programs are able to capture an ever larger share of the available potential over time, as determined by the ramp rates provided in Figure G - 4. The RPM can acquire these technically achievable resources each year up to the quantity it determines to be cost-effective over the full planning period and across the 800 futures tested by the RPM. However, the ramp rate for the measures in a specific cost bin are based on the year in which that bin is deployed in the resource strategy. For example, if bin 4 is deployed in 2020, the achievability for that bin will begin at a low value, based on the *first* year of ramp rate acquisition, or Program Year 1 in Figure G - 4.

The final conservation input into RPM is the capacity value of the savings. Given each conservation measure has an associated savings shape (see Figure G - 5), the contribution of savings during peak hours differs by this shape. For each measure category, the Council calculated the peak contribution for both summer and winter peak hours. The peak contributions, aggregated by levelized cost bin (see Table G - 1), are provided in Table G - 8.

Table G - 8: Peak to energy impact of measures by levelized cost bin.

Bin	Winter Peak Contribution (MW/aMW)		Summer Peak Contribution (MW/aMW)	
	LO	Retrofit	LO	Retrofit
1	1.7	1.4	0.9	1.4
2	1.8	1.4	1.0	1.4
3	1.9	1.5	1.1	1.3
4	1.9	1.6	1.1	1.3
5	2.0	1.6	1.2	1.3
6	2.0	1.7	1.2	1.3
7	2.0	1.7	1.3	1.3

Method for Determining the Cost-Effectiveness Limit for Conservation

Conservation program managers, the Regional Technical Forum, and regulators should use the benefit/cost ratio method outlined below to determine cost-effectiveness. This method assures that all the costs and benefits are captured, that the time-dependent shape of the savings are accounted for, and that the capacity contribution of the measures are fully taken into account. 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 a total resource cost perspective, is greater than one, the measure is considered cost-effective. This ratio is calculated as follows, where all parameters are in constant dollar value[12]:

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

Where *NPV* is the net present value and:

$$energy = kWh_{i,bb} * ((MP + C)_i + RMC) * (1 + 10\%)$$

and

$$capacity = kW_{peak,bb} * (T_{avoid} + D_{avoid} + Gen_{avoid}) * (1 + 10\%)$$

The terms are defined as:

NEI = non-energy impacts

admin = administration cost adder (assumed 20%)

kWh = energy saved by time segment *i* (e.g. heavy/light load hours, monthly)

kW_{peak} = winter peak power saved

bb = busbar

MP = market price forecast ($/kWh) by time segment *i*

C = carbon cost forecast ($/kWh) by time segment *i*

RMC = risk mitigation credit for stochastic variation in inputs ($/kWh)

T_{avoid} = deferred transmission capacity credit ($/kW-yr)

D_{avoid} = deferred distribution capacity credit ($/kW-yr)

Gen_{avoid} = deferred generation capacity credit ($/kW-yr)

10% = Regional Act conservation credit

[12] In actuality, the formulation for the benefit-to-cost ratio is more complicated than this equation represents as the costs and benefits represent a stream of values over time. More details are provided in the ProCost users manual.

Other terms were discussed in the section on calculating levelized cost above and shown in Table G - 1.

This analysis is done in ProCost, which captures all the parameters in the formula above. In preparing the inputs for the RPM, the Council estimates the total resource net levelized cost for the measures that includes many of the parameters of the above formula. However, it does not include the deferred generation credit nor the dollar value of the energy savings. The deferred generation credit was included after RPM findings highlighted the region's need for capacity resources. For this analysis, the Council determined the best estimate for this parameter is the discounted cost for the marginal generation resource that would have been built in absence of conservation.[13] The best fit resource for the *region* is an Aeroderivative simple-cycle combustion gas turbine (SCCT), with a levelized cost of $190 per kilowatt-year.[14] Given that the conservation target is sufficient to approximately offset the build of a SCCT each year, the value of Gen_{avoid} is the annual deferred cost of this SCCT. In calculating this amount, the Council recognizes that SCCT take approximately three years to build once the decision is made; i.e., the first year in the plan horizon that such a generator could be built is 2019. The resulting deferred generation credit is $115 per kilowatt-year. Even though the measure energy savings are known, the total dollar value of these energy benefits is not known *a priori*; it is determined through the RPM findings. While the RPM uses a wide range of market prices, determined stochastically, it would be untenable to calculate each measure's cost-effectiveness on a range of market prices. Instead, the Council chooses the base price forecast for this analysis determined using the avoided marginal dispatch cost estimated in the RPM. This value is a result of each RPM scenario, and reflects the variable cost of dispatching the marginal in-region resource.[15] The market price includes two segments (heavy and light load hours) for each time period (monthly). This time variance of market price provides more value to measures that save energy during higher price periods (generally, heavy load hours in the winter). This is described more fully in the section "Value of Conservation with Respect to Time". In addition, the Council will use the Interagency Working Group's estimate of the social cost of carbon at the three percent discount rate.[16] The Seventh Power Plan's Scenario 2B incorporates this carbon damage cost. The Council thus used the expected avoided marginal dispatch cost out of RPM from Scenario 2B that incorporates this cost in dollars per metric ton of carbon dioxide as well as the heat rates associated with the system (to convert to dollars per megawatt-hour). In other words, $MP + C$ becomes a single price stream.

The final parameter is the risk mitigation credit, represented as the *RMC* factor in the energy benefits formula above. Because the Council uses the data from the RPM, a stochastic model with 800 futures run across a number of scenarios to determine the conservation target, the Council uses the risk mitigation parameter to approximate the value of conservation in reducing risk across all of the future unknowns. In other words, there is a premium to purchasing

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[13] Without a robust capacity market in the Northwest, the Council determined the cost of new generating resource is a good proxy for the long-run cost of capacity.
[14] See Appendix H for more information on Aeroderivative gas turbines.
[15] This price could be estimate by the market price out of Aurora^{XMP}, but accounting for the regional resource builds, including conservation.
[16] More information on this estimate if provided in Chapter 15.

conservation to avoid more expensive resource development across the range of futures that is not represented from a single market price forecast used in ProCost or load forecast used to determine the supply curve inputs. The risk mitigation parameter is estimated so that the potential from all cost-effective measures (the economic achievable potential) is nearly equivalent to the conservation targets.

For the Seventh Power Plan, the Council finds that a *RMC* of $0 per megawatt-hour is needed to achieve the targets provided in Chapter 4, Action Plan, item RES-1. In other words, adding in the deferred generator credit is sufficient to encompass the value of conservation in offsetting system risks. In addition, if the Council had chosen not to include carbon damage cost in the market price, the *RMC* would have been non-zero, around $25 per megawatt-hour.

Table G - 9 shows the regional achievable savings by sector and major measure bundle derived using a cost-effectiveness limit as calculated above, using the base market price and load forecasts. Savings are shown for the near term (2021), mid-term (2026), and for the entire period covered by the Seventh Power Plan (through 2035).

The purpose of Table G - 9 is to show the major sources of energy efficiency identified in the Council's Seventh Power Plan. It is not intended to dictate either the measures or the pace of their acquisition to be included in utility or system benefits charge administrator programs.

Table G - 9: Estimated Cost-Effective Conservation Potential in Average Megawatts 2021 and 2035

Measure Bundle	aMW by 2021	aMW by 2026	aMW by 2035	Description of Bundle
Residential				
Heat Pump Water Heater	9	62	267	Efficiency factor of 2.0 or greater
Behavior	17	38	45	Reduction in home energy usage through improved controls
Computers and Monitors	32	33	36	Efficient Desktop PC and Efficient Monitor
Heat Pump Upgrades & Conversions	7	26	77	Space heating conversion from electric resistance to heat pump and to heat pumps above the federal standard
Duct Sealing	21	29	30	Sealing existing ducts to <10% leakage
Residential Appliances	11	32	68	Clothes Washer, Dishwasher, Microwave
Advanced Power Strips	29	117	185	Reduction in stand-by energy use of peripheral electronics equipment
Weatherization	121	169	180	High performance windows, insulation
Ductless Heat Pump	29	79	166	Converting zonal electric heating or electric forced air furnaces to ductless heat pumps
Lighting	174	372	463	LED lamps
Showerheads	67	100	121	2.0 gallons per minute or lower flow rate
Other Residential Measures	14	48	96	Includes aerators, WIFI thermostats, HVAC commissioning, heat recovery ventilation
All Residential Measures	**530**	**1,104**	**1,734**	
Commercial				
Advanced Rooftop Controller	22	83	117	System for controlling rooftop HVAC systems (rooftop units)
Bi-Level Stairwell Lighting	1	4	9	
Clothes Washer	0	2	4	
Commercial EM	41	59	65	Improved control of existing systems (energy management)
Compressed Air	5	9	17	
Cooking Equipment	6	23	63	Ovens, steamers, hoods, sprayers, holding cabinets and other kitchen equipment

Measure Bundle	aMW by 2021	aMW by 2026	aMW by 2035	Description of Bundle
Embedded Data Centers	55	230	261	
Direct Control Ventilation Parking Garage	8	12	13	
Direct Control Ventilation Restaurant Hood	6	8	8	
Demand Control Ventilation	12	17	18	
Desktop	13	28	56	ENERGY STAR desktop computers
DHP	12	43	60	Ductless heat pumps in commercial applications
ECM-VAV	4	12	30	Efficient motors in VAV applications
Economizer	18	26	26	Rooftop economizer improvements
Exterior Building Lighting	59	126	142	
Grocery Refrigeration Bundle	37	52	57	Grocery store refrigeration measures
Laptop	0	1	4	ENERGY STAR laptop computers
Light Emitting Capacitor Exit Sign	4	9	19	
Lighting Controls Interior	2	6	13	Interior lighting controls
Low Power LF Lamps	14	39	39	
LPD Package	123	234	428	Interior lighting measures based on lighting power density reduction
Monitor	6	12	24	
Motors Rewind	2	4	5	
Municipal Sewage Treatment	14	32	35	Measures for municipal sewage treatment facilities
Municipal Water Supply	5	11	12	
Parking lot Lighting	6	8	8	
Premium Fume Hood	0	1	4	
Pre-Rinse Spray Valve	1	1	1	
Secondary Glazing Systems	1	5	10	
Showerheads	3	4	4	

Measure Bundle	aMW by 2021	aMW by 2026	aMW by 2035	Description of Bundle
Smart Plug Power Strips	30	42	47	
Street and Roadway Lighting	30	57	61	
VRF	5	25	78	Variable refrigerant flow systems
Water Cooler Controls	2	10	12	
WEPT	3	7	7	Web-enabled programmable thermostats
Water Heater Tanks	0	1	2	Efficient water heater tanks
All Commercial Measures	**554**	**1,242**	**1,761**	
Industrial				
Compressed Air	12	16	18	Efficient equipment and system optimization across all industries
Energy Project Management	37	79	87	Multiple-system energy management, tracking and reporting in large facilities
Fans	26	54	60	Efficient equipment and system optimization across all industries
Refrigeration in Food Processing	9	12	14	Refrigeration equipment and system optimization
Controlled Atmosphere and Refrigeration in Food Storage	43	61	67	Refrigeration equipment and controlled atmosphere system optimization
Clean Room HVAC Systems in Hi-Tech	8	13	15	Industry-Specific Processes: Clean rooms and production facilities
Integrated Plant Energy Management	23	42	77	Top tier whole plant optimization in large facilities
Lighting	32	41	45	Lamp, ballast, fixture and control improvements across all industries
Material Handling	12	27	30	Efficient equipment and system optimization across all industries
Arc Furnaces in Metals	0.1	0.1	0.2	Industry-Specific Process: Arc furnace
Motors	0.0	0.0	0.0	Efficient motor rewinds across all industries
Pulp Screening and Effluent Treatment in Paper	3	5	10	Industry-Specific Process: Pulp screening, effluent treatment
Plant Energy Management	27	38	41	Multiple-system O&M in large facilities

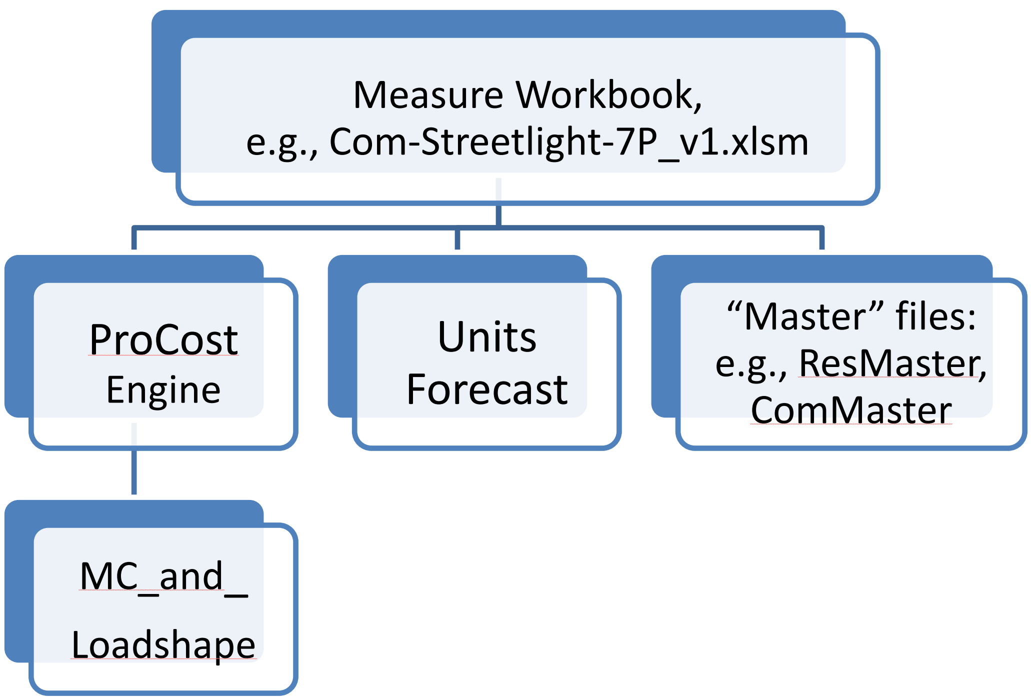
Measure Bundle	aMW by 2021	aMW by 2026	aMW by 2035	Description of Bundle
Refiners and Effluent Treatment in Pulp	3	5	8	Industry-Specific Process: Effluent treatment, refiners
Pumps	42	74	81	Efficient equipment and system optimization across all industries
Material Handling, Drying and Pressing in Wood Products	8	17	19	Industry-Specific Process: Material handling, drying, pressing
All Industrial Measures	**284**	**485**	**571**	
Agriculture				
Irrigation Hardware System Efficiency	32	52	68	Leak reduction, lower pressure delivery, pump & system efficiency
Irrigation Water Management	23	30	41	Scientific irrigation scheduling and low elevation spray application
Irrigation Motor	2	3	3	VFD motors for water pumping
Dairy Efficiency Improvement	0.5	1.1	1.2	Refrigeration, Lighting and motor improvements
Outdoor Lighting	5	7	7	LED lighting for barns
All Agricultural Measures	**63**	**93**	**121**	
Utility Distribution				
Reduce system voltage	12	34	83	Reduce system voltage w/ LDC voltage control method
Light system improvements	7	20	50	VAR management phase load balancing, and feeder load balancing
Major system improvements	8	22	55	Voltage regulators on 1 of 4 substations, and select
All Utility Distribution Efficiency Measures	**28**	**77**	**187**	
All Sectors				
Total	**1,459**	**3,001**	**4,374**	

SUPPLY CURVE WORKBOOK STRUCTURE

There are about 75 Excel workbooks used to develop the conservation assessment. In addition there are dozens of outside sources of data which are referenced. The volume of inputs, calculations, and analysis is too voluminous to include in this appendix so the workbooks are available from the Council website (http://www.nwcouncil.org/energy/powerplan/7/home). Supporting data sources are identified and summarized in each measure workbook or otherwise made available to the extent it is not proprietary. Measure level workbooks are generally structured in a similar fashion across all sectors. Figure G - 7 shows the main components and structure of the conservation assessment workbooks.

The name of the workbook contains the sector (e.g. Com for commercial) and the measure name (e.g. "Streetlight"). Each workbook contains measure input data, as well as cost and benefit results calculated using ProCost. Most of the measure workbooks are linked to a "Units Forecast" workbook, which contains the units forecast by sector and state, and a "Master" workbook which contains significant input data. The "ProCost Engine" is the tool used to calculate the TRC net levelized costs, busbar savings, peak demand impacts, and monthly heavy and light load hour savings contributions of the conservation measures.[17] The "MC_and_Loadshape file contains many of the data inputs for ProCost, include the peak period definition, market price forecasts for natural gas, measure load shapes, etc.

Figure G - 7: Conservation Supply Curve Workbook Components



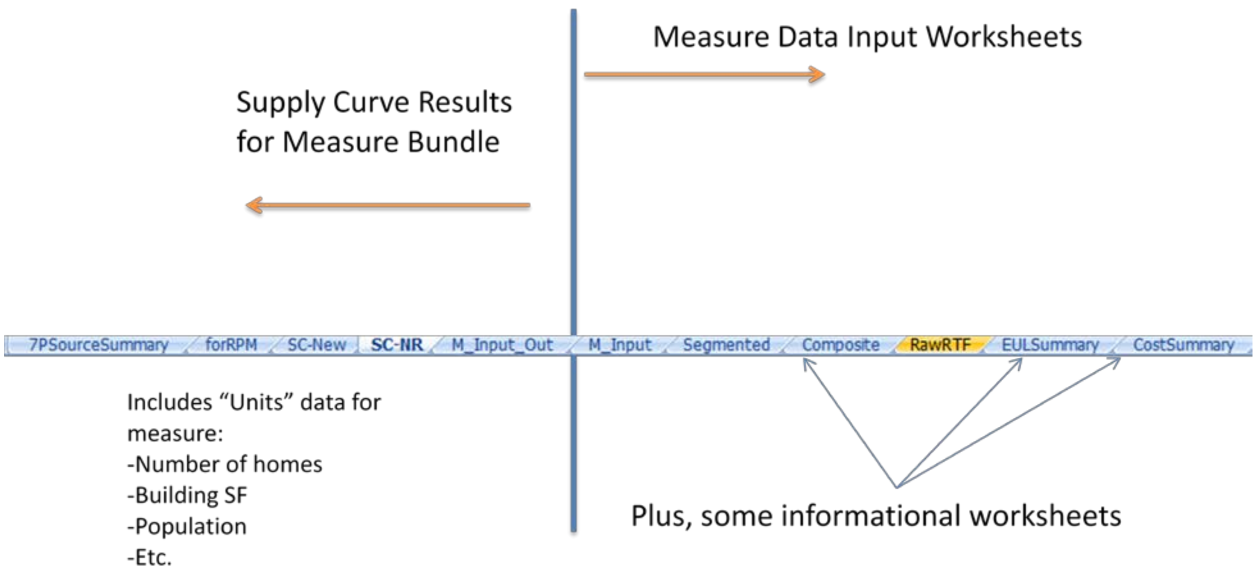
[17] ProCost produces many more details related to the costs and benefits of measures, but are not used for developing the inputs to the Resource Portfolio Model.

The structure of each measure workbook is basically the same, as illustrated in Figure G - 8. The “7PSourceSummary” worksheet provides descriptive information about the measure and its sources. This is the best place to start when trying to understand the assumptions for a measure or measure bundle.

In addition, in each workbook, there are primarily two different types of worksheets: data input worksheets and supply curve results. The primary data input worksheet is called “Measure Input” or “M_Input_Out” or something similar. This sheet contains the specific measure cost, savings, life, and other parameters specific to each measure permutation. These are the data that get run through ProCost to determine, in part, the TRC net levelized cost of each measure. The other worksheets, typically to the right of the Measure Input sheet, are supporting data.

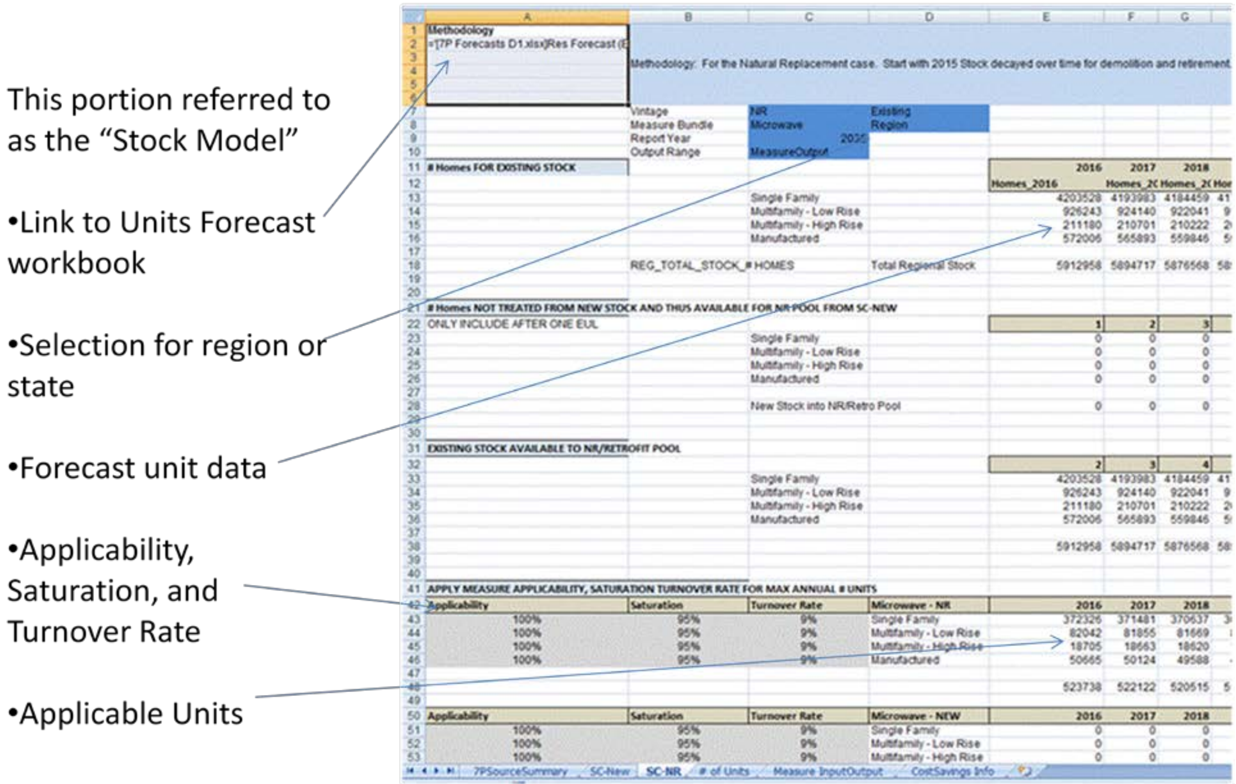
The supply curve results worksheets are shown to the left of the blue line in Figure G - 8. There could be three of these worksheets: new construction, natural replacement (NR), and retrofit applications. These sheets combine the measure data with information from the “Units Forecast” file to produce the technical achievable potential for the measure.

Figure G - 8: Conservation Supply Curve Workbook Structure



The layout of the “SC” worksheets is shown in Figure G - 9**.** This is where all of the measure-related data get pulled together to produce achievable technical potential estimates. It includes forecast data (e.g., housing units, commercial building floor area), application of ramp rates, applicability factors, and turnover rates. These data are used to produce the achievable number of units for a given measure, which are multiplied by measure unit savings. The potential estimates are then summed by levelized cost bin to produce the supply curve.

Figure G - 9: Conservation Supply Curve Worksheet Layout



Finally, each workbook contains a "forRPM" worksheet. This sheet summarizes the key data required for the RPM inputs.

Note of Caution about B/C Ratio

The supply curve workbooks are used for developing the inputs to the RPM. It is the RPM that determines the cost-effective level of conservation required. Therefore, the benefit cost ratios (TRC B/C Ratio) produced by ProCost during this input stage of development are not relevant or accurate.

Subsequent to the Seventh Power Plan conservation supply curve development, additional components of avoided cost, including capacity and risk components are included for use in development of measures during the action plan period. The Regional Technical Forum will use the full set of cost-effectiveness assumptions in developing measures during this period. See the prior section "Determining the Cost-Effectiveness Limit for Conservation" for more detail.

RESIDENTIAL SECTOR

For the Council's conservation analysis the residential sector includes single family, multifamily units, and manufactured homes buildings. Single family buildings are defined as all structures with four or fewer separate dwelling units, including both attached and detached homes. Multifamily structures include all housing with five our more dwelling units, up to four stories in height.[18] Manufactured homes are dwellings regulated by the US Department of Housing and Urban Development (HUD) construction and safety standards (USC Title 42, Chapter 70). Modular homes, which are regulated by state codes, are considered single family dwellings.

One of primary inputs into the residential sector conservation assessment is the number of units that each conservation measure or measure bundle could be applied to in the region. Space conditioning savings are a function of both the characteristics of the structure and the climatic conditions where the home is located. Therefore, the Council's assessment includes estimates of the number of new and existing dwelling units of each type (i.e., single family, multifamily, manufactured homes) in nine different climate zones. The Council defines climate zones by specific combinations of heating and cooling degree days. Table G - 10 shows the nine climate zones in the region.

Table G - 10: Regional Heating and Cooling Climate Zones

Climate Zone	Heating Degree Days	Cooling Degree Days
Climate Zone: Heating 1 - Cooling 1	< 6,000	<300
Climate Zone: Heating 1 - Cooling 2	< 6,000	> 300 - 899
Climate Zone: Heating 1 - Cooling 3	< 6,000	> 900
Climate Zone: Heating 2 - Cooling 1	6,000 - 7,499	<300
Climate Zone: Heating 2 - Cooling 2	6,000 - 7,499	> 300 - 899
Climate Zone: Heating 2 - Cooling 3	6,000 - 7,499	> 900
Climate Zone: Heating 3 - Cooling 1	> 7,500	<300
Climate Zone: Heating 3 - Cooling 2	> 7,500	> 300 - 899
Climate Zone: Heating 3 - Cooling 3	> 7,500	> 900

Measure Bundles

Nearly 60 residential-sector measures are analyzed in the Seventh Power Plan. These measure bundles do not and should not dictate the way measures are bundled for programmatic implementation. Many of the residential-sector measures are reviewed by the Regional Technical Forum (RTF) and incorporate those most recent data. However, in some cases, the final measures included in the Seventh Power Plan may be consolidated from the RTF measure list. For example, HVAC unit count information is of limited statistical significance between heating zones 2 and 3. As such, the savings for weatherization measures are estimated at the regional level, rather than individual climate zones, for each specific HVAC type. The measure bundles, each of which has an individual Excel workbook, are provided by end use in Table G - 11.

[18] The conservation potential for water heating, lighting, appliances and consumer electronics in high rise multifamily dwellings (i.e., those covered by non-residential codes) are included in the residential sector. However, the savings from building shell and HVAC improvements in high rise multifamily buildings is not included in the Council's assessment of regional conservation potential due to lack of data.

Table G - 11: Residential Measure Bundles by End Use

End Use	Measure Bundle(s)
Dryer	Heat pump clothes dryer
Electronics	Monitor
	Desktop
	Laptop
	Advanced power strips
Food Preparation	Microwave
	Electric oven
HVAC	Controls, Commissioning, & Sizing
	Duct Sealing
	Ductless heat pump
	DHP with ducted system
	Ground-source heat pump
	Heat recovery ventilation
	Weatherization
	Air-source heat pump conversion
	ASHP upgrades
	Variable-capacity heat pump
	WIFI enabled thermostats
Lighting	LED lighting
	LED lighting - pre 2020
	Linear fluorescent lamps
Refrigeration	Refrigerator
	Freezer
Water Heating	Aerator
	Clothes Washer
	Dishwasher
	Wastewater heat recovery
	Heat pump water heater
	Showerheads
	Solar water heater
Whole Bldg/Meter Level	Behavior
	Electric vehicle supply equipment

As noted above, there are additional conservation measures that were not included in the Seventh Power Plan due to limited data or resources. Some of these measures are: hot water pipe insulation, variable-speed drive pump for well water, brushless permanent magnet motor for HVAC systems, whole house attic fans, reflective roofs, thermostatic shower restriction valves, and low-U doors.

Overview of Methods

For the residential sector measures, the unit of measure is a function of the measure type. Most measures apply to a fraction of the building stock in a particular building type. For example, insulation measures are a function of the number of households with electric heat, refrigerator efficiency improvements are a function of the number of refrigerators that are replaced or purchase new each year, and the potential savings from heat pump water heaters are function of the number of single family homes with electric water heating.

For every measure or practice analyzed, there are five major methodological steps to go through. These steps establish number of units, baseline conditions, measure applicability, and measure achievability. For the residential-sector conservation measures, each of these is treated explicitly for each measure bundle.

Physical Units

The conservation supply curves are developed primarily by identifying savings and cost per unit and estimating the number of applicable and achievable units that the measure can be deployed on. In the residential sector analysis, the applicable unit estimates for space conditioning, water heating, lighting, and appliances are based on the number of existing housing units and forecast of future housing growth from the Council's Demand Forecasting Model. The housing units from the forecasting model were allocated to climate zones based on the population weighted average heating and cooling degrees for each county in the region. The housing unit data by state are contained in the Excel workbook entitled "7P Forecast.xls." The estimates of physical units available include the number of units available annually. For example, for new buildings, the estimate of available new building stock is taken from the Council's baseline forecast for annual additions by building type. Similarly for equipment replacement measures the annual stock available is taken from estimates of the turnover rate of the equipment in question. For retrofit measures, the annual stock availability is a fraction of the estimated stock remaining at the end of the forecast period. Most of the unit saturations are from the Residential Building Stock Assessment (RBSA), which provided a detailed analysis of homes across the region. The breakdown of measures by climate zone and building type is available in a workbook entitled "RBSA Saturations.xls". These are incorporated into the individual supply curve workbooks as applicable. In addition, much of these data are also in the "Res_Master.xls" workbook.

Baseline Characteristics

Baseline conditions are estimated from current conditions for existing buildings and systems. Estimates of current conditions and characteristics of the building stock come from several sources. Key among these are the market research projects of the Northwest Energy Efficiency Alliance (NEEA), selected studies from utilities, Energy Trust of Oregon, and other sources.

For new buildings and new and replacement equipment, baseline conditions are estimated from a combination of surveys of new buildings, state and local building energy codes, and federal and state appliance efficiency standards. The most recent survey data for new buildings is from the NEEA New Single Family and New Multifamily Buildings Characteristics studies completed in 2007 which looked at buildings built in the 2003-2004. For existing buildings, the Residential Building

Stock Assessment (RBSA), completed in 2012, is the source for saturations of most equipment and appliances.

Baseline characteristics for major appliances (washers, dishwashers, refrigerators, and freezers) are generally the national sales weighted average efficiency levels, or based on equipment appliance database from the California Energy Commission. Cost data for appliances was obtained from an analysis of the Oregon Residential Energy Tax Credit data and Internet searches. Heating, cooling, insulation, and window cost were obtained from an analysis of program data from Puget Sound Energy and the Energy Trust of Oregon. The assumptions were often tied to those determined by the Regional Technical Forum (RTF) in its development of unit energy savings.

Measure Applicability

There are hundreds of applicability assumptions in the residential-sector conservation assessment. Applicability assumptions by measure appear in the Res_Master workbook. The baseline saturation is provided in tab "BASE", the technical feasibility is provided in the tab "FEAS". The final applicability (the product of FEAS * (1 - BASE)) is provided on tab "APPLIC".

Measure Achievability

The measure achievability is provided in the Res_Master workbook, tab "ACHIEV". The overall ramp rates are given on the top of the sheet, while the mapping to each measure index name is provided below.

Guide to the Residential Conservation Workbooks

Table G - 12 provides a cross-walk between the measures included in the Council's assessment of regional conservation potential in the residential sector and the name of the individual workbooks. The most recent versions of these workbooks are posted on the Council's website and are available for downloading http://www.nwcouncil.org/energy/powerplan/7/technical.

Table G - 12: Residential Sector Supply Curve Input Workbooks

File Name	File Scope
Res_Master.xlsx	Master workbook for residential conservation modeling
Res-Lighting-7P_v4.xlsx	Lighting, above EISA 2020 requirements
Res-Lighting_PPA-7P_v5.xlsx	Short-term lighting below EISA 2020 requirements
Res-LFLighting-7P_v1.xslx	Linear fluorescent lighting in residential applications
Res-Dishwasher-7P_v4.xlsx	Efficient Dishwasher
Res-ClothesWasher-7P_v4.xlsx	Efficient Clothes Washer
Res-GFX-7P_v3.xlsx	Gravity film heat exchanger
Res-Showerhead-7P_v5.xlsx	Low-flow showerheads
Res-HPWH-7P_v4.xlsx	Heat pump water heaters
Res-EVCharger-7P_v2.xlsx	Tier 2 electric vehicle supply equipment
Res-ClothesDryer-7P_v2.xlsx	Heat pump clothes dryer
Res-RefrigFreezer-7P_v4.xlsm	Efficient refrigerators and freezers
Res-SWH-7P_v1.xlsx	Solar water heater
Res-Oven-7P_v3.xlsx	Efficient ovens
Res-Microwave-7P_v3.xlsx	Efficient microwaves
Res-Computers-7P_v4.xlsx	Efficient desktop and laptop computers, and monitors
Res-SF_HP-7P_v5.xlsx	Single-family heat pump (air-source and ductless) conversions and upgrades
Res-MH_HP-7P_v2.xlsx	Manufactured homes heat pump (air-source and ductless) conversions and upgrades
Res-Duct_Seal-7P_v4.xlsx	Duct sealing
Res-WiFitstat-7P_v3.xlsx	WiFi thermostat for heat pump controls
Res-Aerator-7P_v5.xlsx	Low-flow faucet aerator
Res-COP-7P_v2.xlsx	Behavior-program influenced reductions
Res-HRV-7P_v1.xlsx	Heat recovery ventilation in new construction
Res-GSHP-7P_v2.xlsx	Ground-source heat pump
Res-FAF_to_DHP-7P_v2.xlsx	Forced-air furnace to ductless heat pump conversions
Res-PowerStrips-7P_v6.xlsx	Advanced power strips
Res-CCS-7P_v4.xlsx	Controls, commissioning, and sizing
Res-SF_Wx-7P_v7.xlsx	Single-family weatherization improvements
Res-MF_Wx-7P_v6.xlsx	Low-rise multi-family weatherization improvements
Res-MH_Wx-7P_v4.xlsx	Manufactured housing weatherization improvements
RBSA Saturations.xlsx	Equipment and appliance saturations
RTFStandardInformationWorkbook_v2_2.xls	Costs and benefits information that is standard across multiple measure assessments, developed by the RTF

All of the individual measure files are linked to the "Res_Master.xls" file. This file contains the complete measure list, commercial building characteristics, baseline data, applicability factors, and ramp rates (achievability rates). The reference data in ResMaster are primarily in matrices by measure bundle and building type. The primary reference data in the ResMaster file are listed and described in Table G - 13.

Table G - 13: Reference Data in ResMaster Workbook

Sheet Name	Contents
Overview	Overview of model structure
MLIST	Master list of measure bundles
FILES	List and links to measure-level files
APPLIC	Applicability factors for the measure. Calculated from data on FEAS and BASE.
FEAS	Technical feasibility for the measures.
BASE	Baseline penetration of the measure. Fraction of stock where the measure is already in place.
STOCK	Vintage cohort that the measure applies to
TURN	Turnover rate for stock to which measure applies, based on measure life
ACHIEV	Achievable rate of acquisition for measure bundles by year
SATS	Measure saturations by building type

COMMERCIAL SECTOR

For the Council's conservation analysis in the commercial sector, the majority of the conservation measures are derived based on savings per square foot of floor area by a specific building type. In a few other cases, a commercial conservation measure may be based on population (savings per person) or a direct estimate of unit count, such as the number of streetlights.

The commercial sector in the Pacific Northwest includes 3,350 million square feet in 2013, which are divided into 18 distinct building segments for analysis. Table G - 14 shows these segments and their associated floor area. Note that the office, retail, and food sales were further divided into categories by building size. In addition, over 900 million square feet of new floor space are expected to be added by 2035 based on the Council's medium forecast.

Table G - 14: Commercial Building Types

Primary Activity	7P Building Type	Name Used in Models	Gross Floor Area in Square Feet	Regional Floor Area (million sf)
Office	Large Office	Large Off	>50,000	323
Office	Medium Office	Medium Off	5,000 to 50,000	316
Office	Small Office	Small Off	<5,000	95
Retail	Extra Large Retail	Xlarge Ret	>100,000	134
Retail	Large Retail	Large Ret	50,000 - 100,000	32
Retail	Medium Retail	Medium Ret	5000 - 50,000	346
Retail	Small Retail	Small Ret	<5000	59
School	School K-12	School K-12	Any	245
School	University	University	Any	124
Warehouse	Warehouse	Warehouse	Any	442
Retail Food Sales	Supermarket	Supermarket	> 5000	65
Retail Food Sales	MiniMart	MiniMart	< 5000	12
Restaurant	Restaurant	Restaurant	Any	53
Lodging	Lodging	Lodging	Any	171
Health Care	Hospital	Hospital	Any	104
Health Care	Residential Care	Residential Care	Any	125
Assembly	Assembly	Assembly	Any	369
Other	Other	Other	Any	333

Measure Bundles

Nearly 40 individual commercial-sector measure bundles are analyzed in the Seventh Power Plan. These measures were bundled for analytical convenience and should not dictate the way measures are bundled for programmatic implementation. Table G - 15 shows these commercial sector measure bundles with their associated end-uses.

Table G - 15: Commercial Measure Bundles

End-Use	Measure Bundle		End-Use	Measure Bundle
Compressed Air	Compressed Air		Lighting	Bi-Level Stairwell Lighting
Electronics	Data Centers			Exterior Building Lighting
	Desktop			LEC Exit Sign
	Laptop			Lighting Controls Interior
	Monitor			Low Power LF Lamps
	Smart Plug Power Strips			Lighting Power Density
Food Preparation	Cooking Equipment			Parking Garage Lighting
	Pre-Rinse Spray Valve			Street and Roadway Lighting
HVAC	Advanced Rooftop Controller		Motors/Drives	ECM-Variable Air Volume
	Commercial Energy Management			Motors Rewind
	DCV Parking Garage		Process Loads	Municipal Sewage Treatment
	DCV Restaurant Hood			Municipal Water Supply
	DCV Buildings		Refrigeration	Grocery Refrigeration Bundle
	Ductless Heat Pumps			Water Cooler Controls
	Economizer		Water Heating	Water Heater Tanks
	Premium Fume Hood			Showerheads
	Secondary Glazing Systems			Clothes Washer
	Variable Speed Chiller			
	Variable Refrigerant Flow			
	Web-Enabled Programmable Thermostats (WEPT)			

As noted in Chapter 12, there are additional conservation measures that were considered but not included in the Seventh Power Plan due to limited data or resources. There are undoubtedly cost-effective savings available from some of these measures and they should not be excluded from program consideration in plan implementation. These measures include:

- AC Heat Recovery for Water Heating (& Reverse Cycle Chillers)
- Appliances - Freezers, Refrigerators
- Chiller retrofits
- Circulation pump ECM and drive
- Drain water heat recovery
- Elevator efficiency
- Energy recovery ventilator
- Engine generator block heaters
- Evaporative cooling
- Heat pump conversion & upgrade
- Heat pump water heaters
- Integrated Building Design[19]
- Low pressure distribution complex HVAC
- Packaged refrigeration equipment
- Perimeter daylighting controls (Advanced)
- Pool blankets
- Pool pumps
- Premium HVAC equipment
- Roof insulation
- Signage
- Top daylighting
- Ultra low energy building
- Variable speed chiller
- Weatherization - School

[19] The Sixth Power Plan included a measure called "Integrated Building Design" where synergistic effects of multiple measures in new buildings were captured as cost and performance savings above the application of individual measures. While the synergistic impacts of integrated design measures was not explicitly included in the Seventh Power Plan analysis, most new-building savings above code are being captured through individual measures in new buildings.

Overview of Methods

For the commercial sector measures, the unit of measure is a function of the measure type. Most measures apply to a fraction of the building floor area in a particular building type. For some measures, especially HVAC-related measures, the space heating fuel type is important. Some measures, like lighting, apply across all building types while others such as pre-rinse spray valves apply only to facilities with commercial kitchens.

For every measure or practice analyzed, there are five major methodological steps to go through. These steps establish number of units, baseline conditions, measure applicability, and measure achievability.

Physical Units

The conservation supply curves are developed primarily by identifying savings and cost per unit and estimating the number of applicable and achievable units for which the measure can be deployed. In the commercial sector analysis, the applicable unit estimates are based on the existing building floor area by building type and forecast of future new building growth from the Council's Demand Forecasting Model. The floor space unit data by state are contained in the Excel workbook entitled "7P Forecast.xls." The estimates of physical units available include the number of units available annually.

For example, for new buildings, the estimate of available new building stock is taken from the Council's baseline forecast for annual floor area additions by building type. Similarly for equipment replacement measures the annual stock available is taken from estimates of the turnover rate of the equipment in question. For retrofit measures, the annual stock availability is a fraction of the estimated stock remaining at the end of the forecast period. These are incorporated into the individual supply curve workbooks as applicable. In addition, much of these data are in the "Com_Master.xls" workbook.

For some measures, the applicable units are based on other metrics such population and forecasted population growth. Table G - 16 shows examples of measure bundles and their corresponding unit savings basis and associated growth forecast.

Table G - 16: Commercial Measure Unit Savings Basis

Measure Bundle	Unit Savings Basis	Growth Forecast
Compressed Air	kWh savings per motor horsepower	Building floor space
Computers, laptops, monitors, power strips, pre-rinse spray valves, cooking equipment, water coolers	Count of units	Population forecast
Water and wastewater	Million gallons per day flow	Population forecast
All other measures	Floor area by building type	Building floor space

Baseline Characteristics

Baseline conditions are estimated from current conditions for existing buildings and systems. Estimates of current conditions and characteristics of the building stock come from several sources. Key sources include the market research projects of the Northwest Energy Efficiency Alliance (NEEA), selected studies from utilities, Energy Trust of Oregon, and other sources.

For new buildings, new and replacement equipment, baseline conditions are estimated from a combination of surveys of new buildings, state and local building energy codes and federal and state appliance efficiency standards. The most recent survey data used is from the NEEA New Buildings Characteristics study completed in 2008 which looked at buildings built in the 2002-2004. In addition, data for the post 2004 cohort sample of the 2014 CBSA were used in some cases to represent new stock characteristics. Codes and standards are continually being upgraded. The baseline assumptions used for codes and standards in the Seventh Power Plan are those that were adopted by the end of 2014.

Baseline lighting systems are estimated from a combination of sources. The 2014 CBSA provided the mix of lighting systems types in common use by building type. There are five indoor fixture application types modeled each with separate baseline lamps and lighting power densities. A similar set of baselines characteristics is used for exterior lighting also based on CBSA. CBSA provided estimates of lighting power density and lighting hours of operation all of which are key components of the lighting baselines. Most lighting conservation measures are new, remodel, or replace on burnout situations where current practice baselines are used. To establish current practice baselines, CBSA lighting characteristics were adjusted to reflect applicable federal lighting standards and applicable state codes. For example, federal standards now require minimum efficacies for most four foot fluorescent lamps effective in 2014 and with an increase in efficacy mandated by 2018. A ballast efficacy standard also took effect in 2014. These federal standards reduce the lighting power densities for fluorescent lighting systems found in the CBSA because as the lamps and ballast burn out, they must be replaced with new more efficient models.

Embedded data centers are a growing end use in the commercial sector. The CBSA collected characteristics of data centers embedded in commercial buildings which established the baseline saturation of data centers and the equipment in them. Energy use in data centers is primarily driven by the density and utilization of the servers, storage, and network equipment with relatively fast turnover rates. No mandatory standards require minimum efficiencies for new and replacement equipment in data centers. Thus baseline estimates of efficiency are based instead on market trends and analysis of ENERGY STAR and other data. Significant commercial building modeling work was conducted in preparation of the Sixth Power Plan. The results of this work were again used to help establish baselines for some HVAC related measures in the Seventh Power Plan. For measures where significant achievements were recorded since the Sixth Power Plan, adjustments were made to the baseline electricity use intensity values.

Measure Applicability

There are hundreds of applicability assumptions in the commercial sector conservation assessment. Applicability assumptions by measure appear in the Com_Master workbook. The baseline saturation is provided in tab “BASE”, the applicability factors “APPLIC” and final applicability (1-BASE)*APPLIC is provided on tab "APPLIC". For some measures, applicability factors reside in the measure workbook.

Measure Achievability

The measure achievability is provided in the Com_Master workbook, tab "ACHIEV". The overall ramp rates are given on the top of the sheet, while the mapping to each measure index name is provided below.

Guide to the Commercial Conservation Workbooks

Table G - 17 provides a cross-walk between the measures included in the Council's assessment of regional conservation potential in the commercial sector and the name of the individual workbooks. The most recent versions of these workbooks are posted on the Council's website and are available for downloading. http://www.nwcouncil.org/energy/powerplan/7/technical

Table G - 17: Commercial Sector Supply Curve Input Workbooks

File Name	File Scope
Com_Master_7P.xlsx	Master workbook for commercial conservation modeling
Com-Bi-Level Stairwell-7P_V4.xlsx	Bi-level stairwell lighting
COM-CompressedAir-7P_V4.xlsm	Compressed air demand reduction, VFD, controls, and equipment upgrades
COM-Computers-7P_V3.xlsx	Efficient desktop and laptop computers, and monitors
COM-Cooking-7P_V5.xlsm	Efficient commercial steamers, hot food holding cabinets, combination ovens, fryers, and convection ovens
Com-DataCenters-7P_V6.xlsx	Embedded data center improvements
Com-DCV-7P_V5.xlsm	Demand control ventilation
COM-DCV-Garage-7P_V3.xlsm	Demand control ventilation in enclosed parking garages
COM-DCV-KitchenVent-7P_V3.xlsm	Demand control ventilation for commercial kitchens
COM-DHP-7P_V2.xlsm	Ductless heat pumps for small commercial buildings
COM-ECM-VAV-7P_V4.xlsm	Electrically commutated motors for VAV systems
COM-Economizer-7P_v2.xlsm	Economizer maintenance and repair improvements
Com-EM-7P_V5.xlsm	Energy management (controls optimization)
Com-ExitSign-7P_V3.xlsx	Light Emitting Capacitor (LEC) exit signs
Com-ExteriorLighting-7P_V14.xlsx	Exterior lighting
COM-FumeHood-7P_V2.xlsm	Laboratory fume hood controls
Com-Grocery-7P_V7.xlsx	Grocery refrigeration system improvements
Com-HPLowPowerGSFL-7P_V8.xlsx	High performance low power fluorescent lamp
Com-InteriorLightingControls-7P_V10.xlsx	Interior lighting controls
Com-LightingInterior-7P_v40.xlsx	Interior lighting power density improvements
COM-MotorsRewind-7P_v3.xlsm	Motor rewinds
Com-ParkingGarageLighting-7P_v7.xlsx	Efficient lighting for parking garages
COM-PowerStrips-7P_V5.xlsm	Advances power strips for offices
COM-PreRinseSpray-7P_V3.xlsm	Pre-rinse valves for commercial kitchens
Com-RooftopController-7P_V6.xlsm	Advanced rooftop controller (ARC)
COM-Showerhead-7P_v5.xlsm	Low flow showerheads in hotels, athletic facilities
Com-Streetlight-7P_V9.xlsx	LED streetlights
COM-VRF-7P_V6.xlsm	Variable refrigerant flow HVAC systems
COM-Washer-7P_V1.xlsm	Commercial clothes washers
COM-Wastewater-7P_V6.xlsm	Municipal wastewater treatment system improvements
Com-WaterCooler-7P_V6.xlsx	Upgrade to ENERGY STAR water coolers and controls
COM-WaterSupply-7P_V6.xlsm	Municipal water supply system improvements
COM-WEPT-7P_V2.xlsm	Web-enabled programmable thermostats
COM-WHTanks-7p_v6.xlsm	Efficiency upgrades for tank-style electric water heaters
Com-WindowSGS-7P_V5.xlsx	Secondary glazing window systems (interior retrofit)
Int_Light_Comp-7P_v2.xlsx	Data development common to all lighting measures
PNLPricePerfLED.xlsx	Forecast of price and performance of solid state lighting
Standard Information Workbook_v2.2	RTF data source for inputs common to all measures

All of the individual measure files are linked to the "Com_Master_7P.xls" file. This file contains the complete measure list, commercial building characteristics, baseline data, applicability factors, and ramp rates (achievability rates). The reference data in ComMaster are primarily in matrices by measure bundle and building type. The primary reference data in the ComMaster file are listed and described in Table G - 18.

Table G - 18: Reference Data in ComMaster Workbook

Sheet Name	Contents
Overview	Overview of model structure
MLIST	Master list of measure bundles
FILES	List and links to measure-level files
APPLIC	Applicability factors for the measure. Fraction of stock for which the measure applies
BASE	Baseline penetration of the measure. Fraction of stock where the measure is already in place
STOCK	Vintage cohort that the measure applies to
TURN	Turnover rate for stock to which measure applies
ACHIEV	Achievable rate of acquisition for measure bundles by year
CHAR	Key characteristics for stock by vintage and building subtype. Used to develop applicability
FLOOR	Floor area by building segment
labels	Building type list

INDUSTRIAL SECTOR

The Seventh Power Plan's assessment of conservation potential in the industrial sector covers a broad range of measures in 19 industrial segments, but excludes the direct service industries.[20] The industrial sector utilizes a top-down methodology for estimating the conservation potential, so the key driver is total load by segment. The industrial segments and their 2016 (start year) and 2035 loads (end year) are shown in Table G - 19.

[20] Direct service industries (DSIs) are large industrial facilities historically served directly by the Bonneville Power Administration.

Table G - 19: Industrial Loads in 2016 and 2035

Industrial Segment	2016 aMW	2035 aMW
Mechanical Pulp	336	486
Kraft Pulp	210	296
Paper	403	601
Foundries	105	77
Frozen Food	151	142
Other Food	275	364
Wood - Lumber	102	71
Wood - Panel	136	82
Wood - Other	250	174
Sugar	48	67
Hi Tech - Chip Fab	115	114
Hi Tech - Silicon	32	40
Metal Fab	139	76
Transportation, Equip	123	194
Refinery	87	131
Cold Storage	87	129
Fruit Storage	190	386
Chemical	264	513
Misc Manf	460	539
Total	3,514	4,482

Measure Bundles

The industrial sector has a wide range of segments, end-using equipment, and function. The energy conservation measures need to apply to the end-use loads and therefore there is significant diversity in the number and type of industrial conservation measures. The industrial measure bundles are shown in Table G - 20.

Table G - 20: Industrial Measure Bundles

Air Compressor Demand Reduction	Fan Energy Management	Mech Pulp: Premium Process
Air Compressor Equipment1	Fan Equipment Upgrade	Mech Pulp: Refiner Plate Improvement
Air Compressor Equipment2	Fan System Optimization	Mech Pulp: Refiner Replacement
Air Compressor Optimization	Food: Cooling and Storage	Metal: New Arc Furnace
CA Retrofit -- CO2 Scrub	Food: Refrig Storage Tuneup	Motors: Rewind 101-200 HP
CA Retrofit -- Membrane	Fruit Storage Refer Retrofit	Motors: Rewind 201-500 HP
Clean Room: Change Filter Strategy	Fruit Storage Tuneup	Motors: Rewind 20-50 HP
Clean Room: Chiller Optimize	Groc Dist Retrofit	Motors: Rewind 501-5000 HP
Clean Room: Clean Room HVAC	Groc Dist Tuneup	Motors: Rewind 51-100 HP
Cold Storage Retrofit	HighBay Lighting 1 Shift	Panel: Hydraulic Press
Cold Storage Tuneup	HighBay Lighting 2 Shift	Paper: Efficient Pulp Screen
Efficient Centrifugal Fan	HighBay Lighting 3 Shift	Paper: Large Material Handling
Efficient Lighting 1 Shift	Integrated Plant Energy Management	Paper: Material Handling
Efficient Lighting 2 Shift	Kraft: Efficient Agitator	Paper: Premium Control Large Material
Efficient Lighting 3 Shift	Kraft: Effluent Treatment System	Paper: Premium Fan
Elec Chip Fab: Eliminate Exhaust	Lighting Controls	Plant Energy Management
Elec Chip Fab: Exhaust Injector	Material Handling VFD1	Pump Energy Management
Elec Chip Fab: Reduce Gas Pressure	Material Handling VFD2	Pump Equipment Upgrade
Elec Chip Fab: Solidstate Chiller	Material Handling1	Pump System Optimization
Energy Project Management	Material Handling2	Wood: Replace Pneumatic Conveyor

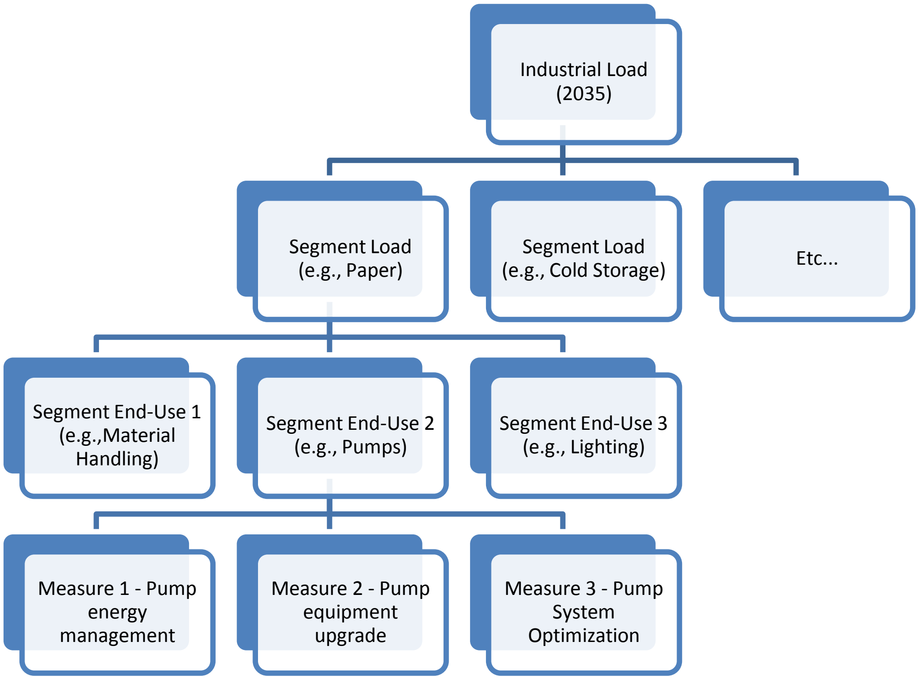
Overview of Methods

The industrial sector conservation assessment utilizes a top-down methodology rather than the bottom-up methods used in the other sectors. The overall industrial load is forecasted by state and region. As part of this forecast, the loads are disaggregated into the 19 industrial segments. The consumption estimates were then split into estimates of electricity use by major process end use. Then energy conservation measures are applied to the use by end use estimates as a percent savings with associated costs. Finally, factors for measure applicability, measure interaction, and achievability rates over time are applied. Accomplishments since 2010 are accounted for by adjusting the achievability rates.

Physical Units

The overall structure of the industrial sector model is shown in Figure G - 10. The physical units are derived from the forecasted 2035 industrial load. Each industrial segment has a unique set of end-use loads, and each end-use load has a measure or set of measures associated with it. Since the measures are defined as a percent savings share of the end-use load, the resulting savings are total for the region rather than for an individual facility or process.

Figure G - 10: Industrial Model Structure



Baseline Characteristics

The baseline characteristics of the industrial sector are defined by the electricity end-uses in each of the segments. The original research and model development for the industrial sector was conducted prior to the development of the Sixth Power Plan. For the Seventh Power Plan, the same model, methodology and measure list were used. However, significant updates were made to the baseline conditions.

One of the primary baseline components is the industrial load by segment (shown previously in Table G - 19). These baselines loads are based on the regional end-use load forecast for the industrial sector (see Chapter 7 and Appendix E). Loads for each segment were developed using a variety of sources including the Industrial Facility Site Assessment (IFSA).

A second major baseline component is the share of consumption by end-use. Estimated end-use shares from the Sixth Plan were reviewed and revised using new data sources including the IFSA and the Energy Information Agency's 2010 Manufacturing Energy Consumption Survey.

Finally, measure baseline saturation updates were made by reviewing the conservation measures completed since the Sixth Power Plan. Data were provided by the Six Going on Seven project sponsored by BPA, which included data from 2010-2013. Savings data were projected for 2014 and 2015. These achieved savings were used to update the baseline saturation of measures.

Measure Applicability

Each of the 60 or so industrial measures has a physical applicability number associated with it, along with a "fraction incomplete" factor. The combination of these makes up the measure applicability.

Measure Achievability

The industrial measure technical achievability is largely 85 percent, similar to the other sectors. However, the industrial sector has a few measures that have less than 85 percent achievability due to limiting factors within a given industry or measure group, including the electronic chip fabrication (25%), pulp and paper (50%), and energy management (50%-75%). New ramp rates were applied to the measures for the Seventh Power Plan. Since most of these measures were new in the Sixth Power Plan, the pace of achievement since 2010 played a significant role in selection and application of ramp rates. The industrial measures are all considered retrofit.

Guide to the Industrial Sector Workbooks and Data

Table G - 21 provides of the individual workbooks utilized in the industrial sector assessment. The most recent versions of these workbooks are posted on the Council's website and are available for downloading. http://www.nwcouncil.org/energy/powerplan/7/technical

Table G - 21: Industrial Sector Supply Curve Input Workbooks

Item	Description
Measure Analysis Tool *Industrial_tool_7thPlan v09.xlsm*	Excel workbook containing the major elements of the industrial sector characterization, the estimates of end use splits and the details on the energy conservation measures
NPCC Supply Curve *IND-All-7P-v5.xlsm*	Excel workbook which translates the costs and savings from the Measure Analysis Tool into supply curve data for the Regional Portfolio Model. Uses ProCost to develop TRC Net levelized costs.
Achievements and Applicability Adjustments *Achievements and Applicability v07.xlsm*	This workbook contains the detailed data and mapping for the measures and measure saturation. The IFSA and the Six Gong on Seven data were utilized for updating measure baselines.
Systems Whole Plant Optimization Overview	Description of the system optimization and whole plant measure bundles, the input assumptions, and supporting sources. This document was created for the Sixth Power Plan, but the Seventh Plan utilizes the same measures.
Industrial Lighting Analysis *IND-Lighting-7P_V2.xlsx*	This workbook contains a separate industrial lighting analysis based on data from the Industrial Facilities Site Assessment.

AGRICULTURAL SECTOR

The Seventh Power Plan's assessment of conservation potential in the agriculture sector covers irrigation hardware system efficiency improvements, irrigation water management (scientific irrigation scheduling [SIS] and low-energy spray application [LESA]), and dairy farm milk processing. Consistent with the conservation assessments in prior plan's, the largest potential savings in the agriculture sector are available through irrigation hardware system efficiency improvements, including reducing system operating pressures, reducing system leaks, and improving pump efficiency. The next largest savings in this sector come from improved water management practices followed by efficient barn lighting and dairy milk processing savings. This is the first Council plan to estimate savings from LESA and efficient barn lighting.

Measure Bundles

Seven measure bundles are considered in the Seventh Power Plan, five of which are irrigation measures. The five irrigation bundles are:

1. Generic irrigation hardware system efficiency improvements and three "operation and maintenance" (e.g., gasket and nozzle replacement) measures,
2. Irrigation water management practices were considered as a bundled measure consisting of moisture monitoring hardware and software,
3. Converting high/medium pressure center pivot systems to low-pressure systems,
4. Low-elevation spray application, using ultra-low pressure (<10psi) center pivot systems,
5. Efficient green motor rewind practices for irrigation motors.

The remaining two measure bundles include improving the energy efficiency of dairy milking barns and milk processing and converting barn area lighting to high-efficiency LEDs.

As noted above, the Seventh Power Plan does not include all potential measures. Some missing measures include: high-volume low-speed fans, variable speed drives for well pumps, and low-energy livestock waterer. Also, efficiency improvements for indoor agriculture (including greenhouses) were not explicitly analyzed.

Overview of Methods

Many of the assumptions for agriculture measures are based on Sixth Power Plan assumptions. Exceptions are irrigation hardware efficiency, barn area lighting, and green motor rewinds, which have incorporated recent RTF analysis. The Seventh Power Plan has updated irrigated acreage assumptions from the 2013 Farm and Ranch Irrigation Survey.

Irrigation water management savings (SIS) were estimated using a spreadsheet developed by the Columbia Basin Ground Water Management Association (GAMA). This spreadsheet was modified to reflect the average water savings achieved in Bonneville's 2005 study of irrigation water management practices. This evaluation documented the average water savings from scientific irrigation water management as well as the cost of carrying out improved practices. This approach is equivalent to that used in the Sixth Power Plan. Research to be completed in 2016 will better inform available acreage for SIS and baseline practices.

Dairy efficiency improvements were based on detailed audits and retrofits of 30 dairies in New York carried out by the New York State Energy Research and Development Administration (NYSERDA). This approach is equivalent to that used in the Sixth Power Plan. However, baseline saturations were adjusted upwards to account for many of the measures becoming standard practice.

Physical Units

The conservation supply curves are developed primarily by identifying savings and cost per unit and estimating the number of applicable and achievable units that the measure can be deployed on. In the irrigation sector analysis, the applicable unit estimates for irrigated acreage, system types and annual water application were drawn from the 2013 USDA Farm and Ranch Irrigation Survey (FRIS). GAMA provided data on the acreage and crop types present in Columbia Basin Project. The estimate of current diary production in the region also comes from the USDA and the US Department of Commerce. Staff developed a forecast of future milk production growth in the region using historical trends.

Baseline Characteristics

Baseline conditions for irrigation hardware system efficiency improvements were estimated from the USDA Farm and Ranch Irrigation Survey and discussions with Bonneville and utility staff with in-depth experience working with farmers on these systems. Baseline characteristics (i.e., the average amount of water applied by crop type and acreage) for irrigation water management in the Columbia Basin Project was provided by GAMA. Dairy efficiency in the region was assumed to parallel that found by NYSERDA.

Measure Applicability and Measure Achievability

No quantitative study has been conducted in the region to determine the current saturation and remaining opportunities for improvement in either irrigation system hardware or on diaries. Therefore, judgment, based on discussions with Bonneville and utility program staff served as the basis estimating the remaining number of systems and diaries in the region that could carry out cost-effective energy efficiency improvements. Where quantitative data was available (e.g. the acreage irrigated with high pressure systems), these data were used to size the remaining opportunities for savings.

Guide to the Agriculture Conservation Workbooks

The eight workbooks containing the Agriculture Sector conservation resource assessment are downloadable from the web http://www.nwcouncil.org/energy/powerplan/7/technical. These are provided in Table G - 22.

Table G - 22: Agriculture Sector Supply Curve Workbooks

File Name	File Scope
Ag_Master.xlsx	Master workbook for agriculture conservation modeling
Ag-Area_Lights-7P_v4.xlsx	LED barn area lighting
Ag-Convert_P_Irr-7P_v3.xlsx	Conversion of high/medium pressure to low-pressure irrigation systems
Ag-Dairy-7P_v2.xlsx	Dairy farm efficiency measures
Ag-Irr_Eff-7P_v2.xlsx	Low elevation spray application irrigation
Ag-Irr_Hardware-7P_v4.xlsx	Irrigation hardware improvements
Ag-Irr_Motor-7P_v3.xlsx	Green motor rewind
Ag-Irr_WaterMgmt-7P_v2.xslx	Irrigation water management (SIS)

DISTRIBUTION SYSTEM

The Seventh Power Plan includes an update to the conservation potential assessment on the region's electric distribution system that was conducted for the Sixth Power Plan. The original assessment is based on a study completed in 2007 by the Northwest Energy Efficiency Alliance (NEEA). Significant conservation potential was identified the distribution system improvements. A majority of the savings is derived from conservation voltage regulation (CVR) which is a reduction of energy consumption resulting from a regulation of feeder voltage within closer tolerances to minimum standards (ANSI standard C84.1). Baseline energy use, cost data, and revised voltage control measure savings estimates were updated for the Seventh Power Plan.

Measure Bundles

The distribution system efficiency assessment includes four measures to regulate voltage and upgraded systems to achieve energy and capacity savings. The measures differ with respect to the techniques used to manage voltage and other system electrical characteristics to maximize efficiency.

6. Lowers the distribution voltage level only using the line drop compensation voltage control method.
7. System improvements including reactive power management, phase load balancing, and feeder load balancing using either line drop compensation or end-of-line voltage control methods.
8. Voltage regulators on 1 of every 4 substations and select reconductoring on 1 of every 2 substations.
9. Lowers the distribution voltage level using the end-of-line voltage control method.

Overview of Methods

The distribution system conservation assessment uses savings estimates from measured data on actual projects conducted on utility feeders over the course of one year, or more from the 2007 study and subsequent data from a few more recent projects. Savings are a function of the reduction in voltage, the end-use equipment at customers' sites including the mix of resistive and conductive loads, and electrical characteristics of the distribution system configuration. Savings estimates vary by utility for the largest utilities. For smaller utilities, average system characteristics from the measured data set were used to represent electrical and load conditions in smaller utilities. Savings also differ across residential, commercial and industrial feeders. Savings on residential feeders are highest. Costs and savings for four major measures were identified and applied to a descriptive data set of the region's distribution system. The dataset contains system loads by customer class, substation counts, feeder counts, customer counts and climate zones for 137 regional utilities. Savings accomplished since the Sixth Power Plan were accounted for.

Physical Units

The distribution efficiency savings, especially conservation voltage regulation, come from adjusting the feeder voltage which results in a small percentage of the overall kWh consumption. Therefore, the primary units are the total electricity sales by utility, along with the number and type of substations for the utility.

Baseline Characteristics

Baseline updates include the savings accomplishments, updated regional energy use (2012, by utility), and updated knowledge about utility-specific savings inputs.

Measure Applicability

Measure applicability is estimated for residential, commercial and industrial feeders by measure. Applicability is highest for residential feeders (80 – 85 percent) and lowest for industrial feeders (10 – 15 percent). Two key factors which drive the savings are conservation voltage regulation factor and the percent change in voltage achievable. These are taken from the 2007 NEEA study or subsequent utility-specific updates. These input assumptions are worksheet 'RegionWideSubstations'.

Measure Achievability

The Council generated a very slow ramp rate for achievability based on regional experience with the measures to date and advice from its Conservation Resources Advisory Committee. The ramp rate is unique to the distribution efficiency measure set. Sheet 'ACHIEV' contains the details.

Guide to the Distribution Efficiency Workbooks

The distribution efficiency data and calculations are contained in a single workbook (see Table G - 23), available on the web http://www.nwcouncil.org/energy/powerplan/7/technical. One of the key worksheets in this file is called "RegonWideSubstations" that contains a listing of utilities and associated data for the DE measures. Selected other worksheets and their corresponding scopes are also listed in Table G - 23.

Table G - 23: Distribution System Supply Curve Workbook

File Name	File Scope
DE-Distribution-7P_V4.xlsx	This file contains all data and calculates for the DE assessment
Worksheet Name	**Worksheet Scope**
SC-Retro	Contains the final DE supply curve
7PSourceSummary	Descriptive information about the measures and assumptions
Rollup	Summary of the measure data
RegionWideSubstations	Detailed substation information by utility, applicability factors, savings factors, calculations of savings potential by utility and measure and regional totals
Approach for 7th Plan	Descriptive summary of the approach
SixGoingOnSeven	Measure achievement data since the Sixth Power Plan

DISTRIBUTED PHOTOVOLTAICS

Distributed solar photovoltaics (distributed PV) are broadly considered “behind-the-meter” PV panels that are generally mounted on the rooftop of a house, commercial building, or other structure to provide on-site electricity. The primary use of this electricity is for the building with any excess generation sold back to the grid or stored in batteries.

Measure Bundles

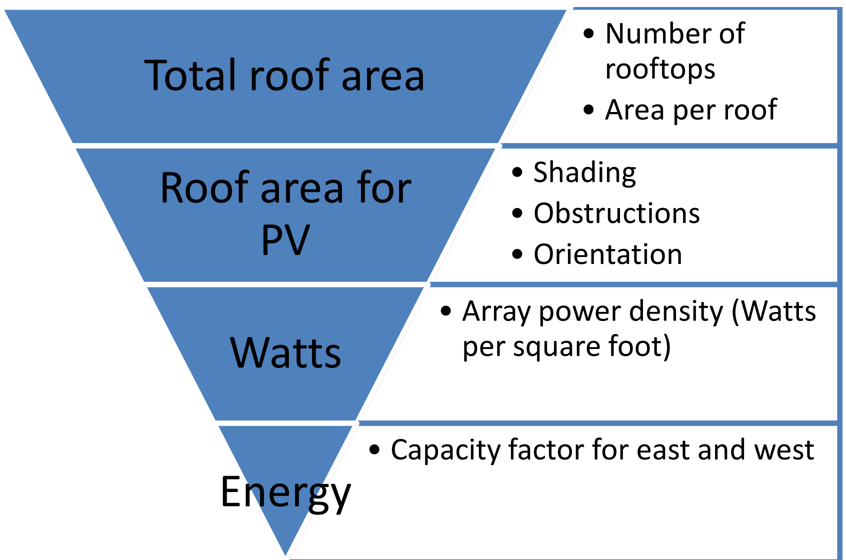
The Council’s analysis considered the potential from distributed PV for the residential and commercial sectors, considering installations on both the west and east side of the Cascade Mountains, to account for variant insolation levels. For analytic simplicity, Portland, Oregon was used as the proxy for the west-side installation, and Boise, Idaho was the proxy for the east-side installations. There were four measure bundles considered:

1. Residential west side
2. Residential east side
3. Commercial west side
4. Commercial east side

Overview of Methods

The Council estimated the potential for distributed PV based on roof area estimates taken from the recent Pacific Northwest residential and commercial stock assessments, accounting for shading factors and rooftop orientation. The solar calculator PVWatts®[21] was used to set the expected annual capacity factor for both the east and west side of the Cascade Mountains. PVWatts also produces hourly generation shapes. Costs are based on 2014 program data from Energy Trust of Oregon, with assumptions of cost declines, resulting in a 2025 cost of about 66 percent of 2014 costs. As a final step, costs were adjusted between 2016 and 2021 to reflect the federal solar tax credit adopted in 2015. The overall approach to estimating the technical potential for distributed PV is provided in Figure G - 11, where the details are discussed below.

Figure G - 11: Approach to estimating PV technical potential



Physical Units

The distributed PV potential is estimated based on the total area of residential and commercial roofs.[22] The Council estimates approximately 2.6 billion square feet of commercial roof area by 2035. For residential buildings, the total roof area is calculated from the assumed average single family home size (2,300 square feet), number of stories (1.4 per home), and total number of buildings (6.3 million in 2035), totaling approximately 10.4 billion square feet.

Not all the available roof area is usable for a PV array. Obstructions, shading, and orientation all limit where an array could be mounted. The Council used estimates of 25 percent of available roofs for residential and 60 percent for commercial can have a PV array.[23] As such, the available roof area

[21] http://rredc.nrel.gov/solar/calculators/pvwatts/version1/change.html
[22] Industrial rooftops were not considered as part of the analysis.
[23] DNV GL, *A Review of Distributed Energy Resources* for NYISO, 2014

decreases to 2.4 billion square feet for residential and 1.6 billion square feet for commercial. These roofs are split approximately 34 percent on the east side and 66 percent on the west side.

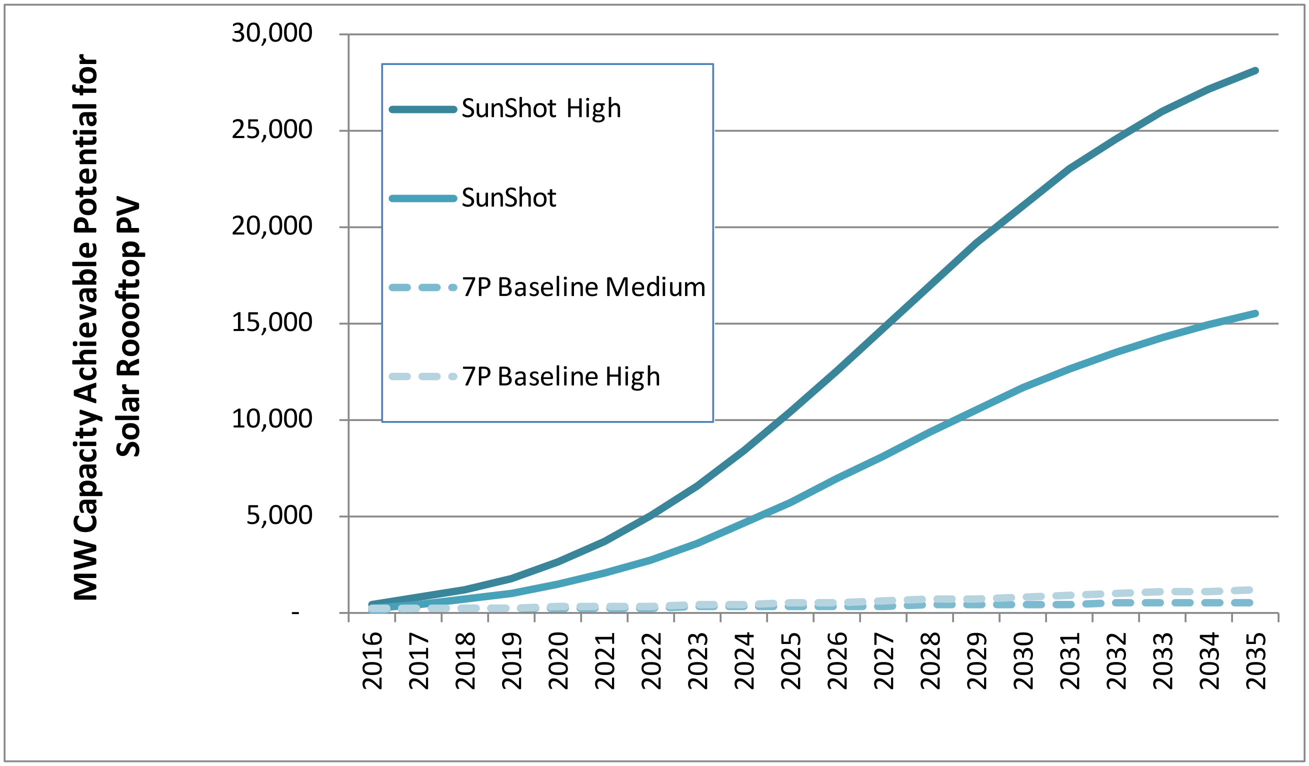
Baseline Characteristics

To estimate the energy generated from the arrays, the Council assumed an array power density of 12.4 watts per square foot.[23] This results in a total distributed PV nameplate capacity technical potential of about 50,000 megawatts (DC) in 2035. To estimate the energy produced, the Council used PVWatts which estimated the average capacity factor for distributed PV as 13 percent for the west side and 17 percent for the east side of the Cascades. The resulting total technical potential is about 5,500 average megawatts in 2035.

Measure Applicability and Achievability

Rooftop solar PV is an emerging technology. There are many barriers to complete adoption of what is technically achievable. The Council estimated the maximum achievable technical potential based on sensitivity analysis done by the National Renewable Energy Lab (NREL) as part of its SunShot Vision project, an assessment in which solar provides a significant share of electricity demand in the U.S. The NREL study analyzed many factors that will influence the pace of penetration of rooftop PV. These included PV prices, regional solar resources, local electricity rates, financing structures, net-metering policy, incentives, and other market characteristics. Figure G - 12 shows the ramp rates that the Council developed from the NREL study to estimate achievable fractions of technical potential by year. The figure shows the high and low range of achievability as well as the potential assumed to be adopted in the baseline demand forecast.

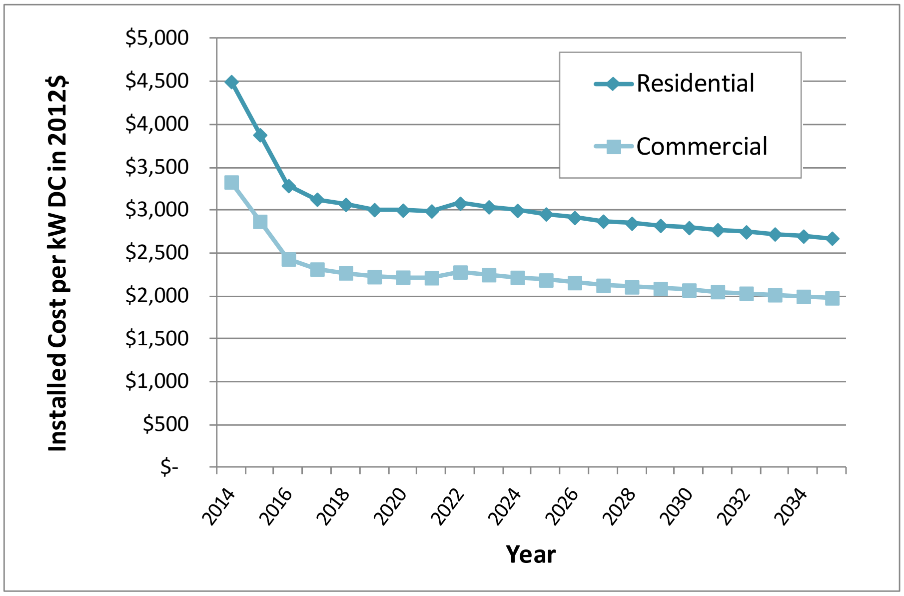
Figure G - 12: Ramp Rates for Achievable Solar PV Potential



Measure Costs

The costs for distributed PV are based on Energy Trust of Oregon program data, for residential and commercial systems. PV has experience rapid decrease in costs in the past few years and these declines are projected to continue. The projected costs for distributed PV declines at the same rates as those used for utility-scale PV (see Chapter 13) and are based on a variety of secondary sources including cost trends from projects planned and constructed in the 2010-2016 period plus forecast estimates from several consulting groups and NREL. The total installation costs (all in 2012$) are summarized in Figure G - 13. The figure reflects the expected decrease in cost of distributed PV due to technical innovation and production volume as well as the federal tax credit currently available. Federal legislation extending the Solar Investment Tax Credit (ITC) was signed into law on December 18th, 2015. The bill extends the 30 percent Solar Investment Tax Credits for both residential and commercial projects through the end of 2019, and then drops the credit to 26 percent in 2020, and 22 percent in 2021 before dropping permanently to 10 percent for commercial projects and 0 percent for residential projects.

Figure G - 13: Forecast of Distributed PV Costs

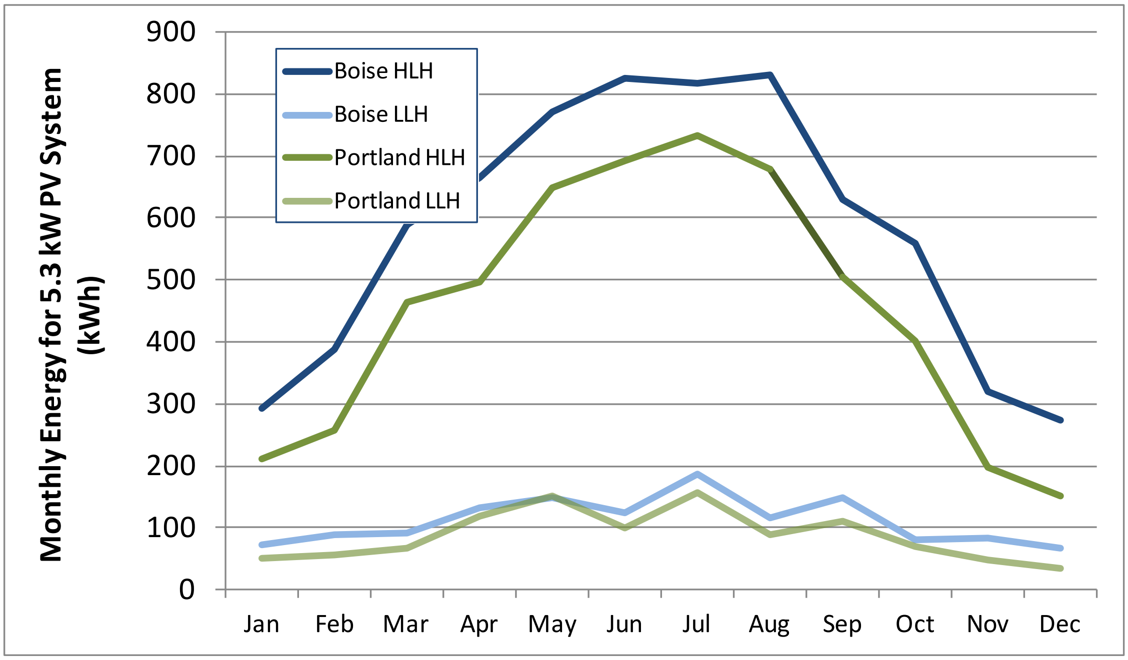


In addition to the installation costs, there is an inverter replacement cost and an annual O&M cleaning cost. Cost estimates for these factors are taken from the NREL studies. An estimate of system integration costs is also included. Bonneville integrations costs from its 2014 tariff were used to estimate integrations costs.

Daily and Seasonal Shape and Capacity Contribution

The solar calculator PVWatts® was used to estimate the hourly, daily and monthly energy, and summer and winter peak contribution of rooftop PV. Figure G - 13 shows Heavy Load Hour (HHL) and Light Load Hour (LLH) energy by month for typical residential applications in Boise and Portland. Daytime energy production is nearly three times higher in summer months than in winter months in both locations. Off hour production is very small relative to daytime heavy load hour production.

Figure G - 14: Monthly Energy from Typical 5.3 kW Residential PV System



Guide to the Distributed PV Workbooks

There is one workbook used for the distributed PV analysis: DisGen-Solar PV _v8.xlsx and is available on the web http://www.nwcouncil.org/energy/powerplan/7/technical. This workbook contains the cost, sizing, and achievability rate.