Appendix E: Conservation Supply Curve Development

OVERVIEW

This Appendix provides an overview of the general Council methodology for estimating the conservation resource potential in the region and describes the major sources of information used to prepare that analysis. It also provides links to spreadsheets containing the detailed input assumptions and specific source data used for each of the measures in the Council's conservation supply curves.

The Council estimates costs and savings for over 1,400 measures. These costs and savings are used to develop supply curves of conservation potential available by year. The supply curves represent the amount of conservation available at different cost levels. Costs are expressed as TRC (Total Resource Cost) net levelized costs so they can be compared to the costs of power purchases and the costs of new resource development.[1] The Council uses an in-house model called ProCost to calculate TRC net levelized cost. The following sections describe the "global" inputs and methodology used by the Council in its assessment of regional conservation resource potential.

Cost-Effectiveness Methodology Used in the Portfolio Analysis Model

The Council uses a multi-step process to evaluate conservation cost-effectiveness. Conservation supply curves are constructed based on cost and savings available from over 1,400 conservation measures 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 Regional Portfolio Model (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 over 750 different futures. The RPM analysis produces strategies for conservation and generation resource development that have lowest cost and lowest 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 E-1.

As with all other resources, the Council uses the RPM to determine how much conservation is cost-effective to develop.[2] 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

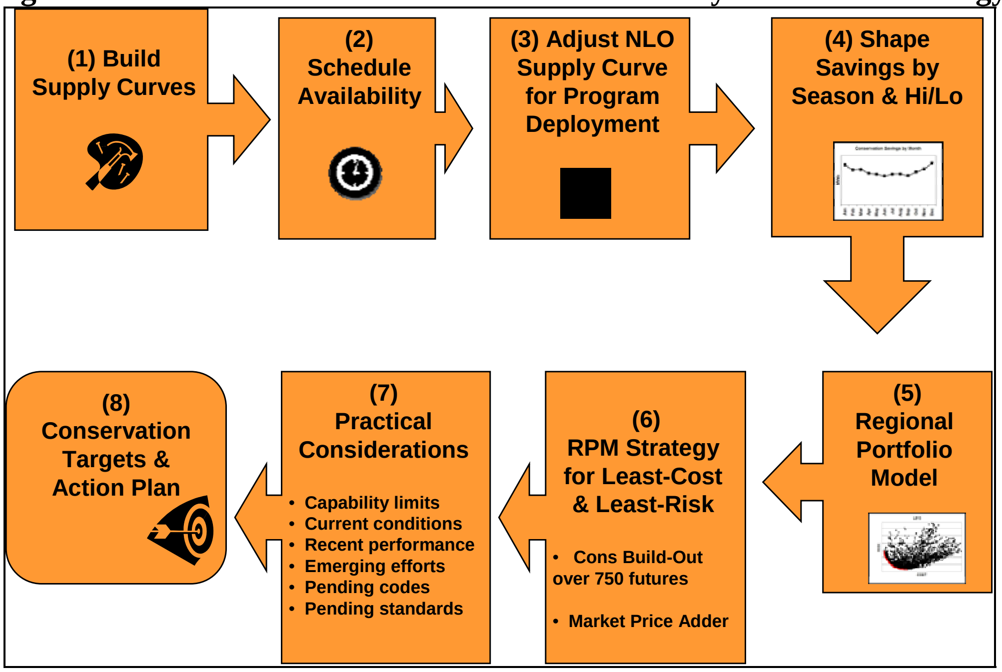
---

[1] "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, then levelized over the life of the program.

[2] A full explanation of how the RPM arrives at the cost-effective amount of conservation is described in Appendix J in the section entitled "The Sources of Increased Conservation".

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.

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



These two supply curves, one for discretionary or non-lost opportunity (NLO) resources and a second for lost opportunity (LO) resources, depict the amount of savings achievable at varying levelized costs. 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.[3] The available savings are also allocated to high-load and low-load time periods to reflect the time-based value of savings and savings impact on capacity needs.

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

The reason the RPM uses separate LO and NLO supply curves is that if a LO 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). Since NLO conservation resources do not have this restricted "window of opportunity," the pace of their acquisition can be accelerated or slowed. Deferring the purchase of high-cost NLO conservation resources to periods when market costs are high reduces cost and risk. That is, a portfolio management strategy that acquires high-cost NLO conservation resources early results in higher cost and risk

[3] Line losses input assumptions based on estimates of marginal line losses avoided by reduced load between generation and the end point of consumption for both the transmission and local distribution system. Overall conservation avoids line losses that range between 9 percent and 10 percent depending on the load shape of each measure's savings.

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 NLO conservation resource is less in the near-term than in the long term. However, since the acquisition of LO conservation resources cannot be deferred there is more value in purchasing these resources at higher cost. In order to reflect the difference in the flexibility and value of these two types of conservation resources the Council's RPM uses acquisition decision rules specific to each resource type.

The RPM models LO resources using twenty annual supply curves that represent the quantity of technically achievable conservation available each year from 2010 through 2029 at levelized cost from zero up to $400 per megawatt-hour ($2006$). The amount of LO 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. The RPM can acquire these technically achievable LO resources each year up to the quantity it determines to be cost-effective over the full planning period and across the 750 futures tested by the RPM. Any LO conservation resource in the supply curve that is not acquired in a given year is not available for deployment in any future year.

The RPM decision rule for LO conservation also reflects that much LO conservation can be developed through improvements in codes and standards, that either by statute or historical tradition, always *increase* in stringency. In order to mimic this effect, the RPM considers that once a cost-effectiveness level on these annual LO supply curves is selected (e.g., LO resources up to $100 per megawatt-hour), that cost-effectiveness level becomes the lower bound for all future LO acquisitions.

In contrast, the RPM models NLO conservation resource acquisition using a single supply curve representing the total technically achievable quantity of these resources over the entire 2010 through 2029 period at levelized cost from zero up to $400 per megawatt-hour (2006$). Because considerably more low-cost NLO conservation resources are immediately available at levelized cost below current market prices (e.g., over 4,000 average megawatts are available at a levelized cost less that $40 per megawatt-hour) constraints are placed on the maximum amount of NLO resources that can be acquired annually. If this were not done, the RPM would produce a portfolio strategy that called for the acquisition of all conservation resources costing less than current market prices in 2010. This strategy, while economically efficient, is clearly not practical since it would result in the acquisition of 3,000 to 4,000 average megawatts in 2010. Consequently, in the 6th Plan, a limit of 160 average megawatts per year was placed on the pace of NLO acquisitions.[4]

In addition to the constraint placed on the pace of NLO conservation resource acquisition, the RPM is also not permitted to "buy its way up the supply curve," acquiring only the least expensive conservation measures the in the near term of the planning period. Instead, NLO the supply curve is modified so that in the near term the RPM must select NLO resources from a

[4] The limit in the 5th Plan was 140 average megawatts per year and was based on the maximum historical levels of conservation acquisition prior to that plans adoption. While the 6th Plan was being developed it was clear that the region was exceeding the 5th Plan's annual conservation targets, so a higher pace was selected. Subsequent to the issuance of the draft 6th Plan the region's most recent conservation achievements were compiled. It now appears that 160 average megawatts per year is a conservative estimate of the maximum level of NLO achievable in the region, since both 2007 and 2008 savings were well above this level totally 200 and 235 average megawatts, respectively.

distribution of cost across the entire technically achievable supply curve with the upper limit based on trends in recent market prices.

This modeling framework is used to reflect the fact that conservation acquisition programs generally include measures across a wide range of levelized cost (e.g., residential weatherization programs include low-cost ceiling insulation and relatively higher cost window efficiency improvements). To represent a preference for lower cost NLO resources in the near term, the RPM samples more frequently from the lower cost portion of the supply curve than from the higher cost portion. The result of this modification is that the lowest cost block on the NLO supply curve is available to the RPM is at a cost of $23 per megawatt-hour. About 1,900 average megawatts are available at that price. After the RPM uses up this first block of low cost conservation, subsequent amounts of conservation, another 1,800 average megawatts, is available at increasing costs up to $400 per megawatt-hour.

Determining the Cost-Effectiveness Limit for Conservation

The RPM determines the amount of conservation that is cost-effective by testing the value of acquiring increasingly costly conservation compared to purchasing additional power from the wholesale market. However, the cost-effectiveness limit for conservation is not the wholesale market price of power. This is because the future wholesale market price of power in the WECC is both uncertain and does not fully reflect the cost of developing new resources. For example, Resource Portfolio Standards (RPS) require that some utilities purchase renewable resources that are beyond their current need for power. As a result, this will create a systematic surplus in the wholesale power markets in the West. This market will largely consist of existing non-RPS resources, a portion of whose cost are already being borne by utility customers and need not be recovered in the market.

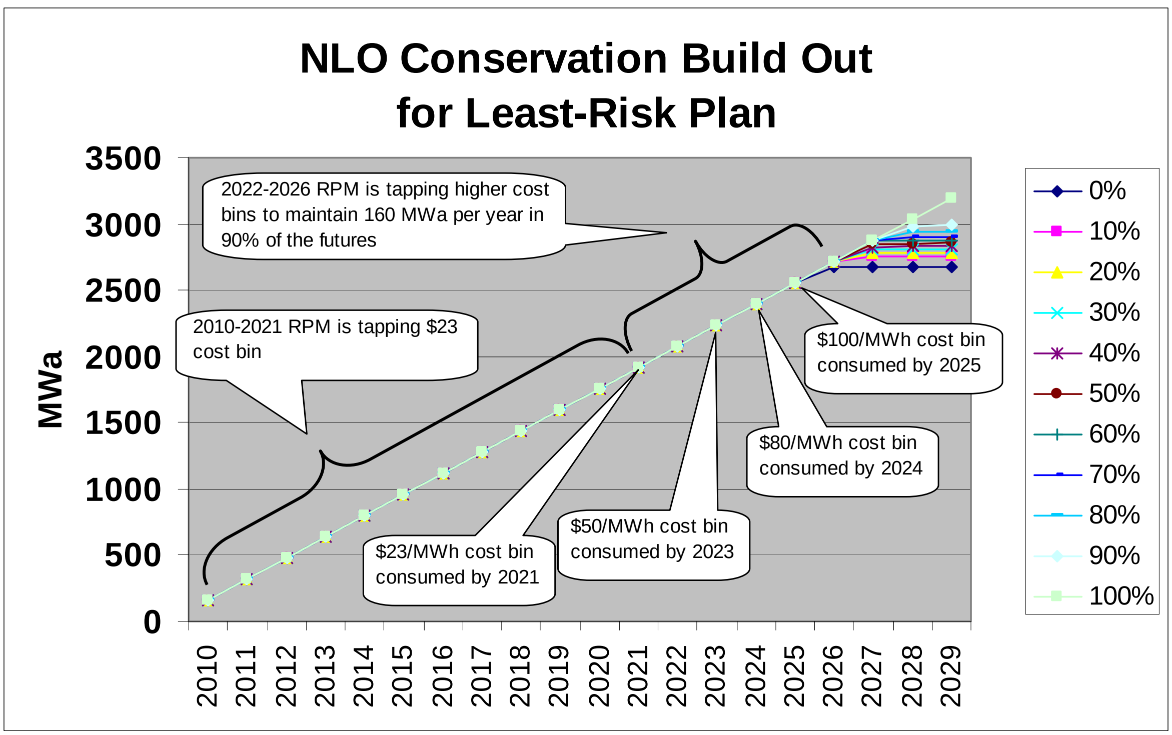
In lieu of using the wholesale market price another traditional approach to determining the “cost-effectiveness” limit for conservation has been to compare its cost to that of what is viewed as the “avoidable resources,” for example a combined cycle combustion turbine. The problem with this is that in the Council’s planning process the expected “online” date and long-rung cost of the “avoidable resource” varies across the 750 futures tested by the RPM. In order to address this uncertainty, the RPM tests alternative “adders” to the short-run market price to reflect the long run cost of new generating resources and the range of uncertainties for all key determinants of those cost across the 750 futures. Different adders are tested for LO and NLO resources.

The market adders for LO conservation resources along the efficient frontier ranged from a low of $20 per megawatt-hour over market prices at the least-cost end of the efficient frontier to $50 per megawatt-hour over market prices adder at the least-risk end. In both least-risk and least-cost cases the NLO adder was $80 per megawatt-hour, significantly higher than the LO adder. The reason for this is that there is a large quantity of low cost NLO resources and the pace their of development is constrained such that the NLO adder does not affect the amount and average cost of NLO resources acquired until the very end of the planning period (i.e., post-2025). To confirm this Council compared the amount of NLO resources developed using a $10 per megawatt-hour and with that developed using an $80 per megawatt adder. The amount of NLO resources developed through 2023 was identical regardless of which adder was used.

In contrast, the market price adder for LO conservation resources affects the amount of resources acquired and their average cost beginning in 2010. This means that the RPM tests the effect of the market adder for LO conservation resources every year of planning period for each of the 750 futures. As a result, when the RPM tests a market price adder for LO conservation resources that results in acquisition costs that are too high, the addition of high cost resources increases the net present value cost of the power system in all futures where market prices are lower. The RPM then test alternative LO market price adders until the one that produces the lowest cost portfolio for each level of risk is identified. It can be inferred from this that the near term market price adder for NLO conservation resource should be similar to the LO adder since the acquisition of high cost NLO resources would produce the same result (i.e., a higher net present value cost to the power system).

Figure E-2 shows the average quantity of NLO conservation resources acquired across all 750 futures tested in the RPM for the least risk plan identified by the RPM. As can be seen from this figure the RPM acquires NLO conservation resources up to the160 average megawatt per year limit through 2025. In fact, there are no futures where the pace falls below 160 average megawatts per year through 2025.

Figure E-2: NLO Conservation Resources Acquired Across 750 Futures with a $80/MWh "Market Adder"



A review of Figure E-2 also reveals that the RPM develops about 2,400 average megawatts of NLO conservation resources by the end of 2025 in all 750 futures. Based on the Council's NLO conservation resource supply curve, in order to for the RPM to acquire this quantity of NLO conservation resources by the end of 2025 it acquires conservation resources at levelized cost up to $70 per megawatt-hour over this time period. Moreover, in 90 percent of the futures, the RPM acquires over 2,600 average megawatts by the end of 2025. In order to for the RPM to acquire this quantity of NLO conservation resources by the end of 2025, the RPM must acquire conservation resources up to a levelized cost of $100 per megawatt-hour. Therefore, it appears that the near term market adder for NLO must be large enough to secure NLO resources with levelized cost up to $100 per megawatt-hour, but no higher than the $50 per megawatt-hour market adder for LO resources to avoid purchases that prove too costly in the long run.

There are two final steps in establishing the cost-effectiveness threshold for conservation measures and programs. First, as describe above the NLO and LO conservation supply curves described in Chapter 4 are compared to the "expected value" amount of LO and NLO resources developed by the RPM. The final 6th Plan calls for the development of 5,960 average megawatts of conservation by 2030, of which 3,090 average megawatts are lost-opportunity resources and 2,870 average megawatts are non-lost opportunity resources. In order to obtain these quantities of conservation from the 6th Plan's conservation supply curves would require purchasing up to a cost of $100 per megawatt-hour for a measure with the load shape of all conservation in the 6th Plan and an expected measure life of 20 years. As a point of comparison, new generating facilities currently going into service have levelized cost that range from $80 to $120 per megawatt-hour.

However, as stated previously, the use of levelized cost does not capture the value of each measures savings over the course of a day or year nor does it capture any non-energy benefits or costs. Therefore, in order to determine the cost-effectiveness is each conservation measure or program must tested using the Council's PROCOST model or similar model which accounts for the load shape of the measure or programs savings, non-energy benefits and/or cost and which applies the market price adders described above to a single forecast of future wholesale market prices. As described previously, these "adders" adjust the short run market prices to reflect the uncertainty surrounding the long-run cost of acquiring and operating new generating resources across a wide range of potential future conditions, including potential carbon control costs. It appears that a market adder of $50 per megawatt-hour for LO resources and $35 per megawatt-hour over near-term market prices would result in cost-effective conservation resource development.

The PROCOST model computes the present value of all of a conservation measures costs and benefits based on a total resource cost analysis. The Council uses a measures total resource cost benefit-to-cost ratio, not its levelized cost, to determine whether a measure is cost-effective. This ratio captures all the time-differentiated value of a measure's energy and capacity savings, its non-energy benefits and costs, the regional Act 10 percent credit and the measures direct and administrative costs.

Table E-1 shows the regional achievable savings by sector and major measure bundle derived using a cost-effectiveness limit of $100 per megawatt-hour for both lost-opportunity and non-lost-opportunity conservation. The values in this table are based on the Council's medium load forecast and therefore, the actual mix of measures targeted at new construction versus retrofit will differ. Savings are shown for both the near term (2014) and for the entire period covered by the 6th Plan (through 2029).

The purpose of Table E-1 is to show the major sources of energy efficiency identified in the Council's 6th 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 E-1: Estimated Cost-Effective Conservation Potential in Average Megawatts 2010-2014 and 2010 - 2029

Measure Bundle	MWa by 2014	MWa by 2029	Description of Bundle
Residential			
Heat Pump Water Heater	12	490	Energy Star heat pump water heater
Television and Set Top Box	44	470	Energy Star 5.0 or better televisions
Computers and Monitors	33	360	Efficient Desktop PC and Efficient Monitor (Residential & Commercial)
Heat Pump Conversions	38	390	Space heating conversion from electric resistance to heat pump
Residential Appliances	22	170	Clothes Washer, Dishwasher, Refrigerator, Freezer
New Construction Shell	16	170	Measures above current state or local codes
Heat Pump Upgrades	10	100	Space heating heat pumps better than code
Weatherization	96	290	Primarily high performance windows
Ductless Heat Pump	65	195	
Lighting	259	285	Includes both EISA and non-EISA covered lamps
Showerheads	85	85	2.0 gallons per minute or lower flow rate
Other Residential Measures	11	65	
All Residential Measures	**692**	**3070**	
Commercial			
Lighting Power Density	82	370	Lamp, ballast and fixture improvements to lighting power density
Interior Lighting Controls	13	90	Occupancy controls for lighting areas not required by code
Exterior Lighting	28	190	Streetlight, parking, outdoor area lighting to high-efficiency sources and control
Integrated Building Design	7	60	Multiple measures applied in integrated design practice for select new buildings
Packaged Refrigeration Equipment	8	50	Efficient refrigerators beverage merchandisers, ice makers and vending machines
Controls Commission Complex HVAC	32	110	Commissioning on HVAC systems in buildings with complex HVAC systems
Controls Optimization Simple HVAC	19	50	Package Roof Top HVAC measures
Grocery Refrigeration Bundle	28	90	Grocery store refrigeration measures
Computer Servers and IT	15	130	Consolidation & virtualization & upgrade of servers in embedded server
Network PC Power Management	15	70	Control of a networked computer's advanced energy management systems

Measure Bundle	MWa by 2014	MWa by 2029	Description of Bundle
Municipal Sewage Treatment & Water Supply	13	50	Suite of measures for sewage treatment and water supply
Cooking and Restaurant Equipment	7	40	Ovens, steamers, hoods, sprayers, holding cabinets and other kitchen equipment
Other Commercial Measures	23	110	
All Commercial Measures	**290**	**1410**	
Industrial			
Compressed Air	21	40	Efficient equipment and system optimization across all industries
Lighting	22	70	Lamp, ballast, fixture and control improvements across all industries
Fans	21	80	Efficient equipment and system optimization across all industries
Pumps	19	80	Efficient equipment and system optimization across all industries
Transformers	2	10	Transformers more efficient than federal standards across all industries
Belts	7	10	Synchronous belts across all industries
Material Handling	5	30	Efficient equipment and system optimization across all industries
Motors	1	10	Efficient motor rewinds across all industries
Hi-Tech	6	10	Industry-Specific Processes: Clean rooms and production facilities
Pulp	3	10	Industry-Specific Process: Effluent treatment, refiners
Paper	2	10	Industry-Specific Process: Pulp screening, effluent treatment
Food Processing	13	30	Refrigeration equipment and system optimization
Food Storage	35	70	Refrigeration equipment and controlled atmosphere system optimization
Lumber & Wood Products	2	20	Industry-Specific Process: Material handling, drying, pressing
Metals	0.1	0.5	Industry-Specific Process: Arc furnace
Plant Energy Management	9	60	Multiple-system O&M in large facilities
Energy Project Management	17	120	Multiple-system energy management, tracking and reporting in large facilities
Integrated Plant Energy Management	16	100	Top tier whole plant optimization in large facilities
All Industrial Measures	**200**	**760**	

Measure Bundle	MWa by 2014	MWa by 2029	Description of Bundle
Agriculture			
Irrigation Hardware System Efficiency	35	70	Leak reduction, lower pressure delivery, pump & system efficiency
Irrigation Water Management	8	20	Scientific irrigation scheduling
Dairy Efficiency Improvement	4	10	Refrigeration, Lighting and
All Agricultural Measures	**47**	**100**	
Distribution			
Reduce system voltage	47	160	Reduce system voltage w/ LDC voltage control method
Light system improvements	8	80	VAR management phase load balancing, and feeder load balancing
Major system improvements	9	90	Voltage regulators on 1 of 4 substations, and select
Voltage control	4	40	End of Line (EOL) voltage control method
Unique system improvements	5	30	Seattle City Light system implement EOL w/ major system improvements
All Distribution Efficiency Measures	**72**	**400**	
All Sectors			
Total	**1308**	**5740**	

The Costs of Conservation

The costs included in the Council's analyses are the sum of the total installed cost of the measure, and any operation and maintenance costs, or savings, associated with ensuring the measure's proper functioning over its expected life. If the use of an electric efficiency measure increases or decreases the use of another fuel, such as improving the efficiency of lighting in a commercial building may increase the use of natural gas for heating, the cost or savings of these impacts are included in the analysis.

The Value of Conservation

Part of the value of a kilowatt-hour saved is the value it would bring on the wholesale power market and part of its value comes from deferring the need to add distribution and/or transmission system capacity. This means that the marginal "avoided cost" varies not only by the time of day and the month of the year, but also through time as new generation, transmission and distribution equipment is added to the power system. The Council's cost-effectiveness methodology starts with detailed information about when the conservation measure produces savings and how much of these savings occur when distribution and transmission system loads are at their highest. That is, each measure's annual savings are evaluated for their effects on the power system over the 8,760 hours in a year.[5]

The Northwest's highest demand for electricity occurs during the coldest winter days, usually during the early morning or late afternoon. Savings during these peak periods reduce the need for distribution and transmission system expansion. Electricity saved during these periods is also more valuable than savings at night during spring when snow melt is filling the region's hydroelectric system and the demand for electricity is much lower. However, since the Northwest electric system is linked to the West Coast wholesale power market, the value of the conservation is no longer determined solely by regional resource cost and availability.

Value of Energy Saved

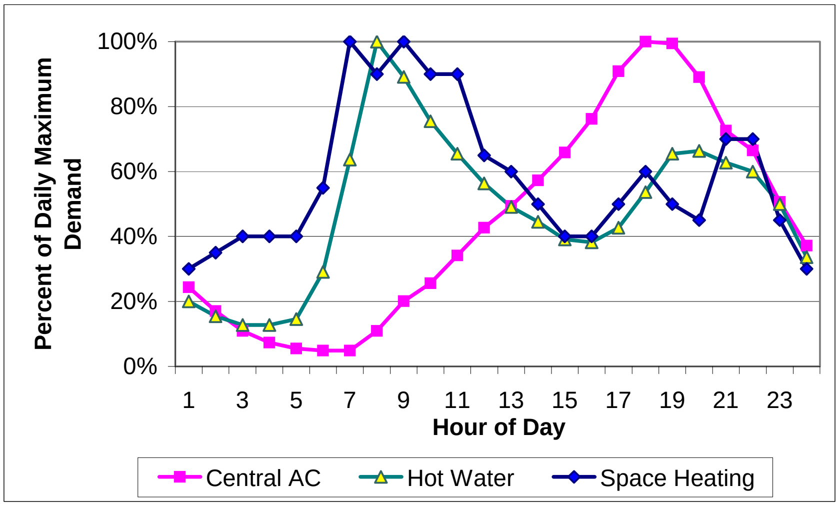
Given the interconnected nature of the West, regional wholesale power prices reflect the significant demand for summer air conditioning in California, Nevada and the remainder of the desert Southwest. Consequently, wholesale power prices are as high as or higher during the peak air conditioning season in July and August than they are when the Northwest system peak demand occurs in the winter. Consequently, a kilowatt-hour saved in a commercial building in the afternoon in the Pacific Northwest may actually displace a kilowatt-hour of high-priced generation in Los Angeles on a hot August day. Whereas a kilowatt-hour saved in street lighting might displace a low-cost imported kilowatt-hour on a night in November.

As noted previously, in addition to its value in offsetting the need for generation during the hours it occurs, conservation also reduces the need to expand local power distribution system capacity. Figure E-3 shows typical daily load shape of conservation savings for measures that improve the efficiency of space heating, water heating and central air conditioning in typical new home built

[5] To simplify this analysis the Council divides each day and week into four time segments representing high, medium high, medium and low demand hours, resulting in four price "periods" per day for each month for a total of 48 prices per year.

in Boise. 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 "0" representing midnight.

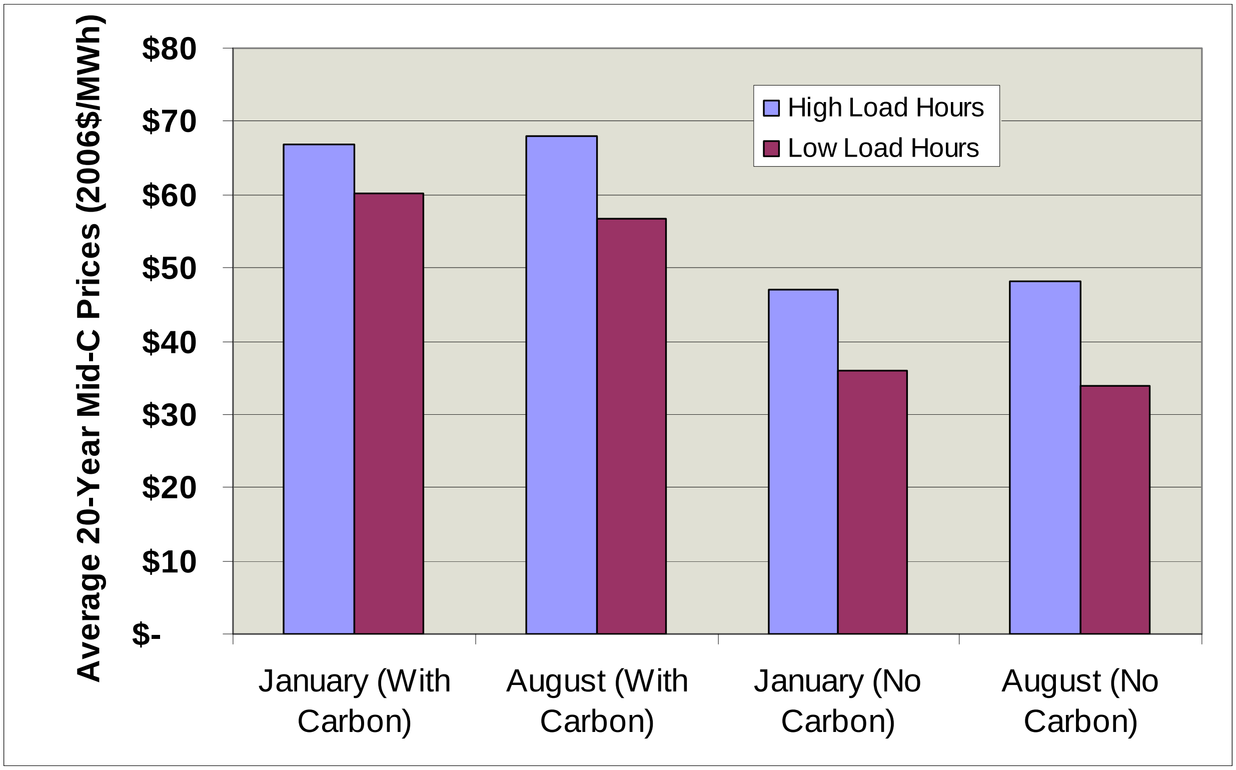
Figure E-3: Hour Load Profile for Residential Central Air Conditioning Water Heating and Space Heating Conservation Savings



As can be seen from inspecting Figure E-3, 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, peaking in late afternoon and decline again as the evening progresses and outside temperatures drop.

The Council's forecast of future hourly wholesale market power prices vary over the course of typical summer and winter days. Figure E-4 shows the average levelized wholesale market prices at Mid-C for January and August for high and low load hours, with and without carbons costs. As can be seen from Figure E-4, high load hour savings are more valuable than those that occur during low-load hours both summer and winter. However, the gap between high- and low-load hour market prices narrows when average carbon costs are included. This occurs because increases in carbon cost have a greater impact on coal fired generating cost than on natural gas fired generation and across the WECC high-load hour electricity is being generated by natural gas turbines, while demand during low-load hours is met by coal-fired generation.

Figure E-4: Forecast Levelized Wholesale Power Market Prices at Mid Columbia Trading HUB for January and August High-Load and Low-Load Hours



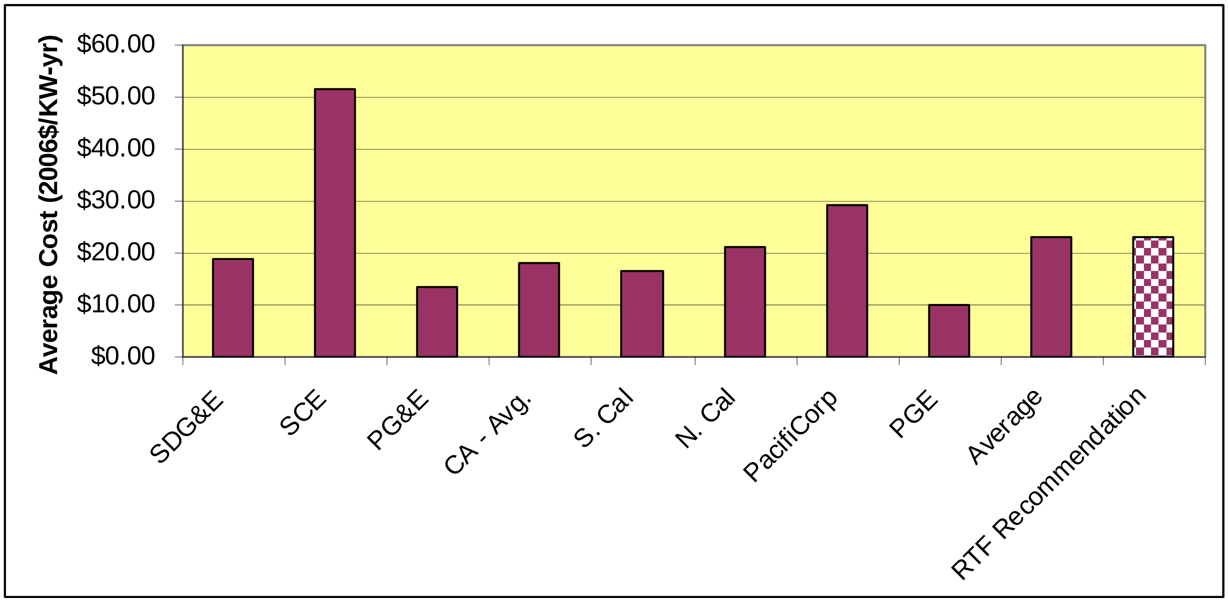
In order to capture this differential in benefits, the Council computes the weighted average time-differentiated value of the savings of each conservation measure based on its unique conservation load shape. Each month's savings are valued at the avoided cost for that time period based on the daily and monthly load shape of the savings. The weighted value of the all time period's avoided costs establishes the cost-effectiveness limit for a particular end use.

Forecast of future wholesale power market prices are subject to considerable uncertainty. Therefore, in order to determine a more "robust" estimate of a measure's cost-effectiveness it should be tested against a range of future market prices. The Council currently uses its "base case" AURORA model forecast of future wholesale market prices to determine conservation cost-effectiveness. However, in order to reflect the uncertainty of future market prices rather than a single market price forecast, the Council adjusts the AURORA market price forecast to incorporate the value that conservation provides as a hedge against future market price volatility. The derivation of this value is described fully in Chapter 9 of the sixth plan.

Value of Deferred Transmission and Distribution Capacity

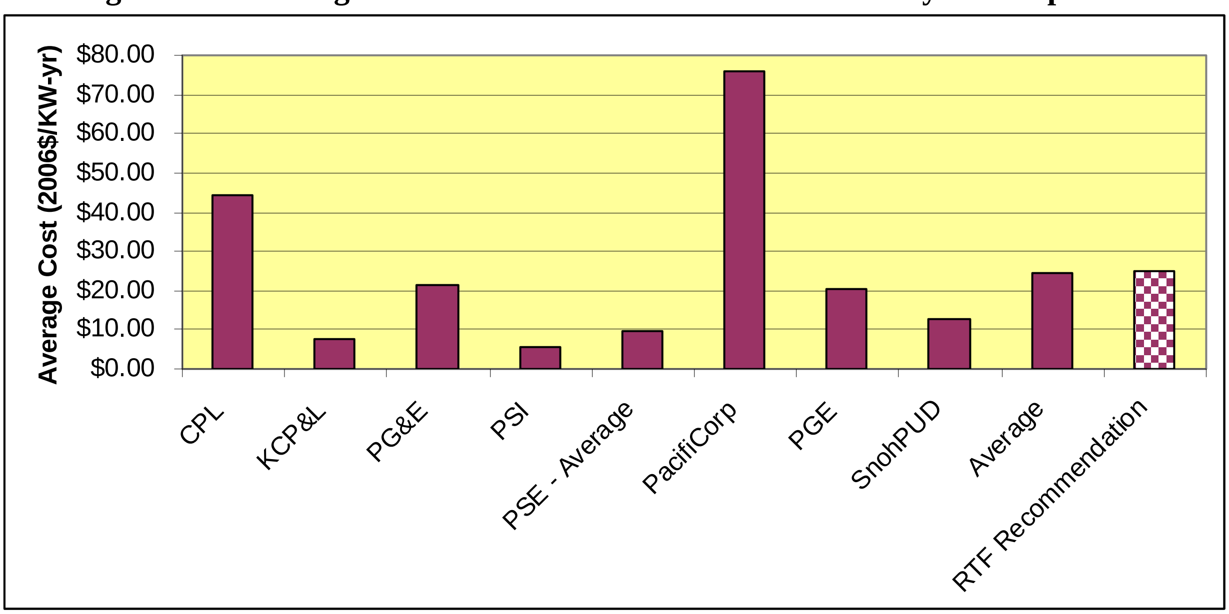
In addition to its value in offsetting the need for generation, conservation also reduces the need to expand local power distribution system capacity. The next step used to determine conservation's cost effectiveness is to determine whether the installation of a particular measure will defer the installation or expansion of local distribution and/or transmission system equipment. The Council recognizes that potential transmission and distribution systems cost savings are highly dependent upon local conditions. However, the Council relied on data obtained by its Regional Technical Forum (RTF) to develop a representative estimate of avoided transmission and distribution costs. Figure E-5 presents data for the avoided cost of transmission system expansion and Figure E-6 presents data for the avoided cost of distribution system expansion.

Figure E-5: Average Avoided Cost of Deferred Transmission System Expansion



After reviewing this data the RTF recommended a value of $23/kW-yr for "representative" of avoided transmission system expansion cost and $25/kW-yr as "representative" of avoided cost of distribution system expansion. The Council adopted the RTF recommended value for distribution system avoided cost. However, because the value of avoiding the transmission system investments is already included in the wholesale market prices produced by the AURORA model the Council did not use the RTF estimate of the benefits of deferring transmission system expansion so as to avoid double counting.

Figure E-6: Average Avoided Cost of Deferred Distribution System Expansion



As discussed above, due to the interconnected nature of the West coast wholesale power market, conservation measures that reduce consumption during the on peak hours are the most valuable, even though the region has significant peaking resources from the hydro-system. In contrast, throughout most of the Northwest region measures conservation measures that reduce peak demand during the winter heating season are of more value to the region's local distribution systems and to its wholesale transmission system.[6] This is because these systems must be designed and built to accommodate "peak demand" which occurs in winter. If a conservation measure reduces demand during these periods of high demand it reduces the need to expand distribution and transmission system capacity.

In order to determine the benefits a conservation measure might provide to the region's transmission and distribution system it is necessary to estimate how much that measure will reduce demand on the power system when regional loads are at their highest. The same conservation load shape information that was used to estimate the value of avoided market purchases was also used to determine the "on-peak" savings for each conservation measure.

Value of Non-Power System Benefits

In addition to calculating the regional wholesale power system and local distribution system benefits of conservation the Council analysis of cost-effectiveness takes into account a measure's other non-power system benefits. For example, more energy efficient clothes washers and dishwashers save significant amounts of water as well as electricity. Similarly, some industrial efficiency improvements also enhance productivity or improve process control while others may reduce operation and maintenance costs. Therefore, when a conservation measure or activity provides non-power system benefits, such benefits should be quantified (e.g., gallons of water savings per year and where possible an estimate of the economic value of these non-power system benefits should be computed. These benefits are added to the Council's estimate of the value of energy savings to the wholesale power system and the local electric distribution systems when computing total system/societal benefits.

Regional Act Credit

The Northwest Power Act directs the Council and Bonneville to give conservation a 10 percent cost advantage over sources of electric generation.[7] The Council does this by 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 and risk avoidance. The Council's Resource Portfolio Model (RPM) does not include the Act's credit for conservation as a decision criteria, so the levelized cost of conservation in the supply curves used by the RPM must be adjusted downward so that this credit is reflected in the RPM's comparison of conservation cost with generating resource costs. The economic value of the Act credit for conservation varies by conservation measure. Each measure has a unique value of energy saved based on when the savings occur and a unique impact on distribution capacity based on the coincidence of savings with peak system loads.

[6] Some areas of the region now experience both summer and winter peaks of almost equal magnitude due to increased use of air conditioning.
[7] Northwest Power Act,§3(4)(D), 94 Stat. 2699.

Financial Input Assumptions

The present value cost of conservation is determined by who pays for it. The 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. Tables E-2 through E-5 show the financial assumptions used in the economic analysis of conservation opportunities in each of the four major economic sectors.

Table E-2: Residential Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	3.90%	4.40%	4.90%	5.00%
Financial Life (years)	15	1	1	1
Sponsor Share of Initial Capital Cost	35%	20%	45%	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%	50%	50%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

Table E-3: Commercial Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	6.70%	4.40%	4.90%	5.00%
Financial Life (years)	20	1	1	1
Sponsor Share of Initial Capital Cost	35%	10%	55%	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%	50%	50%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

Table E-4: Industrial Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	7.60%	4.40%	4.90%	5.00%
Financial Life (years)	20	1	1	1
Sponsor Share of Initial Capital Cost	35%	10%	55%	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%	50%	50%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

Table E-5: Agriculture Sector Financial Input Assumptions

Sponsor Parameters	Customer	Wholesale Electric	Retail Electric	Natural Gas
Real After-Tax Cost of Capital	7.60%	4.40%	4.90%	5.00%
Financial Life (years)	5	1	1	1
Sponsor Share of Initial Capital Cost	35%	10%	55%	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%	50%	50%	0%
Last Year of Non-Customer O&M & Period Replacement		20		

RESIDENTIAL SECTOR

Residential Sector Definition and Coverage

For the Council's conservation analysis the residential sector includes single family, multifamily 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.[8] 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 E-6 shows the nine climate zones in the region.

Measure Bundles

Nearly 60 individual residential-sector measures are analyzed in the Sixth Power Plan. In the case of heat pumps and central air conditioning three measures were consolidated into a single bundle of related measures. Two levels of efficiency above the current federal minimum standards were tested, HSPF 8.5/SEER 14 and HSPF 9.0/SEER 14. For purposes of analytical expediency it was assumed that when a high efficiency heat pump was installed it would also undergo commissioning to ensure it functions properly and that it would have controls installed to optimize its operation. In addition, it was also assumed that in the case of existing homes the duct system would be sealed and in the case of new homes the duct system would be located inside the conditioned space or be sealed. As a result "duct sealing" and "heat pump commissioning and controls" are not identified separated in the supply curve, but are bundled

[8] 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.

with “heat pump efficiency upgrades” and “heat pump conversions.” These measure bundles do not and should not dictate the way measures are bundled for programmatic implementation.

Table E-6: 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

Measures are also consolidated into three types of application modes. These modes are new, natural replacement and retrofit. The new mode applies primarily to new buildings or new equipment. The natural replacement mode applies to subsystems and equipment within buildings that are replaced on burnout, at the end of their useful life, or at the time of remodel of the building or system within a building. Examples of this mode include appliance and water heater replacements and conversions of electric forced air furnaces to air source heat pumps are assumed to take place when the existing furnace needs to be replaced. Retrofit mode is used where a measure or a building subsystem upgraded, replaced or retired before the end of its useful life. The installation of insulation, window replacements and installation of ductless heat pumps to provide higher efficiency supplemental space conditioning are all examples of retrofit measures.

There are three reasons to distinguish the new, natural replacement and retrofit 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.

Overview of Methods

Measure costs and savings are developed at a level of detail compatible with data availability, expected variance in measure costs and savings, the diversity of measure applications and practical limitations on the number of measures that can be analyzed. Costs and savings are based both on engineering estimates as well as estimates based on results from the operation of existing programs. Savings potential is the product of savings per unit and the forecast of number of units that the measure is applicable to. 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 ductless heat pumps are function of the number of single family homes with zonal electric heating systems.

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

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 used 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. Codes and standards are continually being upgraded. The baseline assumptions used in the Sixth Power Plan are those that were adopted at the end of 2008, with a few exceptions. Some of these include standards that are adopted now 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. Baseline characteristics for major appliances (washers, dishwashers, refrigerators and freezers) are the national sales weighted average efficiency levels. This data was obtained from the American Home Appliance Manufacturer’s Association (AHAM). 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.

Measure Applicability

Measure applicability reflects several major components. 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. There are hundreds of applicability assumptions in the residential-sector conservation assessment. Applicability assumptions by measure appear in the three supply curve summary workbooks. Table E-6 shows the measures covered by each of these three workbooks.

Measure Achievability

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. In addition to a limit of 85 percent, the Council considers near-term achievable penetration rates for bundles of conservation measures. Several factors are used to estimate near-term achievability rates. Recent experience with region wide conservation program accomplishments is one key factor. But in addition to historic experience, the Council also considers a bottom-up approach to estimate near-term achievability.

In the bottom-up approach, the Council estimates near-term achievability rates of each bundle of conservation measures based on the characteristics of the measures in the bundle being described
In the bottom-up approach, the Council estimates near-term achievability rates of each bundle of conservation measures based on the characteristics of the measures in the bundle being described
and consideration of likely delivery mechanisms. This detailed bottom-up approach is a new element in the Sixth Power Plan. In the Sixth Plan, the Council uses a suite of typical ramp rates to reflect near-term penetration rates. 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 shower heads, might take only half a dozen years to fully implement. Whereas retrofit measures in complex markets might take 20 years to reach full penetration. Assumptions for the bottom-up approach are detailed in the conservation supply curve workbooks shown in Table E-7 below.

Table E-7: Measures Covered in Residential Supply Curve Summary Worksheets

Measures	Worksheet Name
New and existing lighting Clothes washers and dryers Dishwashers Refrigerators and Freezers Microwaves and ovens High efficiency water heaters, including heat pump water heaters Showerheads Waste water heat recovery Solar water heating Solar photovoltaic	PNWResDHWLight&ApplianceCurve_6thPlanv1_7.xls
Thermal Envelop Improvements (insulation, windows, air sealing) High Efficiency heat pumps (upgrades and system conversions) High Efficiency air conditioners (Room AC and Central AC) Duct Efficiency (sealing and interior ductwork) Heat pump commissioning and controls Ductless heat pumps	PNWResSpaceConditioningCurve_6thPlanv1_8.xls
Televisions Set Top Boxes Desktop computers Desktop computer monitors	PNWConsumerElectronicsSupplyCurve_6thPlanv1_7.xls

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 and zone allocations are all contained in the spreadsheet entitled "PNWResSectorSupplyCurveUnits_6thPlan.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.

The number of applicable and achievable units for consumer electronics were derived from national and regional sales data and forecast for televisions, set top boxes and desktop computers and monitors. The estimates of physical units for these products are embedded in the consumer electronics supply curve workbooks cited in Table E-7.

Guide to the Residential Conservation Workbooks

Table E-8 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.

Table E-8: Residential Sector Supply Curve Input Workbooks

File Scope	File Name
Lighting - Existing	EStarLighting_ExistingFY09v1_1.xls
Lighting - New	EStarLighting_NewFY09v1_0.xls
Refrigerator	EStarRefrigeratorFY09v1_0.xls
Dishwasher	EStarResDishwasherFY09v1_0.xls
Freezer	EStarResFreezersFY09v1_0.xls
Window AC Upgrades	EStarRoomACFY09v1_0.xls
Clothes Washers and Dryers - Multifamily	EStarWasher_DryerMultifamily_FY09v1_0.xls
Clothes Washers and Dryers - Single Family	EStarWasher_DryerSingleFamily_FY09v1_1.xls
Marginal Cost and Load Shape Date File (needed to run Procost models to update cost-effectiveness)	MC_and_LoadShape_6P.xls
Climate Zone Assignments by State and County	PNWClimateZones_6thPlan.xls
Consumer Electronics (Televisions, Set-top-Boxes, Computers & Monitors)	PNWConsumerElectronicsSupplyCurve_6thPlanv1_7.xls
Housing Foundation Types	PNWFoundTypes-_6thPlan.xls
Residential Appliance, Lighting and Domestic Water Heating Supply Curve for Draft 6th Plan	PNWResDHWLight&ApplianceCurve_6thPlanv1_7.xls
Residential Supply Curve Housing and Appliance Units	PNWResSectorSupplyCurveUnits_6th_Fnl.xls
Residential Space Conditioning Supply Curve	PNWResSpaceConditioningCurve_6thPlanv1_8.xls
New and Existing Single Family & Manufactured Home HVAC Conversions and Upgrades to High Efficiency Heat Pumps	ResDHP&HPConversions_UpgradesFY09v1_5.xls
Showerhead	ResDHW_2_0gpmShowerheads_FY09v1_0.xls
Efficient Water Heater Tanks and Heat Pump Water Heaters	ResDHWFY09v1_1.xls
Waste Water Heat Recovery	ResDHWHeatRecoveryFY09v1_1.xls
New Multifamily Thermal Shell	ResNewMF_wAdvancedLightingsqftFY09v1_2.xls
New Manufactured Home Thermal Shell	ResNewMH_wAdvancedLightingsqftFY09v1_2.xls
New Single Family Thermal Shell	ResNewSF_wAdvancedLightingsqftFY09v1_2.xls
Microwaves and Ovens	ResOven_MicrowaveFY09v1_0.xls
Residential Sector Supply Curve Summary	ResSectorConAsmnt_112509Summary.xls
Multifamily Weatherization	ResWxMF_w/AdvancedLightingsqftFY09v1_2.xls
Manufactured Home Weatherization	ResWxMH_w/AdvancedLightingsqftFY09v1_2.xls
Single Family Weatherization	ResWxSF_w/AdvancedLightingsqftFY09v1_2.xls
Solar Domestic Water Heating	SolarDHW_FY09v1_1.xls
Solar Photovoltaic	SolarPV_FY09v1_0.xls

COMMERCIAL SECTOR

Commercial Sector Definition and Coverage

For the Council's conservation analysis the commercial sector includes non-residential buildings except for industrial, as well as non-building economic activities such as street and highway lighting, outdoor area lighting, municipal sewage treatment, and water supply systems.

Commercial building floor area is one of the key drivers of the commercial conservation assessment. Floor area estimates are driven by economic forecasts of business activity, employment, demographics, and other factors such as floor area per employee. The development of the commercial floor area and load forecasts is described in Appendix C. The commercial building sector is categorized into 11 economic activity types and 18 separate building types. These building types are listed in Table E-9.

Table E-9: Building Types Covered in Commercial Supply Curve Summary Worksheets

Primary Activity	Council Building Type	Gross Floor Area in Square Feet	Number of Stories	Note, Comment, or Example
Office	Large Office	> 100,000	Any	
Office	Medium Office	20,000 to 100,000	Any	
Office	Small Office	< 20,000	Any	
Retail	Big Box	> 50,000	1	Includes some Grocery
Retail	Small Box	<50,000	1	
Retail	High End	< 20,000	1	High lighting density
Retail	Anchor	> 50,000	>1	
Education	K-12	Any	Any	
School	University	Any	Any	University, community college
Warehouse	Warehouse	Any	Any	Excludes refrigerated warehouse
Retail Food	Supermarket	> 5000	Any	
Retail Food	MiniMart	< 5000	Any	
Restaurant	Restaurant	Any	Any	Fast food, sit-down, café & bar
Lodging	Lodging	Any	Any	Hotel, motel & residential care
Health Care	Hospital	Any	Any	Medical, surgical, psychiatric
Health Care	Other Health	Any	Any	Outpatient health, labs, ambulance
Assembly	Assembly	Any	Any	Churches, museums, airports, stadiums, etc.
Other	Other	Any	Any	Parking lots, fire protection, car wash, gasoline , cemetery, air traffic control

Estimates of existing stock by building type and vintage cohort are based on data from the Commercial Building Stock Assessments from 2001 and 2004, construction data from F.W. Dodge, and other sources. Figure E-7 identifies floor area estimates for the 18 building types for 2010. Figure E-8 shows total historic and base case forecast commercial floor area for the period 1987 through 2029. Figure E-9 shows annual additions to commercial floor space for the same period. The year-by-year forecast of floor area by building type, employment and population used to estimate future stock is in the workbook Commercial Forecast 6P.xls identified in table E-13. The file also contains a detailed mapping of economic activity types to building types. Economic activity definitions are base on the North American Industry Classification System (NAICS) codes.

Figure E-7: Commercial Floor Area by Building Type for 2010

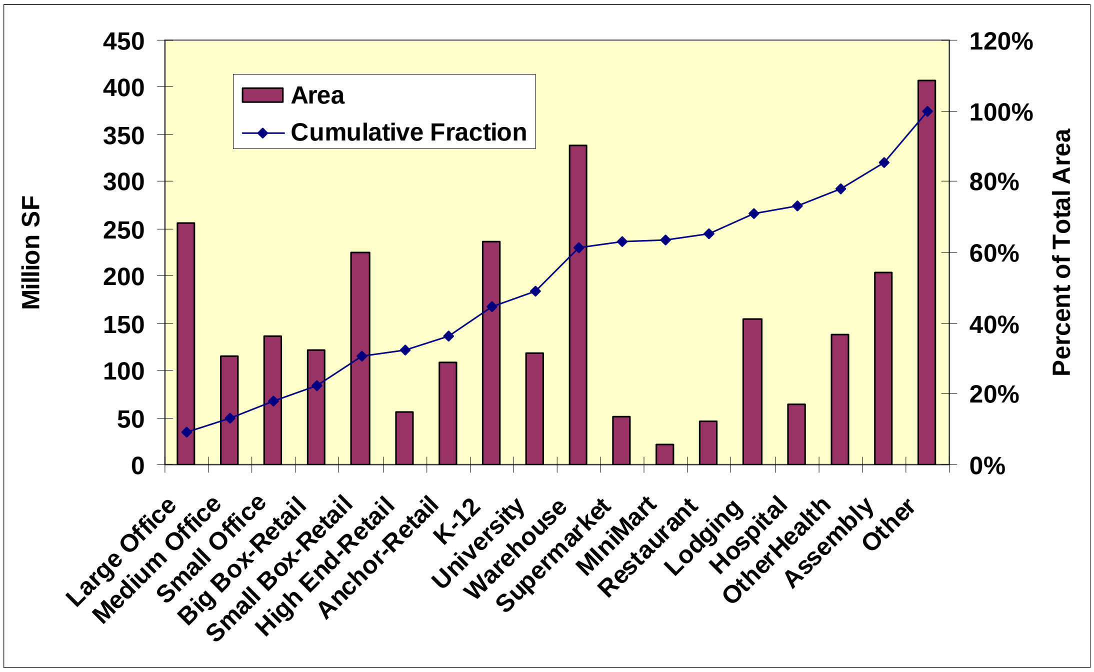


Figure E-8: Total Commercial Floor Area 1987-2029

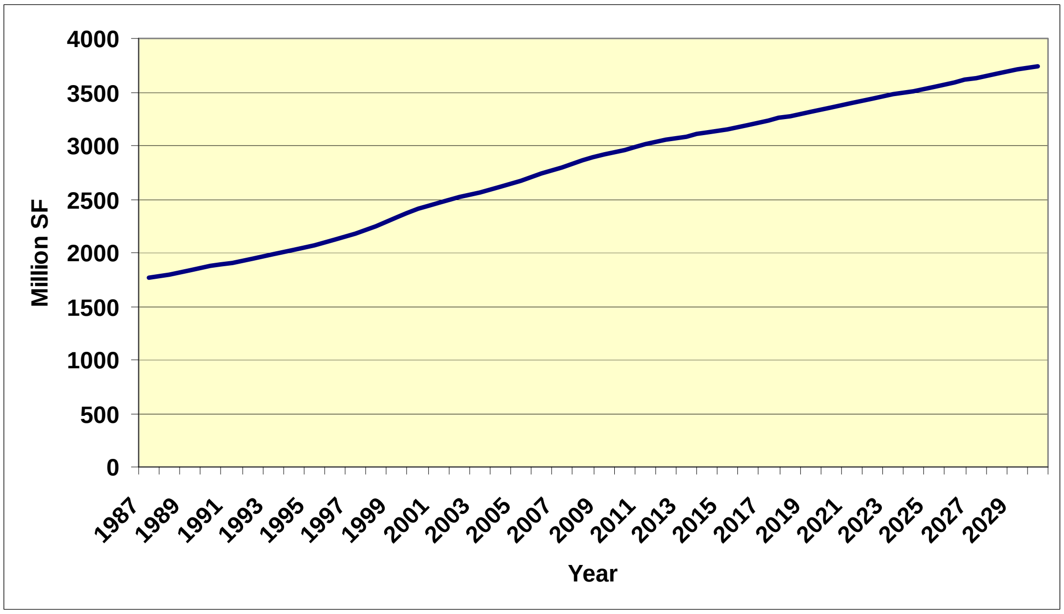
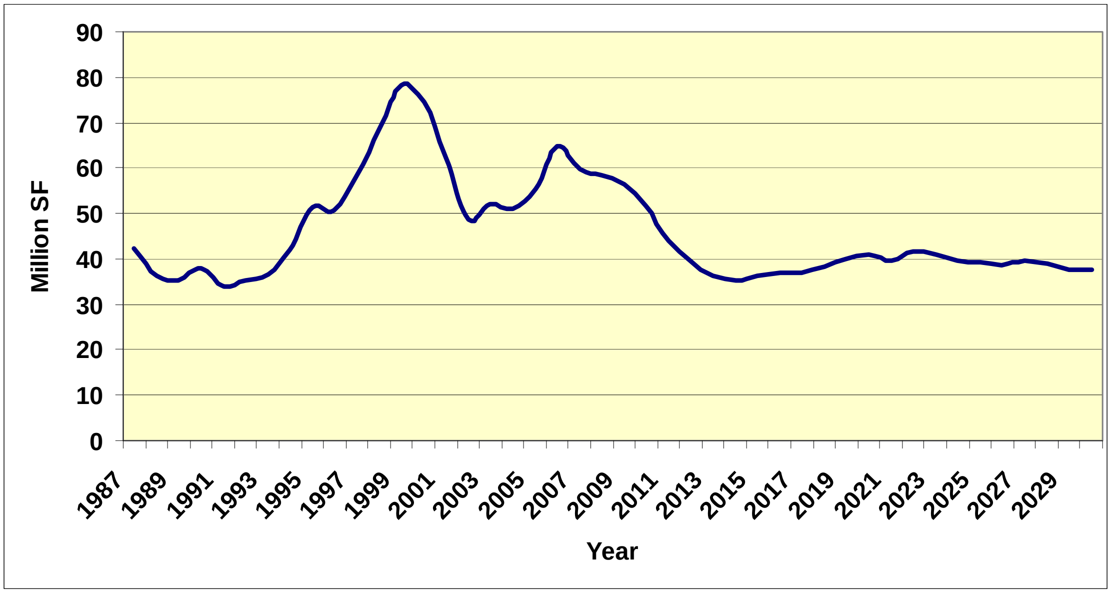


Figure E-9: Annual Commercial Floor Area Additions 1987-2029



Measure Bundles

Over 250 individual commercial-sector measures are analyzed in the Sixth Power Plan. These measures are consolidated into 45 bundles of related measures. The measure bundles are chosen primarily for analytical expediency. For example, measures that reduce interior lighting power density (LPD) are bundled together. Measures that reduce lighting hours through occupancy sensors are bundled separately. Measures that reduce interior lighting through daylighting are also bundled separately. Measure bundles do not always correspond to the way measures are bundled for programmatic implementation.

Measures are also consolidated into three types of application modes. These modes are new, natural replacement and retrofit. The new mode applies primarily to new buildings or new equipment. The natural replacement mode applies to subsystems and equipment within buildings that are replaced on burnout, at the end of their useful life, or at the time of remodel of the building or system within a building. Retrofit mode is used where a measure or a building subsystem is replaced or retired before the end of its useful life.

There are three reasons to distinguish the new, natural replacement and retrofit 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 for high performance T8 fluorescent lamps and ballasts in a new application only include the additional cost above standard T8 lamps and ballast. But in a retrofit application, the cost of removing and disposing of existing tubes and ballast are added to the measure cost.

Table E-10 lists the commercial sector measure bundles, a short description of the measures, the number of measures in each bundle and the technical energy savings potential by 2029 in each bundle by application mode.

Table E-10: Commercial Sector Measure Bundles

Measure Bundle	End Use	Number of Measures in Bundle	Measure Description	Technical Potential in MWa by Year 2029 New	Natrual Replacement	Retrofit	Total
Lighting Power Density	Lighting	54	Lamp, ballast and fixture improvements to lighting power density	51	354	38	443
Daylighting with Skylights	Lighting	6	Skylights with lighting controls	16	0	0	16
Daylighting with Windows	Lighting	6	Perimeter daylighting controls	3	12	0	15
Lighting Controls Interior	Lighting	6	Occupancy controls for areas not required by code such as open office, warehouse aisle, classrooms	6	65	8	79
Exit Signs	Lighting	2	LED and electroluminescent "Exit" signs	0	0	0	0
Premium HVAC Equipment	HVAC	4	HVAC equipment more efficient than applicable code or standard practice	8	31	0	39
Variable Speed Chiller	HVAC	2	Variable speed chillers	1	14	0	15
Controls Commission Complex HVAC	HVAC	20	Commissioning on HVAC systems in buildings with complex HVAC systems	10	0	124	134
Package Roof Top Optimization and Repair	HVAC	8	Suite of measures and control strategies for buildings served by package roof top HVAC units	4	8	16	29
Low Pressure Distribution Complex HVAC	HVAC	2	Dedicated Outside Air or Underfloor Air distribution systems in buildings with complex HVAC systems	6	0	0	6
Demand Control Ventilation	HVAC	5	Fan control strategies, DCV and Fleet Strategy DOAS with heat recovery in simple HVAC systems	4	4	14	22
ECM Motors on Variable Air Volume Boxes	HVAC	2	Electically Commutated Motors on Variable Air Volume Boxes	3	9	0	12
Evaporative Assist Cooling	HVAC	0	Evaporative Assist Cooling	0	0	0	0
Windows	HVAC	39	Windows and glazing more efficiecnt that code or standard practice	3	8	22	33
Roof Insulation	HVAC	2	Add insulation during re-roofing	0	3	0	3
Duct Sealing and Repair	HVAC	0	Sealing and repair of ductwork in unconditioned spaces	0	0	0	0
Efficienct fans, pumps and drives	HVAC	0	Variable speed fans, pumps and drives, pump and fan system efficiencies and demand control	0	0	0	0
Exterior Building Lighting	Ext Lighting	4	Effiicient façade, walkway, area and decorative exterior lighting, such as LED	0	67	0	67
Integrated Building Design	Multi	13	Multiple measures applied in integrated design practice	61	0	0	61
Street and Roadway Lighitng	Ext Lighting	2	Efficient street and roadway lighting, LED and induction	8	42	0	51
Parking Lighting	Ext Lighting	2	Efficient parking lot and garage lighting and controls	1	38	0	38
LED Traffic Lights	Ext Lighting	1	LED traffic signals	0	0	0	0
Signage	Ext Lighting	1	LED advertizing signs	0	5	0	5
Municipal Sewage Treatment	Process	10	Suite of measures for sewage treatment	0	0	27	27
Municipal Water Supply	Process	5	Suite of measures for water supply systems	0	0	13	13
Network PC Power Management	Process	1	Control of a networked computer's advanced energy management systems	0	0	40	40
Packaged Refrigeration Equipment	Process	20	Efficient refrigerators and freezers, beverage merchandizers, ice makers and vending machines	52	0	0	52
Commercial Clothes Washers	Process	0	Clotheswashers more efficient than federal standard	0	0	0	0
Cooking Equipment	Process	0	Efficient cooking equipment such as hot food holders, grills, fryers and steam tables	0	0	0	0
Office Equipment	Process	2	Efficient Desktop PC and Efficient Monitor	0	0	0	0
Computer Servers and IT	Process	2	Consolidation & virtualization & upgrade of servers in embedded server rooms in buildings	0	0	88	88
DCV Restaurant Hood	Process	1	Demand control ventilation systems for large restaurant hoods	0	0	4	4
DCV Parking Garage	Process	1	Demand control ventilation systems for parking garages	0	0	0	0
Grocery Refrigeration Bundle	Process	12	Grocery store refrigeration measures	0	0	68	68
Plug Load Sensor	Process	1	Occupancy controls for task lighting and other ancillary loads in offices	0	0	0	0
Premium Fume Hood	Process	1	Effiicient fume hoods in labs	21	0	0	21
Pre-Rinse Spray Wash	Process	1	Low-flow pre-rinse spray valves for restaurant kitchens, cafeterias, and food-serving	0	0	2	2
Total		**238**		**258**	**662**	**462**	**1382**

Overview of Methods

Measure costs and savings are developed at a level of detail compatible with data availability, expected variance in measure costs and savings, the diversity of measure applications and practical limitations on the number of measures that can be analyzed. Costs and savings are based both on engineering estimates as well as estimates based on results from the operation of existing programs. Savings potential is the product of savings per unit and the forecast of number of units that the measure is applicable to. For most of the commercial sector measures, building floor area, by building type, is the primary unit of measure. Most measures apply to a fraction of the building stock in a particular building type. In addition to building floor area, several of the measure potential estimates are based on forecast of equipment stock, equipment turnover rates, equipment sales data, population, and process capacity.

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

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 Pacific Northwest Commercial Building Stock Assessment (CBSA), the national Commercial Building Energy Consumption Survey (CBECS), 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. Codes and standards are continually being upgraded. The baseline assumptions used in the Sixth Power Plan are those that were adopted at the end of 2008, with a few exceptions. Some of these include standards that are adopted now 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.

Measure Applicability

Measure applicability reflects several major components. 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. There are hundreds of applicability assumptions in the conservation assessment. Applicability assumptions and source references are detailed in the workbooks for each measure bundle.

Measure Achievability

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. In addition to a limit of 85 percent, the Council considers near-term achievable penetration rates for bundles of conservation measures. Several factors are used to estimate near-term achievability rates. Recent experience with region wide conservation program accomplishments is one key factor. But in addition to historic experience, the Council also considers a bottom-up approach to estimate near-term achievability.

In the bottom-up approach, the Council estimates near-term achievability rates of each bundle of conservation measures based on the characteristics of the measures in the bundle being described and consideration of likely delivery mechanisms. This detailed bottom-up approach is a new element in the Sixth Power Plan. In the Sixth Plan, the Council uses a suite of typical ramp rates to reflect near-term penetration rates. 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 shower heads, might take only half a dozen years to fully implement. Whereas retrofit measures in complex markets might take 20 years to reach full penetration.

Assumptions for the bottom-up approach are detailed in the conservation supply curve workbooks. The worksheet “ACHIEV” in the workbook ComMaster contains all the achievability assumptions by 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 commercial sector analysis, the applicable units’ estimates come from several sources. For measures in buildings, the units are primarily floor area with applicable characteristics. These data come primarily from the Commercial Building Stock Assessment (CBSA). For some of the equipment measures, additional unit data from utility surveys of characteristics, national data from Commercial Building Energy Consumption Survey (CBECS), equipment sales data, census data, and many others.

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. The estimates of physical units available are called stock models and are embedded in the measure bundle workbooks. The worksheets that contain the stock models are identified by the prefix “SC”.

Guide to the Commercial Conservation Workbooks

There are about 50 Excel workbooks used to develop the commercial-sector conservation assessment. In addition there are dozens of outside sources of data which are referenced. The Council workbooks are available from the Council website.[9] Supporting data sources are identified in the workbooks and the key supporting data from these sources is summarized in the Council workbooks. All outside source data is cited in the workbooks or otherwise made available to the extent it is not proprietary.

Figure E-10 describes the main components and structure of the commercial conservation assessment workbooks. The workbooks and brief descriptions of their purpose are listed in Table E-11.

[9] http://www.nwcouncil.org/energy/powerplan/6/supplycurves/default.htm

Figure E-10: Main Components and Structure of the Commercial Conservation Assessment Workbooks

ProCost Measure Workbooks: These workbooks contain the detailed analysis for all the measures. Generally there is one workbook for each bundle of similar or related measures.

Naming convention starts with PC (For example: PC-ECMVAV-6P-D1.xls means is the ProCost workbook for the measure Electronically Commutated Motors on VAV systems, 6th Plan, Draft 1)

These files contain the ProCost engine used for cost-effectiveness analysis. They also contain the supporting analysis of measure cost and savings as well as links to data used to support the analysis. They also contain supply curves for the measure bundle.

Basic layout as follows:

SC worksheets: Calculates supply curve total savings potential by cost bin by year. Uses output data from MData worksheets along with unit forecasts from floor space sheet and achievability rates from ComMaster. Usually there are several SC worksheets for new, retrofit and natural-replacement applications since cost and savings and units are different for each application.

ProData worksheet: Control panel for ProCost analysis.

MData worksheets: Measure data sheets. Measure level inputs and outputs for ProCost. Normalized to floor area with one to several hundred permutations of costs and savings. At least two permutations of the MData tab exist in each sheet. One is for the "measure" level which represent costs and savings for an individual measure. This provides the cost and savings estimates for individual measures regardless of the measure's applicability. The other is the "regional" level which includes costs and savings weighted for applicability across the region. ProCost output by measure ends up here too and is passed to the supply curve sheets to develop supply curves. Inputs to MData are usually harvested from MMap tab.

MMap worksheet: Measure Map. Used to assign costs and savings inputs to each application and permutation of the measure. Feeds MData worksheets.

Notes and Sources worksheet Contains notes, savings calculations and links to sources.

Supporting worksheets: A variety of supporting worksheets, documentation and administrative notes are also included.

6PSummary: Summarizes key input assumptions, sources and calculation methodology.

ComMaster

Contains measure list, links to all supporting files and sheets for other administrative functions.

Contains key characteristics common among measures used to calculate savings estimates. Includes measure applicability (APPLIC), baseline penetration (BASE), applicable vintage cohort (STOCK), achievability rates (ACHIEV), fuel saturations, equipment saturations and other key characteristics (CHAR) used in the analysis by building occupancy type and application (New, Retro or Natural Replacement (NR)) . Also includes common variables, labels (VAR & Labels) and other administrative functions.

ComFloorAreaForecast.xls (or similar name)

Output from regional forecast model. Supply curve estimates are driven primarily by floor space estimates, equipment count or population. File contains stock estimates relevant to the measures by building occupancy type, state and vintage.

MC_AND_ LOADSHAPE

Contains avoided cost and shape of savings data. Called by ProCost.

SUPPLYCURVEBUNDLER

Bundles all measures into supply curves by cost bin and year for input to portfolio model.

Table E-11: List of Commercial-Sector Workbooks

File Name	File Description
Com_Master	Master Workbook for Commercial Sector Conservation
ComLighting_v2008-D2	Support file for lighting power density measure workbook
Commercial Forecast 6P	Floor area and population forecast
InteractionsBldgType01082004-	Space Heat and Cooling Interaction Factors for Lighting Savings
MC_AND_LOADSHAPE_6P	Marginal Cost and Load Shape Data File
PC-Cooking-6P-D1	Measure workbook: Cooking
PC-DCVGarage-6P-D1	Measure workbook: Demand Control Ventilation Parking Garage
PC-DCVHood-6P-D1	Measure workbook: Demand Control Ventilation Restaurant
PC-DemandControlVent-6P-D4	Measure workbook: Demand Control Ventilation for HVAC
PC-DuctSeal-6P-D1	Measure workbook: Duct Sealing
PC-ECMVAV-6P-D4	Measure workbook: ECM Motors in Variable Air Volume HVAC
PC-EvapAssist-6P-D1	Measure workbook: Evaporative Assist Cooling
PC-Exit Sign-6P-D2	Measure workbook: Exit Signs
PC-ExtLight-6P-D1	Measure workbook: Exterior Building Lighting
PC-FanPumpDrive-6P-D1	Measure workbook: Adjustable Drives for Fans & Pumps
PC-FumeHood-6P-D1	Measure workbook: Efficient Lab Fume Hood
PC-Grocery-6P-D3	Measure workbook: Grocery Store Measures
PC-HVACControls-6P-D4	Measure workbook: Controls Commission Complex HVAC
PC-HVACEQUIP-6P-D7	Measure workbook: Premium HVAC Equipment
PC-IntDesign-6P-D1	Measure workbook: Integrated Building Design
PC-Lighting Controls Interior-6p-	Measure workbook: Lighting Controls Interior
PC-Lodging-6P-D1	Measure workbook: Lodging-Specific Measures
PC-LowPressureDist-6P-D1	Measure workbook: Low Pressure Distribution Complex HVAC
PC-LPDPackage-6P-D16	Measure workbook: Lighting Power Density Interior
PC-NetworkPC Power	Measure workbook: Network PC Power Management
PC-OfficeEquip-6P-D1	Measure workbook: Office Equipment
PC-Pack Refrig Equip-6P-D3	Measure workbook: Refrigerators, freezers, ice makers,
PC-PackRTOptimize-6P-D6	Measure workbook: Package Roof Top Optimization and Repair
PC-Parking Lighting-6P-D1	Measure workbook: Parking Lighting
PC-PlugLoadSensor-6P-D1	Measure workbook: Plug Load Sensor
PC-ReRoof-6P-D1	Measure workbook: Roof Insulation
PC-ServerRooms and IT-6P-D1	Measure workbook: Computer Server Room Efficiency
PC-SideDaylight-6P-D1	Measure workbook: Day Lighting Control - Windows
PC-Singage-6P-D1	Measure workbook: LED Signage
PC-Spray Head-6P-D1	Measure workbook: Pre-Rinse Spray Valve
PC-StreetRoadway-6P-D2	Measure workbook: Street and Roadway Lighting
PC-TopDaylightNew-6P-D5	Measure workbook: Day Lighting Control - Skylights
PC-Traffic Signals-6P-D1	Measure workbook: LED Traffic Signals
PC-VSDChiller-6P-D3	Measure workbook: Variable Speed Chillers
PC-Wastewater-6P-D1	Measure workbook: Municipal Wastewater
PC-WaterSupply-6P-D3	Measure workbook: Municipal Water Supply
PC-Windows-6P-D10	Measure workbook: Windows
ProCostFinAssumptions_Sector	Financial Assumptions
SupplyCurveBundlerLO	Bundles all Lost-Opportunity Measures into Supply Curves
SupplyCurveBundlerRetro	Bundles all Retrofit Measures into Supply Curves

The main workbook is named ComMaster. ComMaster contains the master measure list, the measure bundles, common assumptions used throughout the analysis and links to the ProCost measure files where detailed measure-specific analysis resides. The reference data in ComMaster are primarily in matrices by measure bundle and building type. The reference data in the ComMaster file are listed and described in Table E-12.

Table E-12: 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. Plus housekeeping.
APPLIC	Applicability factor for the measure. Fraction of stock the measure applies to.
BASE	Baseline penetration of measure. Estimated 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.
ACHIEVE	Achievable rate of acquisition for measure bundles by year
CODE	Tables developed to estimate regional baseline penetration for various elements of energy codes by jurisdiction
CHAR	Key characteristics for stock by vintage cohort and building subtype. Used to develop regional application of meas
FLOOR	Floor area forecast summary used to develop data in CHAR
VARS	List of variables used in the CHAR tab and elsewhere in the files.
Labels	Map of building types labels from different sources.
Lookup	Lookup table for vintage cohort
EUI	Reference EUI from various sources including CBECS & CBSA.

INDUSTRIAL SECTOR

Overview

The Sixth Plan Industrial Supply Curve (ISC) conservation assessment was prepared by a contractor, Strategic Energy Group (SEG) with guidance from Council staff and an advisory group. The assessment includes an Excel workbook, referred to as the Measure Analysis Tool, which contains industrial load data, measure data, conservation supply curves and documentation. There is another Excel workbook, referred to as the NPCC Supply Curve Generator, which converts measure costs and savings data to conservation supply curves for input to the Council's Resource Portfolio Model. The contractor also prepared documentation of the development of the analysis, the Measure Analysis Tool, and a detailed description of the modeling of a subset of the measures referred to as System Optimization Measures.

In addition to these major components, the assessment includes a rich dataset of sources referred to as the Industrial Data Catalogue and a guide to that catalogue. Finally, the project also developed a detailed database on motor loads at industrial facilities in the Northwest. This is called the Northwest Industrial Motor Database.

Industrial Sector Overview and Coverage

The Council's industrial sector analysis covers most of the region's non-DSI industries plus refrigerated warehouse storage. The assessment does not include savings estimates for the direct-service industries. Nor does it cover savings potential in the information technology sector (IT). These two subsectors were beyond the scope of the industrial assessment.

Structure of the Analysis

The conservation assessment model is structured differently that the Council's assessments in other sectors. The ISC model uses estimates of energy savings as a fraction of load by end use by industry.

First, data were collected on electricity use by industry by state. These data came from a variety of sources primarily utility-provided reports. But other sources were considered too including data supplied by individual plants, proprietary datasets and publicly-available data. These data were calibrated to industrial load data reported by state to EIA. Then the consumption estimates were split into estimates of electricity use by major process end use. Then energy conservation measures (ECMs) 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. A detailed summary of the structure of the assessment is available in the document entitled "ISC Model Review R4".

Guide to the Industrial Sector Workbooks and Data

Table E-13 identifies the key workbooks and files that comprise the industrial conservation assessment.

Table E-13: List of Industrial Sector Workbooks

Item	Description
Measure Analysis Tool	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
Description of Measure Analysis Tool	Description of the structure and development of the Measure Analysis Tool
NPCC Supply Curve Generator	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 consistent with estimates in other sectors
Documentation on System Optimization Measures	Excel workbook containing detailed derivation of costs, savings and measure applicability for a suite of measures related to system optimization of key industrial processes
Systems Whole Plant Optimization Overview	Description of the system optimization and whole plant measure bundles, the input assumptions, and supporting sources
Industrial Data Catalogue and Guide	Large database of industrial data sources. A compilation of published and unpublished resource assessments, market and technology reports, datasets, case studies and guidebooks focused on industrial energy efficiency and energy management. The files include N electronic collection of these resources
Northwest Industrial Motor Database	Information on motors that collected over 20 years by the Industrial Assessment Center (IAC) at Oregon State University (OSU). The Northwest Industrial Motor Database includes a database of a total of 22,514 records, each with detailed motor application data.

AGRICULTURAL SECTOR

Overview

The Sixth Power Plan's assessment of conservation potential in the agriculture sector covers irrigation hardware system efficiency improvements, irrigation water management (scientific irrigation scheduling) and diary 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 dairy milk processing savings. This is the first Council plan to estimate savings from irrigation water management and diary milk production.

Measure Bundles

Seven generic irrigation hardware system efficiency improvements and three "operation and maintenance" (e.g., gasket and nozzle replacement) measures are analyzed in the Sixth Power Plan. Irrigation water management practices were considered as a bundled measure consisting of moisture monitoring hardware and software. Four individual, non-interactive measures were considered for improving the energy efficiency of dairy milking barns and milk processing.

Overview of Methods

The irrigation hardware efficiency measures were evaluated using savings derived from an engineering spreadsheet model that simulates the energy use of a center pivot system using alternative pump efficiencies, static and dynamic head, annual water throughput and system leakage rates. Each hardware efficiency measure's savings were estimated based on water supplied by a well of average depth and water supplied by a deep well for each of the Northwest states. Data on well depth, amount of water applied, average pump size and irrigated acreage served by each type of irrigation system were drawn from the most recent USDA Farm and Ranch Survey. All data used from this survey are shown in the "IrrgAgHardwareSupplyCurve_6Pv1_1.xls."

Irrigation water management savings 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 evaluation of irrigation water management. This evaluation documented the average water savings from scientific irrigation water management as well as the cost of carrying out improved practices. Dairy efficiency improvements were based on detailed audits and retrofits of 30 dairies in New York carried our by the New York State Energy Research and Development Administration (NYSERDA).

Baseline Characteristics

Baseline conditions for irrigation hardware system efficiency improvements were estimated from the USDA Farm and Ranch 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) this data was used to size the remaining opportunities for savings.

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 USDA Farm and Ranch Survey. 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.

The three workbooks containing the Agriculture Sector conservation resource assessment are downloadable from the web. These are:

- Irrigation Hardware System Efficiency Improvements - IrrgAgHardwareSupplyCurve_6Pv1_1.xls
- Irrigation Water Management - SIS_SupplyCurve_6thPlanv1_1.xls
- Diary Efficiency Improvement - DairySupplyCurve_6thPlanv1_1.xls

DISTRIBUTION SYSTEM

Overview

The Sixth Power Plan includes a conservation potential assessment on the region's electric distribution system. The assessment is based on a study completed in 2007 by R.W. Beck for the Northwest Energy Efficiency Alliance (NEEA).

Structure of the Analysis

The distribution system conservation assessment uses savings estimates from measured data on 33 utility feeders, and analytical methods developed by RW Beck in the NEEA study. 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, feeders counts, customer counts and climate zones for 137 regional utilities used to generate the units estimates.   Table E-14 below identifies the key workbooks and data used in the analysis.

Table E-14 identifies the key workbooks and files that comprise the distribution system conservation assessment.

Table E-14: List of Agriculture Sector Workbooks

Item	Description
NPPC Supply Curve	Excel workbook used to generate the supply curves with documentation
Supporting Data	Excel workbook containing the data on distributions systems and the key factors for the savings estimates
Distribution Efficiency Initiative	2007 RW Beck Study for NEEA. Findings from this study were used to develop the conservation supply curves