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APPENDIX G

CONSERVATION COST, PERFORMANCE AND VALUE

SUMMARY

This chapter provides an overview of the procedures and major assumptions used to derive the Council's estimates of conservation resources in both the public and private utility service territories. It also describes the results of the Council's analysis of the regional benefits of securing cost-effective conservation.

In the Council's plan, conservation is defined as the more efficient use of electricity. This means that less electricity is used to produce a given service at a given amenity level. Conservation resources are measures that enhance the efficient use of electricity for new and existing residential buildings, household appliances, new and existing commercial buildings, and industrial and irrigation processes. For example, buildings in which heat loss is reduced through insulating and air tightening require less electricity for heating. These electricity savings mean that fewer new power plants are needed to meet growing demand. Conservation also includes measures to reduce electrical losses in the region's generation, transmission and distribution system. These latter conservation resources are also discussed in this section.

Conservation has been a central ingredient in the resource portfolios of previous plans for meeting future electrical energy needs. Each megawatt of electricity conserved means one less megawatt needs to be generated. The amount of conservation that is cost-effective to develop depends upon how fast the demand for electricity grows, future natural gas prices since gas-fired combustion turbines are a key new resource, and year-to-year variations in water conditions.[1] Figure G-1 shows a frequency distribution of the amount of conservation that would be cost-effective to develop across all of these futures. The amount ranges from a low of 835 aMW when demand growth and gas prices are low to a high of 2,150 aMW, corresponding to a future of high demand and high gas prices. The *average* amount of regionally cost-effective conservation across all forecasts and gas futures is approximately 1,535 average megawatts.[2]

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[1] For example, if economic growth occurs according to the Council's medium low forecast, the region will need to add approximately 145 average megawatts of new resources each year. However, if regional economic growth is at the Council's medium high forecast, nearly 425 average megawatts of new resources will be needed each year.

[2] This is the total amount of conservation achievable, given sufficient economic and political resources, over a 20 year period. The 1535 average megawatts of cost-effective potential identified in this plan is very different than the 1500 average megawatts referenced in the 1991 Plan. In this Plan, the 1535 average megawatts is the *mean* (i.e., average) amount of cost-effective and achievable conservation over a 20 year period across the full range of Council load growth scenarios. In the 1991 Plan, the 1500 average megawatts was a "point-estimate" of the amount of cost-effective achievable conservation over a 10 year period assuming the specific conditions of the Council's medium-high load growth.

Figure G-1

Frequency Distribution of Conservation Resource Development

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Table G-1 shows the sector and end-use distribution of the average amount of conservation developed. Approximately one third of this conservation is in new and existing non-aluminum-industry facilities. The Council has not estimated the amount of conservation that may be available in the aluminum industry. There is undoubtedly some additional conservation in that sector as well. The next largest source of potential savings are in residential water heating , including laundry equipment, which represents about one-fifth of the total potential. New residential and commercial buildings combined comprise about one-quarter of the cost-effective potential. The remainder of the conservation potential is spread among existing residential buildings and appliances, existing commercial buildings and irrigated agriculture. The average levelized cost of these resources is approximately 1.7 cents per kilowatt-hour, with no individual conservation measure costing more than 3.0 cents per kilowatt-hour[3]. The levelized average cost of conservation is roughly two-thirds of the cost of new generating resources.

[3] These levelized cost do not include the 10 percent credit provided for conservation under the Northwest Power Act.

Table G-1

Average Achievable Conservation Potential

End Use Sector	Average Megawatts	Average Levelized Cost (Cents/kWh)
Freezers	15	1.9
Refrigerators	45	2.9
Water Heating	335	2.0
Residential Lighting	30	2.6
New Residential Space Heating	140	2.1
Existing Residential Space Heating	25	1.8
New Commercial	230	1.3
Existing Commercial	95	1.4
Commercial Renovation/Remodel	50	1.3
New Non-Aluminum Industrial	225	1.5
Existing Non-Aluminum Industrial	335	1.5
Direct Service Aluminum Industrial	Not Estimated	Not Estimated
Irrigated Agriculture	10	1.8
TOTAL	**1,535**	**1.7**

Securing the region's remaining cost-effective conservation could reduce the Northwest's cost of meeting its future energy service needs by $2.3 billion. Sensitivity studies showed that even under fairly dramatic changes in the need for future resources or the cost of new power generation, the investment in conservation would still provide positive economic benefit to the region. Were the region to experience a sudden loss of 3,000 average megawatts of load, conservation's value to the region would be reduced to $1.9 billion. If the cost of new power generation in the year 2005 were suddenly reduced through some technological breakthrough to roughly half of today's costs, conservation developed by then would still produce a present value benefit to the region of $800 million. Alternatively, should the risk of global climate change due to carbon dioxide and other greenhouse gas emissions result in the imposition of taxes on these emissions, conservation's value could increase by between $3.2 and $6.1 billion. These scenarios are discussed in more detail later in this overview section.

MAJOR CHANGES IN CONSERVATION RESOURCE ESTIMATES

Each time the conservation resource is estimated by the Council in sequential power plans, significant changes need to be taken into account for estimating the remaining conservation potential. Four key changes that needed to be incorporated in this power plan are: 1) reducing the overall amount of conservation resource available in the future because some has been acquired already, or has been incorporated into codes and standards that will mean new buildings and appliances are efficient; 2) reducing the amount of cost-effective conservation because avoided costs for new generation are much lower than in the prior power plans; 3) incorporating changes in technologies, which typically means something that wasn't cost-effective in the past is now cost-effective; and 4) matching changes in the load forecast, which can significantly change the expected number of electrically heated houses or commercial floorspace, which in turn, changes the amount of electricity savings that can be targeted. Table G-2 shows the changes in conservation potential in this draft compared to the 1991 Power Plan due to these factors. The key changes are discussed next.

Table G-2
Summary of Major Changes Influencing Regional Conservation Potential

Factor	Effect on Conservation Potential in Medium Forecast (Average Megawatts)[4] Decrease	Increase
Conservation Acquisition Since 1991 Plan:		
Utility Program Acquisitions[5]	525	0
Revised Commercial Codes and Standards	165	0
New/Revised Federal Standards	410	0
Lower Avoided Cost	560	0
Technology Improvements	0	285
Large Forecast Changes:		
Electric Heating Saturation in Commercial	230	0
Non-Aluminum Industrial Growth Rate	0	110

Conservation Acquisition Since the 1991 Plan

Since the adoption of the Council's 1991 Plan the region has made significant progress in acquiring conservation. Based on reports supplied to the Council by Bonneville and the region's utilities, approximately 525 average megawatts of electricity savings were acquired between 1991 and 1995. Approximately 315 average megawatts of this was accomplished in existing end-uses, which would reduce the future savings that could be achieved from existing houses and commercial/industrial buildings. The remaining 210 average megawatts was secured from new applications, such as new buildings and appliances, which does not reduce the amount of savings that can be achieved in the future. (The 210 average megawatts does not include savings from the construction of efficient buildings in the future due to changes in codes and standards.)

In addition, the states of Oregon and Washington adopted revised building codes for new commercial buildings and those that undergo major renovations or remodeling. These revised state codes -- combined with new federal standards for certain commercial heating, ventilating and air conditioning systems and lighting equipment -- are estimated to save approximately 165 average megawatts by the year 2015 under the Council's medium forecast.

Revised federal standards for clotheswashers, dishwashers and showerheads are projected to save the region a total of 140 average megawatts if regional economic growth matches the Council's medium forecast. Also at the federal level, the energy efficiency standards for manufactured housing were updated for the first time in 20 years. These new standards, in combination with the region's Manufactured Housing Acquisition Program (MAP) successfully transformed the energy efficiency of new manufactured homes. As a result, under the Council's medium forecast the space heating loads of new manufactured homes in the year 2015 will be approximately 270 average megawatts lower.

[4] Utility program acquisition decreases the conservation resource potential available in existing buildings and equipment, the revised codes and standards impact conservation potential in new construction, and lower avoided cost and technology improvement affect both new and existing electricity applications.

[5] Note that not all of this acquisition reduces future potential because not all of it came from existing end-uses, as described in the text.

Lower Avoided Cost Impacts

Another factor that has reduced the amount of conservation remaining to be captured is the substantially lower cost of new power supplies. In the Council's 1991 Plan, conservation resources with real levelized costs below 5.5 cents per kilowatt-hour were considered regionally cost-effective. Adjusting for inflation, this is just over 6.0 cents per kilowatt-hour in 1995 dollars. The "cost-effectiveness limit" used in this analysis is between 2.5 and 2.8 cents per kilowatt-hour, depending upon the daily and seasonal distribution of the savings.[6] Table G-3, shows the reduction in conservation potential under the Council's medium forecast, due to the change in the region's avoided cost. Had the region's avoided cost remained at 6.0 cents per kilowatt-hour, approximately 560 average megawatts of additional conservation potential would have been cost-effective.

Table G-3

Changes in Conservation Potential Due to Lower Avoided Cost

Sector	Average Megawatts
Commercial	225
Residential Space Heating	70
Residential Water Heating	165
Residential Appliances	15
Industrial	55
Irrigation	30
Total	**560**

Technology Improvements

Not all changes that occurred since the adoption of the 1991 Plan have lowered the amount of cost-effective conservation remaining in the region. Technological improvements in residential windows, refrigerators and freezers have added cost-effective savings potential where none existed before. More experience and better understanding of the costs and benefits of thoroughly testing and calibrating commercial building controls and equipment now justify including "building commissioning" as a measure in the region's conservation portfolio. These new technologies have added about 285 average megawatts of conservation potential.

Changes in the Load Forecast

In addition to the factors discussed above, changes in the load forecast can result in major changes in estimates of conservation resource potential. Four factors exert the most influence. These are 1) the number of new residences heated with electricity; 2) the market share of electric water heating; 3) the electric heat saturation in commercial buildings; and 4) the rate of non-aluminum industrial load growth. Table G-4 compares these factors for this draft plan's medium forecast with the medium forecast from the 1991 Plan.

As can be seen from Table G-4, the most significant changes in the Council's estimate of regionally cost-effective conservation that were due to differences in the underlying load forecast are in the commercial and industrial sectors. Due to lower gas prices, more commercial buildings are expected to use natural gas heat. This lowered the commercial sector conservation potential by 230 average megawatts. The non-aluminum industrial sector growth rate is 50 percent higher than in the 1991 Plan. This increased the achievable conservation potential in that sector by 110 average megawatts.

Table G-4`

[6] In this draft Plan, the Council has attempted to differentiate the marginal cost of supplying new power based on the time of day, the day of the week and the month of the year. As a result, the "cost-effectiveness" of a particular conservation measure depends on when it produces savings. See the section entitled "Estimating the Conservation Resource" below for further explanation.

Major Changes in Medium Load Forecast Influencing Conservation Potential

Factor	1991 Plan Value	1996 Draft Plan Value	Impact on Conservation Potential
New Electrically Heated Dwellings	1.18 million dwellings	1.18 million dwellings	No Change
Residential Water Heating Saturation	78 %	81 %	Small Increase
Commercial Electric Heating Saturation	64%	45%	230 MW Decrease
Non-Aluminum Industrial Growth Rate	1.44% per year	2.12% per year	110 MW Increase

ESTIMATING THE CONSERVATION RESOURCE

The following section summarizes the Council's approach in estimating the conservation resources available to the region. Each of the following tasks is described.

- Supply curves: The first task is to develop a "supply curve" of conservation opportunities to initially rank-order measures with those having the lowest levelized cost coming first.
- Screening for regional cost-effectiveness: The supply curve is then screened to keep only those measures that are cost-effective -- lower cost than power from the West Coast market in the near term, or lower cost than a combustion turbine in the long term. Cost effectiveness calculations include the benefits of capacity savings.
- Demand forecast calibration: A check is conducted to ensure that the base-case consumption of a building or appliance in the conservation analysis matches the consumption used in the forecast for the same type of building or appliance. Savings from measures bundled into programs are also compared with evaluation data to the extent historic programs are similar to the conservation envisioned for the future. Finally, the number of appliances, buildings or industrial loads to which the measure savings apply is taken from the forecast and multiplied by individual measure savings. This translates measure savings into technical average megawatt potential if all applications could be secured.
- Technical versus achievable potential: An estimate is made of how much of the technically available cost-effective conservation resource could be acquired if sufficient economic and political will is available.
- Characterization of key resource attributes: Other attributes of the conservation measures, such as their daily, weekly, and monthly distribution, are associated with each program so it's electricity saving characteristics can compete with other electricity options in the Integrated System for the Analysis of Acquisitions (ISAAC) model, described in Appendix H.

Supply Curves

A supply curve is an economic tool that depicts the amount of a product available across a range of prices. In the case of conservation, this translates into the number of average megawatts that can be conserved (and made available for others to use) at various costs. For example, an industrial customer may be able to recover waste heat from a process and conserve twenty- thousand kilowatt-hours at a cost of one cent per kilowatt-hour. This same customer may be able to conserve thirty-, fifty- and sixty-thousand kilowatt-hours of electricity for the respective costs of two, three and four cents per kilowatt-hour. This represents the conservation supply curve for a particular customer. Individual conservation estimates for end uses in each sector are summed across all buildings and applications to arrive at the regional supply curve for that sector.

The supply curves used in this draft plan do not distinguish between conservation resulting from specific programs or consumer response to the price of electricity. Regardless of how the cost of installing a conservation measure are shared, its total cost to the region is the same. The money used to purchase these savings is not available for investment in other resources and goods. If consumers contribute to the purchase of conservation resources, then the cost to the electricity system will be less than the regional costs developed in this chapter.

Conservation supply curves are a function of the conservation measure's savings and cost. Annual savings are typically estimated using engineering analysis that has been calibrated to reflect real world conditions using actual metered data or load forecast results. Costs are taken from field studies or standardized cost estimating tools and include first costs and operations and maintenance expenses over the life of the measure. Finally, the costs and savings are combined in an analysis of the levelized life-cycle cost of all the conservation measures and the least-cost measure is ranked first.[7]

The absolute value of the savings (in terms of kilowatt-hours per year) produced by adding a conservation measure is a function of the existing level of efficiency. The less efficient the existing structure or equipment, the greater the savings obtained from installing the measure. In order to minimize the costs of efficiency improvements, conservation measures are applied in a least cost order.[8]

To ensure consistency between the conservation supply curves and the system model (ISAAC) financial assumptions used in the levelized cost calculation are the same as those used in the system models for other resources. The ISAAC model assumes that conservation will be financed for 15 years or the life of the conservation measures, whichever is shorter, at a real after-tax interest rate of 4.75 percent.

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[7] Levelized life-cycle cost is the present value of a resource's cost (including capital, financing and operating costs) converted into a stream of equal annual payments; unit levelized life-cycle costs (cents per kilowatt-hour) are obtained by dividing this payment by the annual kilowatt-hours saved or produced.

[8] Least cost is defined in terms of a measure's levelized life-cycle cost, stated in cents per kilowatt-hour. Levelized cost is used so that measures with different lifetimes and savings can be compared on a uniform basis.

Screening Measures for Regional Cost-Effectiveness

It must be determined which measures represented in the supply curve are regionally cost-effective. To do this, the present value of each measure's benefits is compared to the present value of its life cycle costs. Benefits include energy and capacity cost savings, transmission and distribution cost savings[9] and the 10 percent credit given conservation in the Act.

The conservation 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. Any measure that has a benefit-to-cost ratio of 1.0 or greater is deemed to be regionally cost effective. "Cost-effective" therefore means that the conservation measure's levelized costs are equal to or less than the region's avoided cost for that measure's savings, as they are distributed over the time of day and the course of the year. Those measures which pass this screening step are then grouped into "programs."[10] The cost of this "program" is then increased to account for program administrative expenses to determine whether the overall package is regionally cost-effective.[11]

Incorporating Capacity Benefits

In this draft plan, the Council has attempted to incorporate more detailed information on the benefits of conservation based on the time of day and season that the savings are produced. The Northwest's highest demand for electricity occurs during the coldest winter days, usually during the early morning or late afternoon. Electricity saved during these periods is more valuable than savings at night during spring when melting snow is filling the region's hydroelectric system and the demand for electricity is much lower. In addition to its value in offsetting the need for generation during periods of high demand, or "peak hours," conservation also may reduce the need to expand local power distribution 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. In order to capture these differences in avoided cost, it was necessary to distribute annual savings over the 8,760 hours in a year.

Figures G-2 and G-3 show typical daily and monthly loads for space heating in houses built to two different efficiency levels (Pre-1979 housing stock and the Council's Model Conservation Standards - MCS) that were monitored in the End Use Load and Conservation Assessment Project. The difference in typical hourly and monthly use between these two houses (shown in Figures G-4 and G-5) represents the time distribution of conservation savings or "conservation load shape" for space heating. The specific cost-effectiveness limit was established for each end use by computing the weighted average time differentiated value of its savings based on its unique conservation load shape. Figure G-6 shows an illustrative example of the levelized avoided cost by month charted alongside the monthly distribution of space and water heating

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[9] To ensure that conservation and generating resources are compared fairly, the costs and savings of both types of resources must be evaluated at the same point of distribution in the electrical grid. Conservation savings and costs are typically expressed at the point of use (meter), such as in the house. In contrast, the costs and generation from a power plant are typically expressed at the generator (busbar) itself. Thus, to make conservation comparable with generation, the costs of the conservation resource must be adjusted to reflect saved transmission and distribution system losses.

[10] The term "program" as used here is a set of measures that affect a particular end-use (e.g., residential refrigeration, commercial lighting, etc.), even though these measures may be secured through a variety of means (e.g., codes, utility actions, consumer actions, etc.).

[11] In addition to the direct capital and replacement costs of the conservation measures, administrative costs to run the program must be included in the overall cost. Administrative costs can vary significantly among programs and are usually ongoing annual costs. In prior power plans, the Council used 20 percent of the capital costs of a conservation program to represent administrative costs. The Council's estimate of 20 percent falls within the range of costs experienced in the region to date. Therefore, the average cost of all conservation programs is increased 20 percent before being compared to generating resources to determine which costs less. The only exception to this assumption is in the industrial sector, where program experience indicates that administrative costs should be assumed to be 10 percent of costs.

savings. Each time period's savings are valued at the avoided cost for that time period. The weighted value of all the time period's avoided costs establishes the cost-effectiveness limit for a particular end use. As can be seen from Figure G-6, the cost-effectiveness limit for space heating will be higher than that for water heating because more space heating energy is saved when avoided costs are higher. Appendices G-5 and G-6 contain the conservation load shape and marginal cost files used to determine which conservation measures were cost-effective in this draft plan. To account for avoided local distribution system costs, conservation savings were credited with $5.00 per kilowatt-year.

Figure G-2
Hourly Space Heating Load Shape

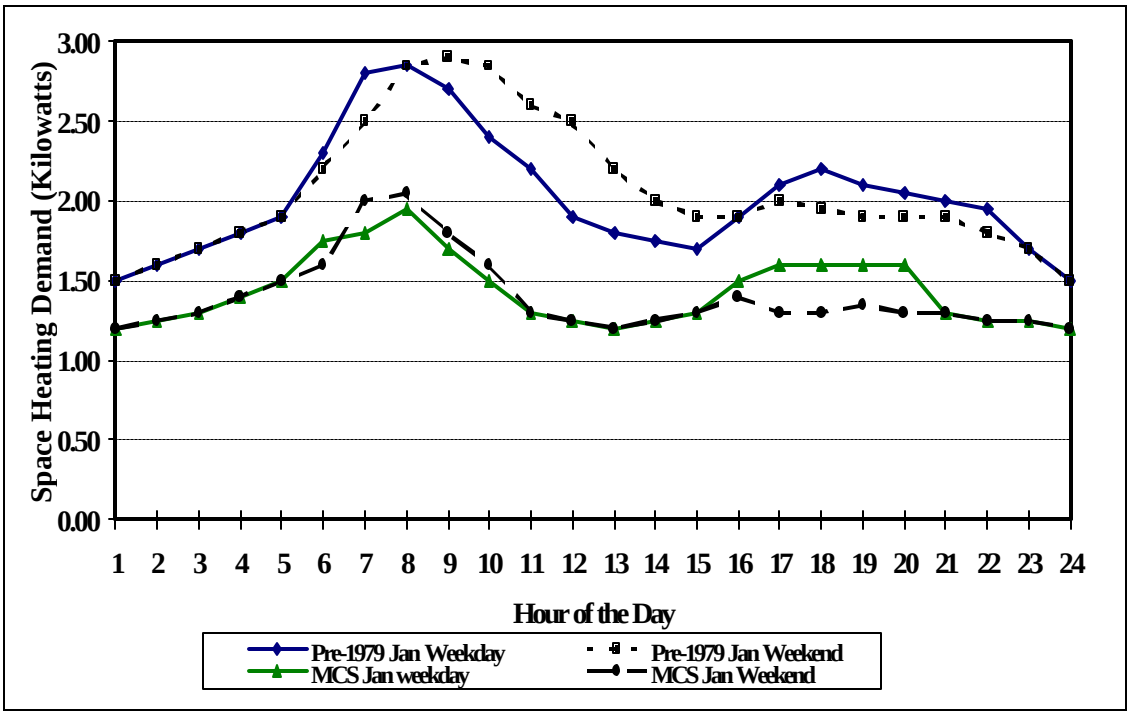


Figure G-3
Monthly Residential Space Heating Load Shape

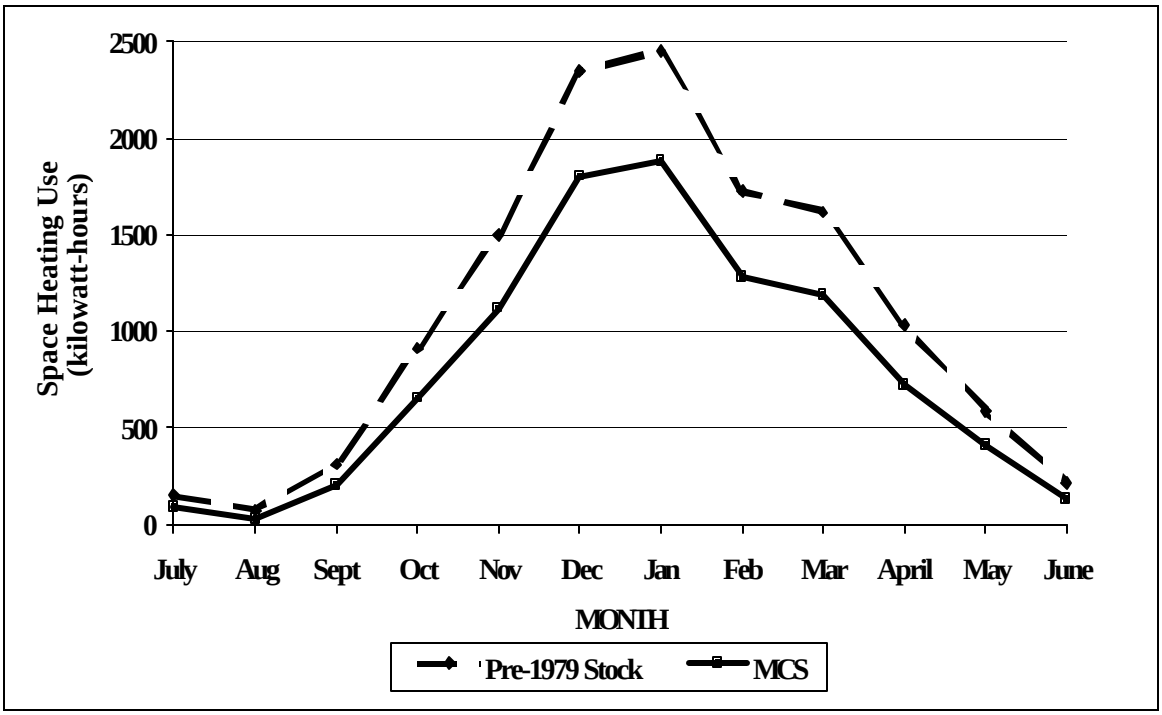


Figure G-4
Hourly Space Heating Conservation Load Shape

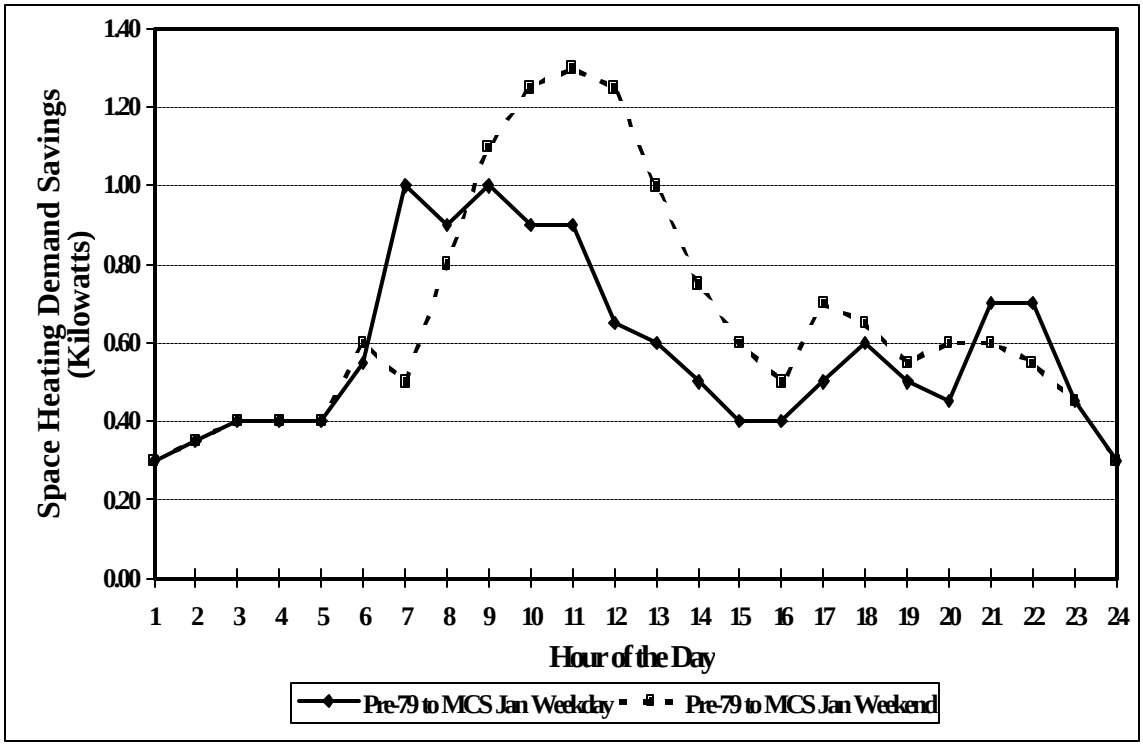


Figure G-5
Monthly Load Shape of Space Heating and Conservation

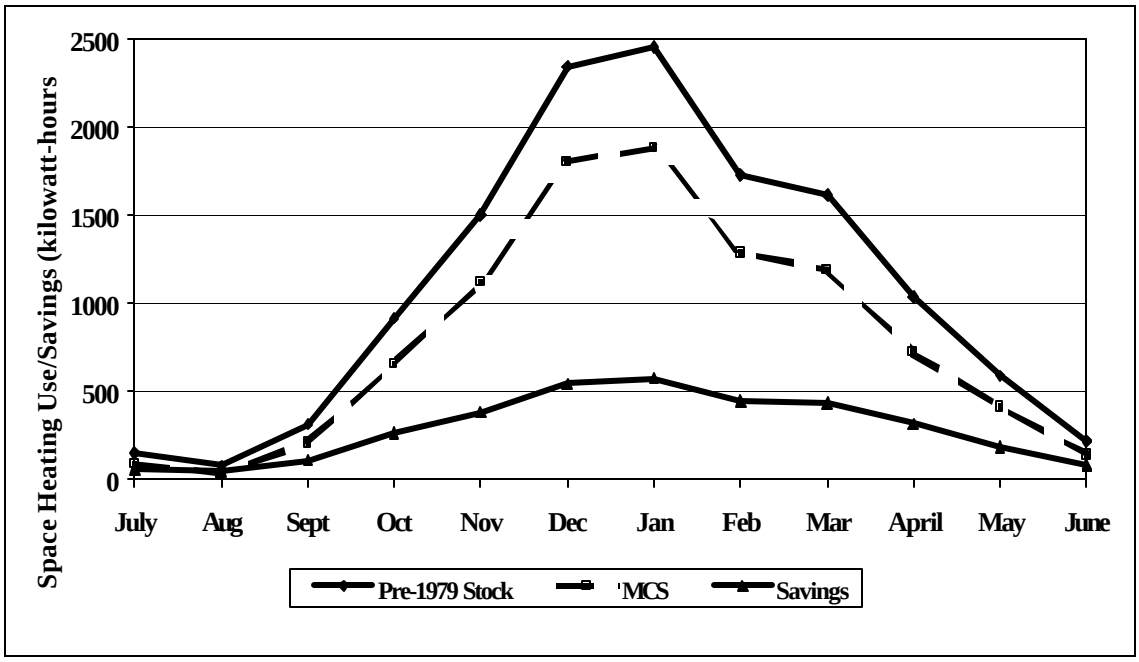
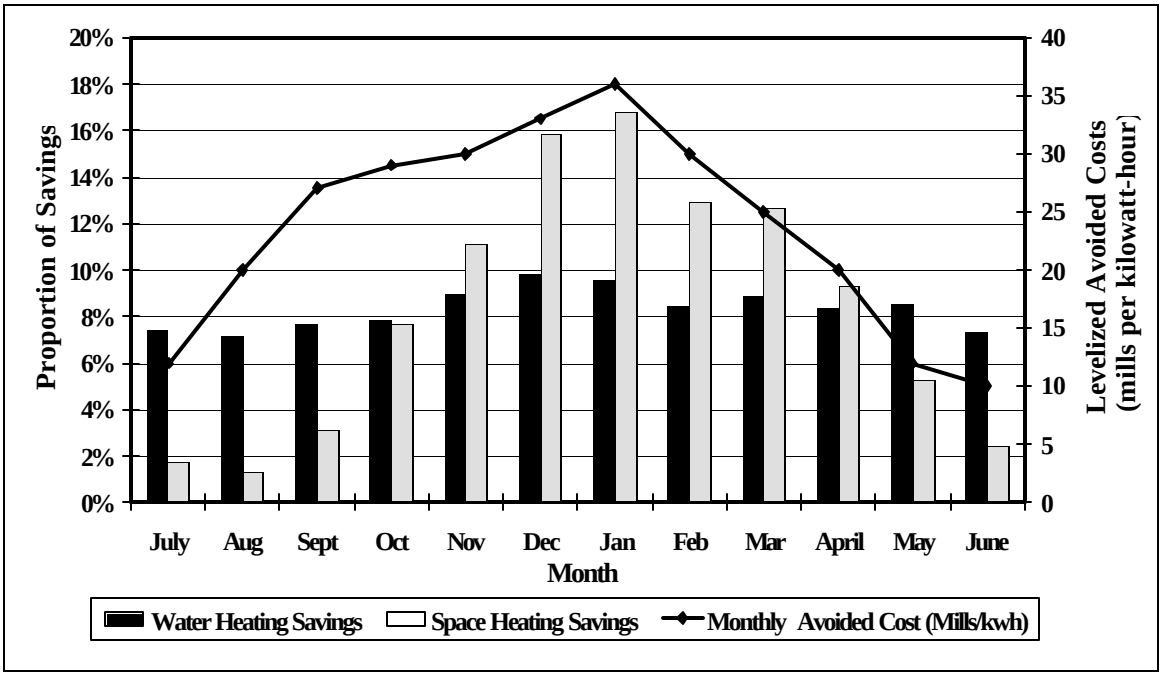


Figure G-6
Monthly Value of Savings for Space and Water Heating



Demand Forecast Calibration

For all the conservation resources, each package of measures or "program" is calibrated with the demand forecast. This is done for two reasons. First, it ensures that savings are not counted twice (once as a reduction of demand in the forecast and again as a conservation measure) or under-counted. Second, it provides a mechanism that consistently accounts for changes in consumer behavior in response to conservation. For example, this step captures how consumers might change their wood heating use in response to changes in electricity prices or in response to the weatherization of their homes. This results in average savings and costs that incorporate expected long-term consumer behavior.

As part of this step, the "calibrated" cost and savings are compared with evaluation data available from the field for comparable programs. This gives an indication of how well the estimates match to actual experience. Generally, these comparisons with evaluation data are made on a "rough" basis because actual past programs often do not match the package of measures being analyzed for the future. For example, the results of the evaluation of the Super GOOD CENTS program for new residential construction is not directly comparable to the conservation estimates presented in here for new residential construction because the historic program funded a different set of measures.

This step also includes multiplying the savings from one building or appliance by the number of buildings or appliances that are expected over the 20 year forecast horizon. This translates measure savings for one application into technical average megawatt potential if all applications could be secured.

Technically Available versus Practically Achievable Conservation Potential

The technical potential is reduced by the portion of the conservation resource that is considered not practically achievable. The remainder, termed "achievable conservation," is defined as the net energy savings the Council anticipates could be developed after taking into account factors such as consumer resistance, quality control and unforeseen technical problems.

Historically, the Council has assumed that 85 percent of the technically available conservation was achievable because it believed that the wide assortment of incentives and regulatory measures provided by the Northwest Power Act could persuade the region's electricity consumers to install a large percentage of the available and cost-effective conservation. In this draft plan, the Council has assumed the amount of conservation that will be developed due to the momentum created by existing utility programs and ongoing consumer actions is approximately 30 percent of what would be achievable using these historic assumptions.

While Bonneville and the region's electric utilities have been the dominant force behind the development of conservation resources in the past, the electric utility industry is in the midst of a transition that is likely to result in major restructuring. The implications of a more competitive, less regulated utility industry for securing potential conservation in the future are unclear. The Council's analysis, discussed in Chapter 6 of the draft plan, concludes that under virtually any restructuring alternative, Bonneville and the region's utilities will not find it in their economic self interest to pursue conservation acquisition at their historic levels. Therefore, this draft plan assumes that approximately 30 percent of the regionally cost-effective conservation will be achieved without further market intervention by some party. However, the "achievable" conservation potential reported in this appendix assumes that some mechanism could be designed and implemented to capture about 85 percent of all the cost-effective conservation resources identified.

Characterization of Key Resource Attributes

This task involves using the cost and savings characteristics of each program to evaluate the conservation resource's cost-effectiveness and compatibility with the region's power system and timing of the need for new resources. The cost and savings data, calibrated to the forecast, along with other characteristics of the end use savings (such as their daily, weekly and monthly distribution) are used in the system model, called the Integrated System for Analysis of Acquisitions (ISAAC), to be compared with other electricity options in the development of the resource portfolio. Cost-effectiveness is determined by comparing each program against other resources to determine which will provide electric service at the lowest cost.

Two key attributes necessary to model the conservation resources are: 1) whether it is a discretionary or lost-opportunity resource, and 2) if it is a discretionary resource, how quickly it can be developed. These are discussed next.

Conservation resources can be divided into two categories. The first category includes those resources that can be secured based on need, such as savings from insulating an existing building. The second category of conservation resource can only be secured economically at a particular point in time, such as at the time of building construction or industrial process change. The first category of conservation resource can be viewed as "discretionary" because it can be acquired "as needed." The second category of conservation has been termed "lost opportunity" or "non-discretionary" because it can only be captured at a specific point in time. Each of the conservation programs are categorized as either discretionary or lost-opportunity.

The development rates for the discretionary resources are subject to management. The amount of "discretionary" conservation that the Integrated System for Analysis of Acquisitions (ISAAC) model schedules in any one year to meet energy needs depends on the need for new resources and on how fast a program can become operational. The rate at which a program can be brought on-line is sometimes known as the program acceleration or *ramp* rate. If the region has surplus power for a long time, but a conservation program is already operating, the rate at which the program can slow down and the minimum level at which that program can remain viable are also important. The minimum viable level of the program, if above zero, determines the amount of savings that would accrue even though the region would prefer to delay purchase of the resource during the surplus period. Each program also has an upper limit on its activity level and a limit on how quickly the activity level can be reduced (decelerated). Table G-5 summarizes the constraints on conservation deployment assumed in the draft plan for discretionary resources.

Table G-5
Discretionary Conservation Program Development Constraints

Resource	Minimum Viable (%/year)	Maximum Acceleration (%/year/year)	Maximum Deceleration (%/year/year)	Maximum Rate (%/year)
Residential Weatherization	**4**	**5**	**5**	**12**
Residential Lighting	**4**	**5**	**5**	**12**
Existing Commercial	**2**	**2**	**2**	**6**
Industrial	**0**	**2**	**2**	**6**
Irrigated Agriculture	**0**	**5**	**5**	**5**

The amount of practically achievable conservation reported in this appendix for each end-use is based on the development rate associated with the Council's medium forecast. Should the region experience high or lower economic growth, the amount of achievable conservation will also be more or less than described here.

Conservation opportunities are available over a wide range of costs. Therefore, in order to maximize the regional benefits of conservation, the region should strive to secure the lowest cost savings first. The decision rules embodied in the ISAAC analysis "develop" conservation resources in their ascending "least cost" order. The next section describes the results of the ISAAC analysis of conservation's value to the regional power system.

THE VALUE OF CONSERVATION TO THE REGION

This section describes the value of conservation to the region over the long-term and then reviews a number of sensitivity cases that explore the strength of the result. It ends with a discussion of the near-term financial risks of acquiring the conservation resource.

Conservation's Benefits, Uncertainties and Risks

The development of cost-effective conservation is the highest-priority electricity resource in the Northwest Power Act. In order to be considered "cost-effective," conservation must be less costly than the next similarly available and reliable generating resource. The goal of each plan has been to find the mix of conservation and new power supplies that produces the lowest (i.e., least cost) total present value cost of meeting the region's energy service needs. In the near term, the levelized cost of the conservation must be less than the estimated levelized cost of market purchases from out of region to be cost-effective. Once the transmission system cannot accommodate further purchases from outside the region, conservation must have a lower levelized cost than new natural gas-fired combustion turbines.

The council has historically viewed the costs and benefits of investing in the region's energy future from a long-term perspective. It has tried to weigh the costs of investments made in new resources over the 20-year planning horizon against the benefits they could return to the citizens of the Northwest over the resources' useful lives. The fact that people tend to place greater weight on near-term costs and benefits than those that might occur far in the future is accommodated by discounting future costs and benefits.[12]

Conservation investments have three characteristics that must be taken into consideration in this sort of long term perspective. First, the costs of conservation are virtually all capital. This means there are no operating costs that can be avoided if, for example, demands grow less quickly than expected or fuel prices fall. Second, for this analysis we have assumed that all the conservation is amortized over 15 years even though some measures produce savings over much longer periods. This means the costs are front-loaded while the benefits are frequently spread out over a longer period. Finally, some of the conservation is very long lived. As a result of all these factors, a long-term perspective exposes these investments to uncertainty and risk.

[12] For this plan a base discount rate of 4.75 percent was used. The amount of conservation that is regionally cost-effective was also tested using discount rates of 3.0 and 6.0 percent. The results of these studies indicated that changes in discount rate would alter the amount of cost-effective conservation by less than 10 percent above and below the potential reported in this section.

Countering these characteristics is the fact the investment in conservation is made incrementally. On average, the pace of acquiring all 1,535 average megawatts of cost-effective conservation would be about 75 average megawatts per year. This means that the region can (and should) regularly revisit the economic merits of further investments in conservation. This limits the risk of potential over-investment. In the following paragraphs, the analysis of the long-term value of conservation is described along with the effects of key uncertainties and risks.

Analysis of the Long Term Benefits of Conservation

The Council analyzed the long-term benefits of conservation using the Integrated System for Analysis of Acquisitions (ISAAC) model. The model is described in more detail in Appendix H. This analysis required: 1) dividing the total amount of cost-effective conservation that could be acquired into cost bins; 2) estimating utility program and price-driven consumer acquisitions; 3) estimating the net present value benefits to the region of developing various levels of conservation. These are described next.

Establish the Amount of Cost-Effective Achievable Potential by Cost Bin

Each end-use sector's total achievable conservation potential was divided into four blocks based on its total resource cost (total direct cost, plus 20 percent administrative costs). The first block contained all conservation costing less than 1.0 cent per kilowatt-hour, the second contained conservation costing between 1.0 and 2.0 cents per kilowatt-hour, the third contained conservation costing between 2.0 and 3.0 cents per kilowatt-hour and the fourth block contained conservation costing between 3.0 and 4.0 cents per kilowatt-hour. Each block was treated as an independent resource.

Figure G-7 shows the distribution of this conservation across the major end uses or sectors at levelized costs between 1.0 and 6.0 cents per kilowatt-hour using a point estimate of future conditions that matches the Council's *medium* economic growth scenario. Table G-6 shows the distribution of the regionally cost-effective conservation resource potential by major end-use sector as well as the distribution of conservation at levelized cost increments between 1.0 and 6.0 cents per kilowatt-hour for this same forecast. The total regionally cost-effective conservation available in the medium forecast shown in Table G-6 is 1,780 average megawatts. Note that as described above, the *average* amount of conservation that appears cost-effective to the region across the full range of Council forecasts is 1,535 average megawatts.

Figure G-7
Conservation Supply Curve for Medium Forecast

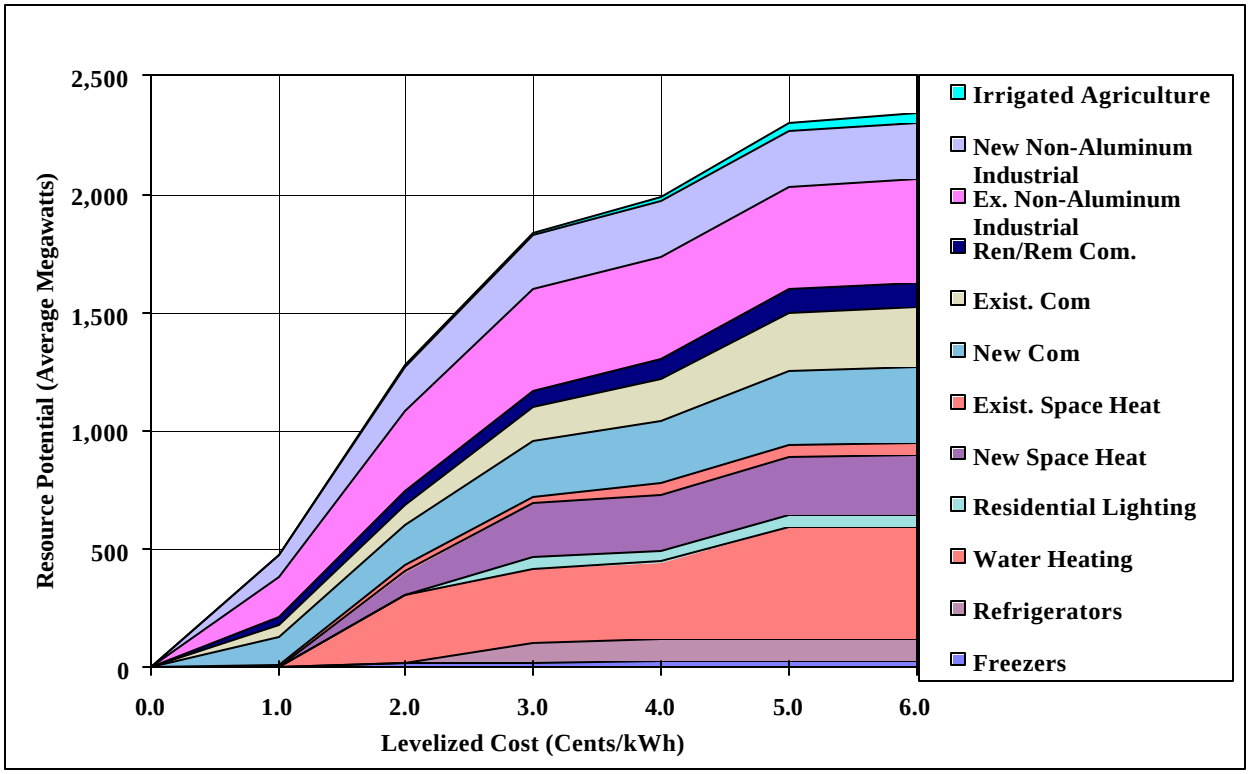


Table G-6
Incremental Conservation Resource Potential in Medium Forecast by End-Use Sector
(Average Megawatts)

Maximum Levelized Cost (Cents/Kilowatt-hour)	1.0	2.0	Cost Effectiveness Limit	3.0	4.0	5.0	6.0
Freezers	0	15	0	0	20	0	0
Refrigerators	0	0	90	0	0	0	0
Water Heating	0	290	25	0	10	150	0
Residential Lighting	0	0	45	0	0	0	0
New Residential Space Heating	0	100	105	20	10	15	0
Existing Residential Space Heating	10	15	0	0	20	5	0
New Commercial	125	45	70	0	25	45	10
Existing Commercial	45	45	50	0	40	65	15
Commercial Renovation/Remodel	40	15	20	0	10	10	5
Non-Aluminum Industrial	260	265	95	30	15	10	0
Irrigated Agriculture	0	5	5	5	5	10	5
TOTAL BY BIN	480	795	505	55	155	310	35
CUMULATIVE TOTAL	480	1,275	1,780	1,835	1,990	2,300	2,335

Estimate Utility Program and Price Driven Consumer Acquisitions

Some of the achievable conservation identified is likely to be developed through ongoing utility programs, and independent consumer actions. An estimate was made of the conservation likely to be developed as a result of the momentum of current utility programs plus that which consumers acting on their own may secure over the longer term. Council staff contacted Bonneville and the region's utilities and asked them to estimate the amount of conservation they are likely to develop over the next five years. The results of this survey indicated that the region's utilities are planning to acquire 290 average megawatts between 1996 and the year 2000. This conservation was assumed to be implemented on a fixed schedule: 70 average megawatts per year the first two years; 60 average megawatts per year the next two years; and 30 average megawatts the fifth year. The total cost of these conservation resources was assumed to be about 1.9 cents per kilowatt-hour. The actual cost to utilities of these acquisitions depends upon the degree of cost-sharing they arrange with their customers.

In addition to the conservation that appears likely to be developed by utilities over the next five years, the Council estimates that an additional 225 average megawatts (15 average megawatts per year) of conservation are likely to be developed each year as a result of consumer response to electricity prices and future market-driven actions on the part of consumers and businesses on their own. This assumption was developed by looking at two approaches to estimate how much of the remaining conservation potential will be secured by market forces. The first approach was to estimate how much conservation has simple economic payback periods that consumers typically find attractive. Figure G-8 shows the amount of conservation available at simple payback periods up to seven years. Evidence suggests that simple payback periods of less than three years are typically needed by commercial and industrial firms in order to invest in conservation. As can be seen from Figure G-8, only about 100 average megawatts meet this criteria.

The second approach used by the Council to determine how much conservation might be developed by the market was to identify specific conservation measures that had substantial non-energy related values or that would likely be adopted as a result of other factors. For example, an industrial facility might invest in a conservation measure as part of a production process improvement or as a consequence of meeting an environmental or safety requirement. In the residential sector, the reduced ultra-violet light wave transmission of super efficient windows may prompt consumer adoption of this measure. Also, for example, the market transformation of the manufactured housing industry may result in continued purchase of highly energy efficient units. Taken together these "market" responses are estimated to produce between 200 to 325 average megawatts of conservation. The Council has estimated that at least 225 average megawatts of these "market driven" resources will be secured by the region's consumers.

Figure G-8
Consumer "Conservation Supply Curve"

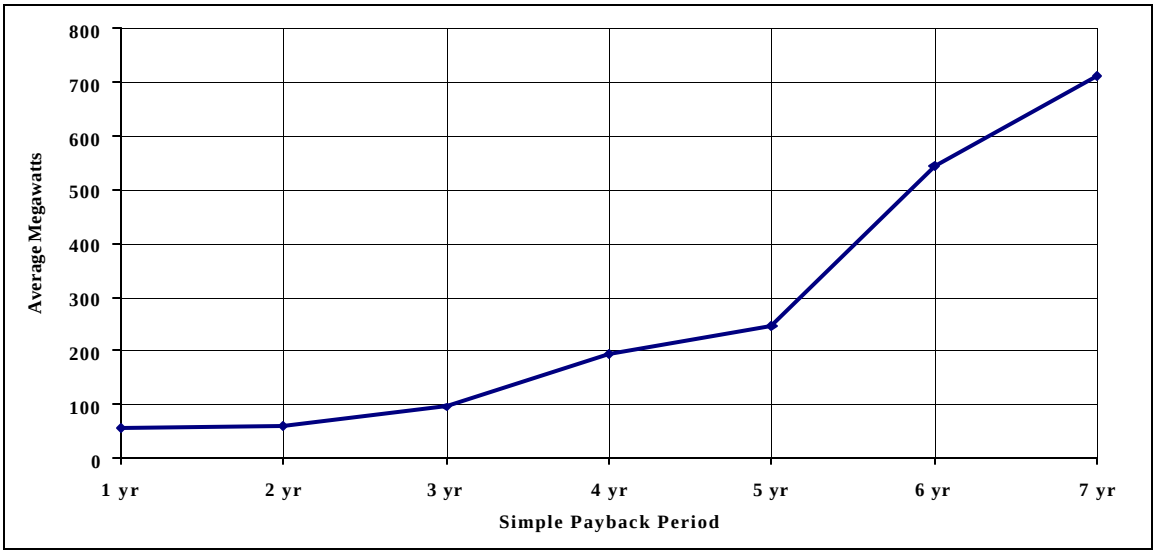
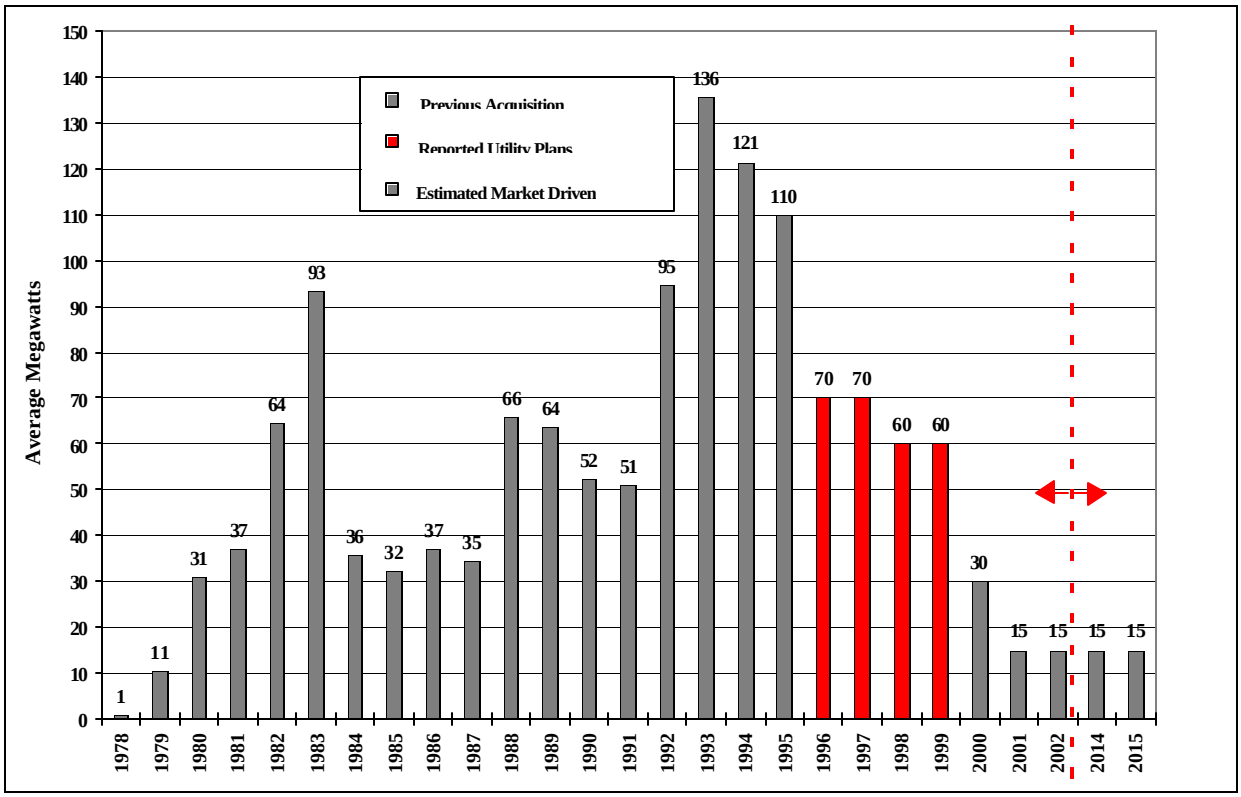


Figure G-9 shows historical (since 1978 annual conservation acquisitions) and projected acquisitions through the year 2015 assumed as the "market driven case." A total of 515 average megawatts of conservation costing an average of 1.6 cents per kilowatt-hour are assumed to be developed by the utility programs, market forces, and ongoing consumer response to electricity prices.

Figure G-9
Historic Utility Conservation Acquisitions vs. Projected Near and Long-term Market Driven Conservation



Of the 515, approximately 260 to 290 average megawatts are assumed to be developed by utilities in the next four to five years based on individual utilities reported plans for this time period. The remaining 225 to 255 average megawatts are assumed to occur through a combination of business and consumer actions in response to a fully competitive marketplace. A more detailed discussion of how the conservation resources were divided into these categories can be found in Appendix G-5: Market Bundles.

Estimating the Regional Value of the Conservation Resource

The ISAAC model was run to simulate 100 potential "future" combinations of economic growth, fuel prices and water conditions. The first set of 100 "futures" assumed that the region relied solely on out-of-region purchases and new combined cycle combustion turbines. This resource portfolio had a present value cost to the region of approximately $27.7 billion. The ISAAC model was then used to simulate these same 100 "futures" with a resource portfolio that offset some of these purchases and new combustion turbines by developing the 515 average megawatts of "market and utility program momentum driven" conservation. These same 100 futures were simulated four more times with the amount of conservation available for development set at a different cost ceiling. That is, one set of these 100 futures was simulated with only conservation costing less than 1.0 cent per kilowatt-hour available. Then another set of 100 futures were simulated with conservation costing up to 2.0 cents per kilowatt-hour. This procedure allowed the Council to determine the incremental benefit of meeting future load growth with increasingly expensive conservation.

The results of this analysis indicated that purchasing conservation up to a levelized cost of 3.0 cents per kilowatt-hour provided a net benefit to the region of approximately $2.3 billion dollars. To place this value in perspective, the estimated present value cost for all resources, except conservation, needed to meet the region's electricity load growth over the next 20 years is $27.7 billion and the value to the region of purchasing power off the West Coast market instead of building combustion turbines in the region is $3.2 billion. By making cost-effective investments in conservation, the $27.7 billion could be lowered to $25.4 billion. Table G-7 shows the incremental net-benefit provided by each "block" of conservation. Also shown are the total tons of carbon dioxide offset by the conservation. This could become important should mitigation of global climate change be required in future.

Table G-7

Regional Benefits of Conservation Resource Development [13]

Conservation Block	Average Present Value $ Millions	Average Megawatts	Carbon Dioxide Offset Millions of Tons
Utility Momentum plus "Market Driven" (Average cost = 1.9 Cents/kWh)	$ 570	515	27
Less than 1.0 Cents/kWh	$ 760	310	16
More than 1.0 and less than 2.0 Cents/kWh	$ 830	525	27
More than 2.0 and less than 3.0 Cents/kWh	$ 140	185	10
Total	**$ 2,300**	**1,535**	**80**

As shown in Table G-7, the $2.3 billion in benefits results from the development of about 1,535 average megawatts of the region's conservation potential.[14] Of this, 515 average megawatts are assumed to result

[13] The present-value benefits shown in Table G-7 do not include the 10-percent credit provided conservation in the Northwest Power Act.

[14] In the medium load growth case the ISAAC model develops roughly 1,700 average megawatts of conservation out of the 1,780 average megawatts of cost-effective potential if no other resources are available. The difference of 80 average megawatts is due to assumed constraints on the pace at which conservation resource development can be accelerated.

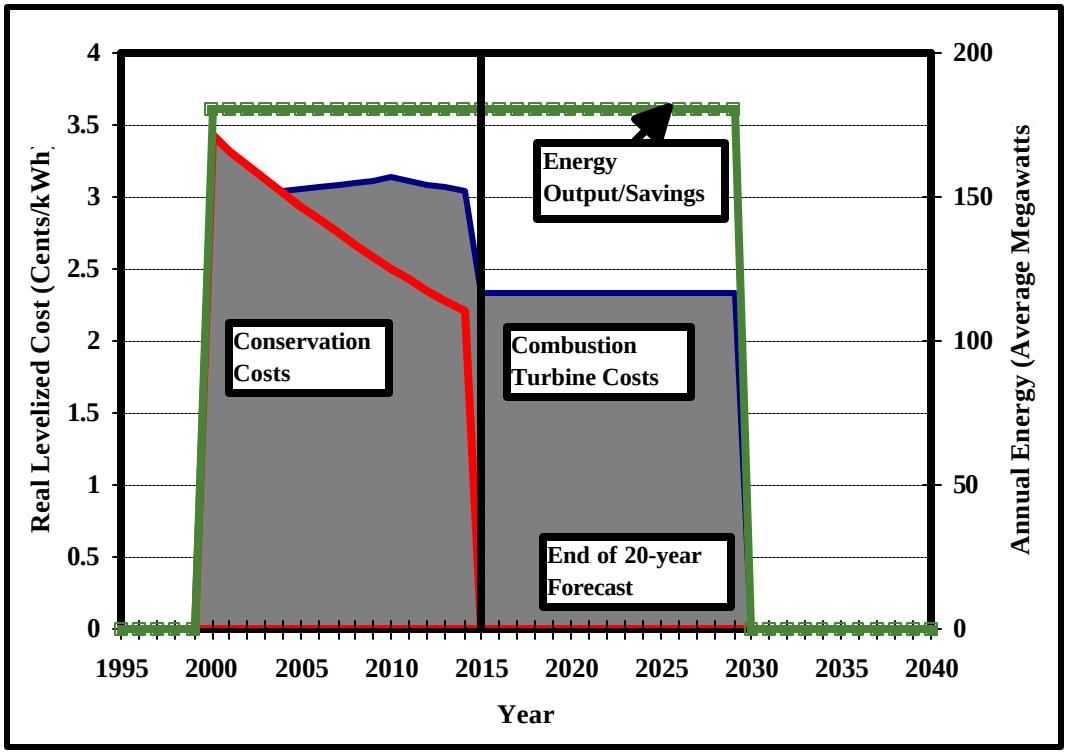
from the "market driven" actions of consumers and momentum from utility programs. Therefore, the region has the potential to secure an incremental benefit of approximately $1.7 billion ($2.3 billion minus $570 million) above what market forces may deliver on their own by developing, on average, an additional 1,020 average megawatts of conservation potential.

It is important to acknowledge that the majority of the benefit shown in Table G-7 occurs over the long term, beyond the 20 year planning horizon. The plan looks at the value of resources developed over 20 years to meet load growth. However, for a resource built in any given year that has a longer lifetime than the 20 year forecast horizon, the costs and benefits of that resource for its entire lifetime are counted. Consider, for example, either a combustion turbine or an equivalent amount of conservation developed in the year 2000. Both are financed over 15 years, both have 30 year lifetimes and both will produce or save kilowatt hours well beyond the 2015 forecast horizon. Figure G-10 shows the cost profile for these two resources over time.

If these two resources were evaluated only up to the year 2015, all of the costs of the conservation would be included, but the fuel and maintenance costs of the combustion turbine after 2015 would be missed. Until the year 2015, the two resources are fairly comparable in total costs, and both resources produce an equal amount of benefits (i.e., energy). But after the year 2015 conservation continues to produce savings for the region at very minimal or no costs. The turbine produces value after 2015, but at a much higher cost. To capture the benefits and costs of resources acquired by 2015, the costs and benefits over their entire lifetime need to be incorporated. The effects of uncertainty regarding future electrical generation costs have been addressed in the Council's analysis and are discussed below.

Figure G-10

Resource Costs and Benefits are Valued Over their Productive Lifetimes

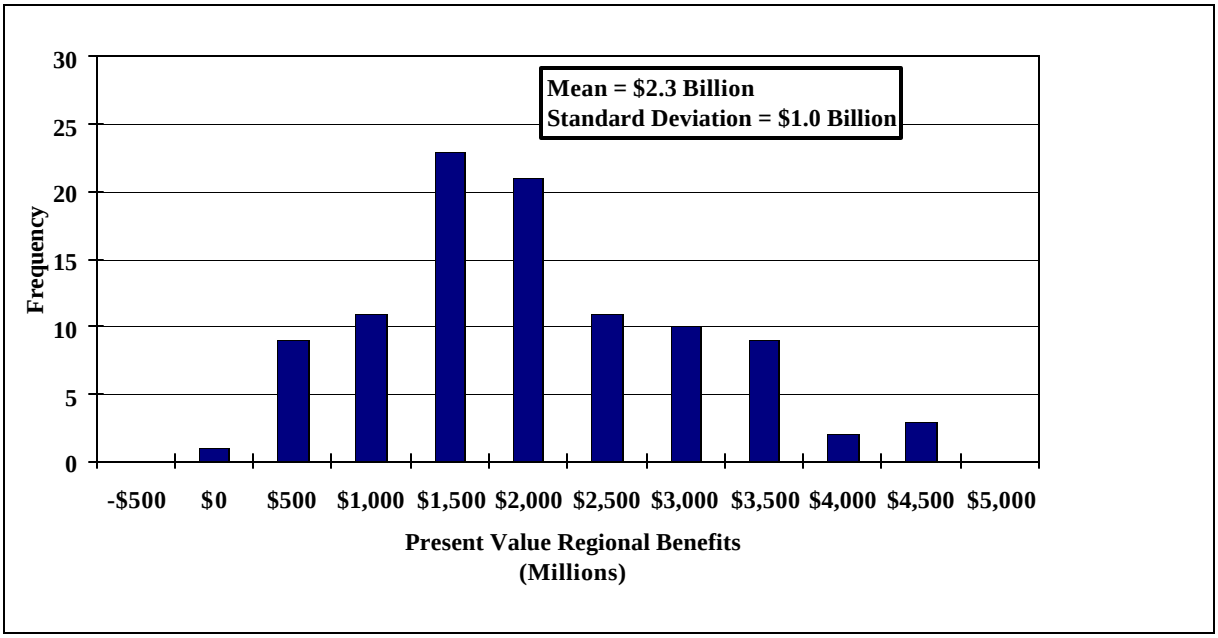


While the average present value of the conservation is of interest, it is important to have a sense of how that value might change with respect to the uncertainty in fuel prices, demand growth and hydro conditions considered in the analysis. The ISAAC model simulates 100 random "futures." That is, it does not follow any specific economic growth path. As a result, alternative resource portfolios can be evaluated by comparing the statistical average of their present value costs across these 100 futures as well as the distribution around that average. Figure G-11a shows the distribution of present value benefits produced by the investments in

conservation. Over the life of the portfolio, the acquisition of this conservation produces a benefit to the region of between $0 and $4.5 billion. The magnitude of both conservation's value and the actual amount developed depends on specific combinations of economic growth, fuel prices and hydroelectric availability the region experiences over the next 20 years. For example, under low economic growth and low fuel prices, just over 800 average megawatts of conservation are developed.

Figure G-11a

Distribution of the Present Value Benefits of Conservation Over Full Resource Life



This conservation is a break-even investment for the region. Alternatively, under high economic growth and high fuel prices, nearly 2200 average megawatts of conservation are developed providing the region with $4.5 billion in present value benefits. On a long term basis, the region's conservation investments are robust, yielding at least break-even or positive benefits to the region.

The reason conservation remains valuable over the wide range of futures modeled is because the conservation is relatively low cost and the cost-effectiveness of additional investments in conservation is continually assessed as the region invests over time. As described above, in futures where low load growth and/or low gas prices occur, the region reduces its investments in conservation and develops much less than 1,535 average megawatts. Because conservation is developed in increments over time it continues to have value, even compared to flexible combustion turbines. If the region were to commit today to developing exactly 1,535 average megawatts of conservation over the next twenty years, there would be a significant number of cases where its present value costs exceeded its benefits. As with any resource, the development of conservation should be periodically assessed.

Sensitivity Analysis on the Long-Term Benefits of Conservation

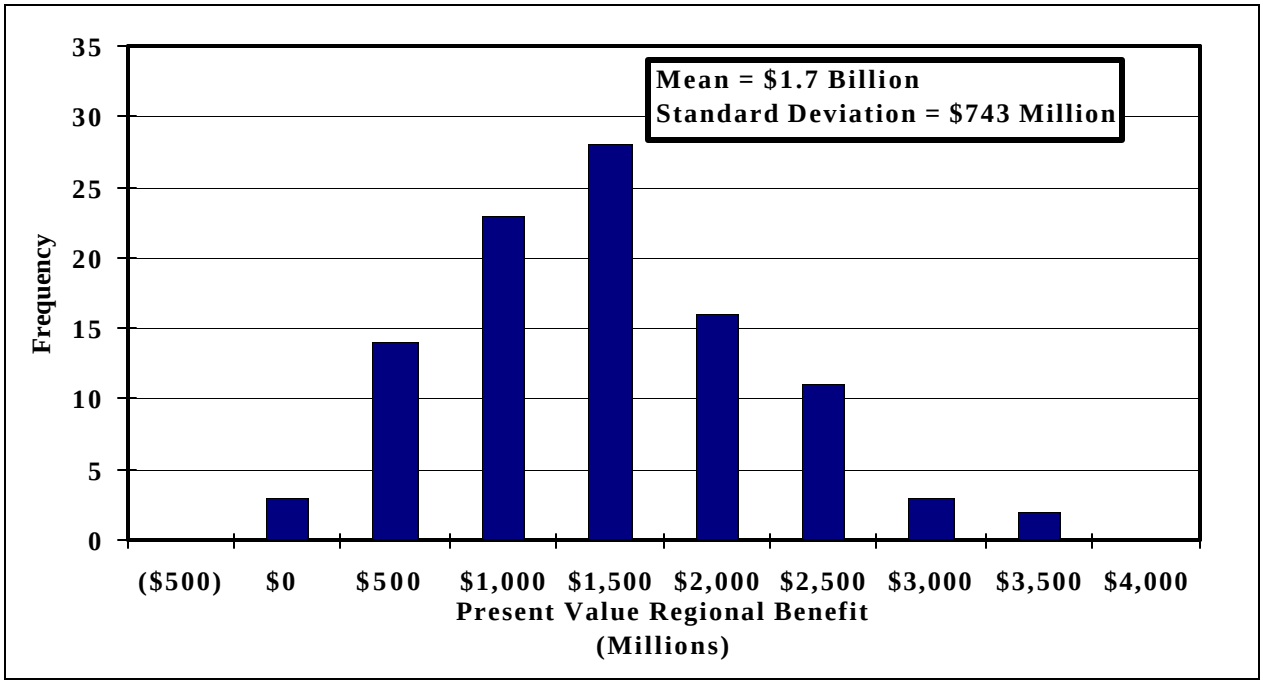
The Council then tested the ISAAC results of the benefits of conservation for sensitivity to changes in major input assumptions. The Council's base analysis accounts for much of the uncertainty associated with fuel prices, demand and hydroelectric conditions. However, there are additional uncertainties and risks to which conservation investment is exposed. These sensitivity cases are described next.

Sensitivity Case 1 - Uncertainty in Conservation Potential

The Council relies on the best information and analysis it can produce in estimating the amount of conservation available for development. Those estimates are, however, subject to some uncertainty. Comments received on the Council's draft conservation estimates for the commercial and industrial sectors argued that they were too optimistic. To test the sensitivity of the ISAAC results to the amount of conservation in the portfolio, the estimated achievable potential of conservation in the industrial sector was reduced 44 percent. Similarly, the commercial sector's conservation potential was reduced by 30 percent to reflect a maximum market penetration rate assumption of 60 percent rather than the 85 percent assumed in the base case. These alternative assumptions regarding the available conservation potential resulted in the development of 1,170 average megawatts of conservation by the year 2015, rather than 1,535 average megawatts, or a 365 average megawatt reduction. This lowered the present value benefits of conservation from approximately $2.3 billion to about $1.8 billion. Figure G-11b shows the distribution of the present value benefits across the 100 futures simulated in the ISAAC analysis for this sensitivity study.

Figure G-11b

Distribution of Present Value Regional Benefits with Lower Conservation Potential



Sensitivity Case 2 - Sudden and Significant Loss of Load

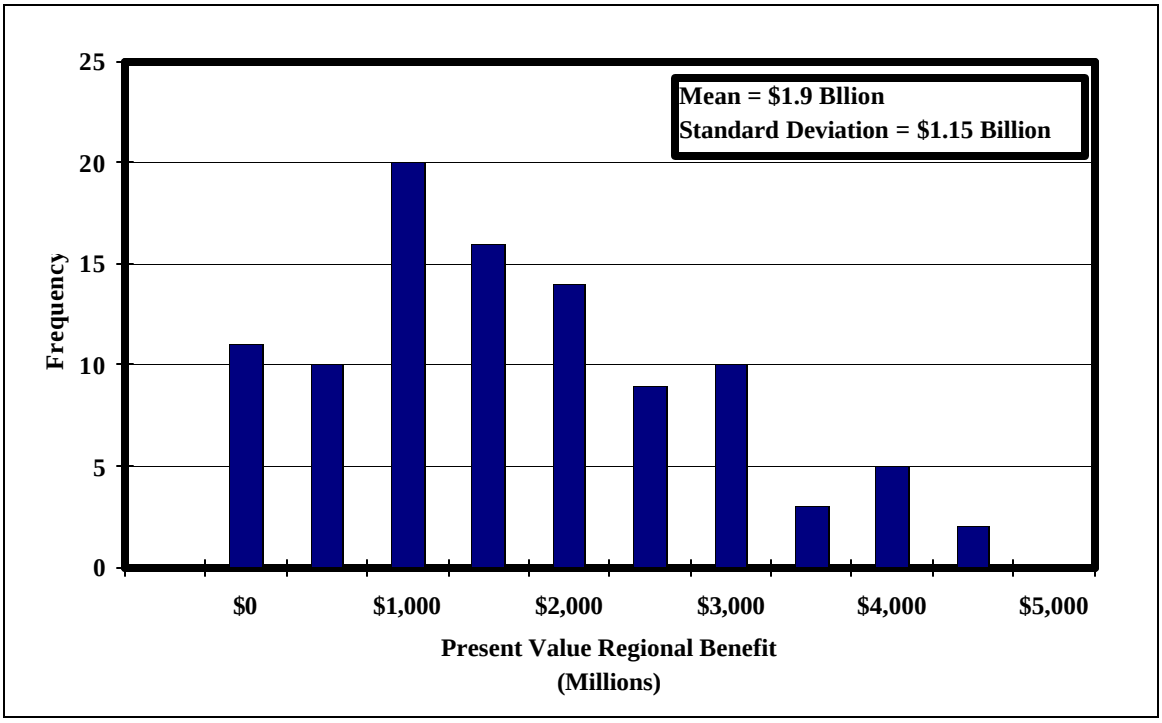
The primary risk the region takes in purchasing conservation is that once the capital is invested it can no longer be used for some other purpose. Virtually all of the cost of conservation is a fixed, up front capital cost that is repaid in savings over many years. Once the capital is spent on a conservation measure, there is no simple way to recover its value, other than to wait for the savings to accrue. If the region were to suddenly lose a large amount of load, some conservation investment would be unneeded.

This possibility was investigated by assuming that the region looses 3,000 average megawatts of firm electrical load in the year 2005 as a result of industrial plant closures or economic downturn. In this scenario, the development of cost-effective conservation still provides the region with $1.9 billion in present value savings compared to $2.3 billion in the base case. This is a result of three factors. First, because the region is already relying heavily on market purchases to meet its needs, it can respond to rapid changes in loads by curtailing purchases. Secondly, less than 10 percent of the conservation that is typically scheduled for development by the year 2005 has a levelized life cycle cost to the region of more than 2.0 cents per kilowatt-

hour. Consequently, since it is less expensive than continued market purchases, it retains its value to the region. Third, because the conservation is implemented incrementally at about 75 average megawatts per year, further conservation investment is reduced when the loss of load occurs. Figure G-11c shows the distribution of the present value benefits across the 100 futures simulated in the ISAAC analysis for this sensitivity study.

Figure G-11c

Distribution of Present Value Regional Benefit With Sudden Large Loss of Load

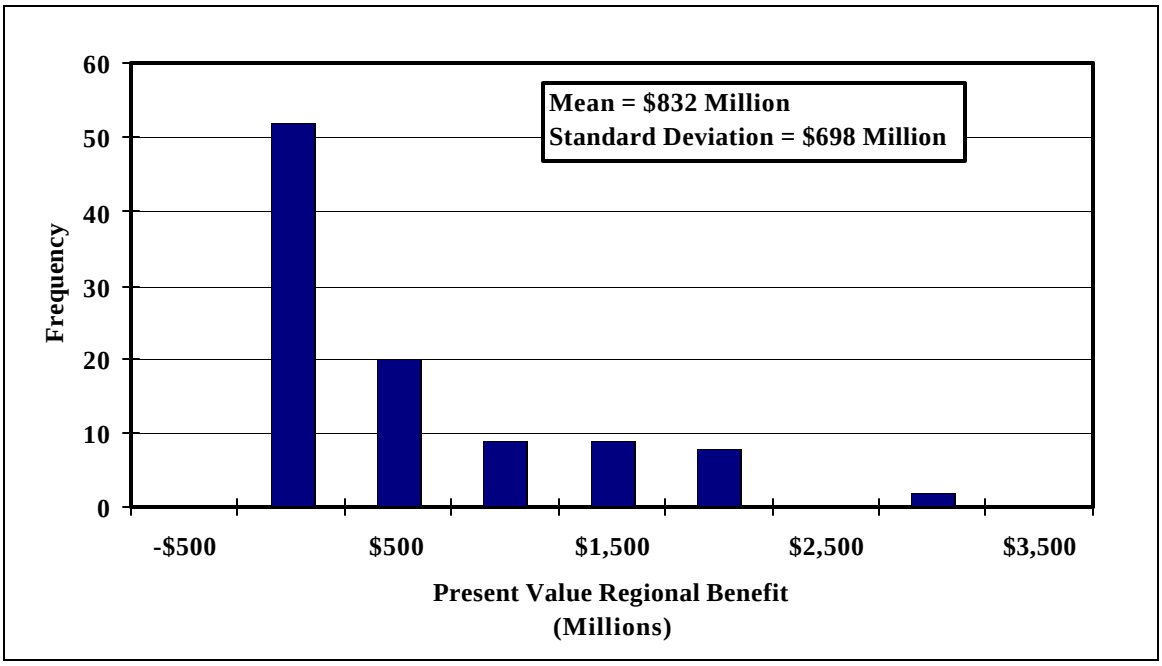


Sensitivity Case 3 - Technological Breakthrough in Generation Technology

Another way in which conservation investment would be at risk would be if there were some dramatic and unanticipated improvement in generation technology that would reduce the value of conservation savings. This was tested by assuming that some technological breakthrough reduces the cost of new generation by nearly 50 percent (to 1.5 cents per kilowatt-hour) in the year 2005 and that this source of power is immediately available to serve all regional loads. The costs of this resource were assumed to be all variable costs, and thus it would have complete flexibility to be turned on and off to meet load fluctuations. Should this occur, it would reduce conservation's average present value benefit to the region to approximately $800 million. Figure G-11d shows the distribution of the present value benefits across the 100 futures simulated in the ISAAC analysis for this sensitivity study.

Figure G-11d

Distribution of Present Value Benefit of Conservation With Reduced Cost of New Generation



Sensitivity Case 4 - Global Climate Change Risk

Not all the risks the power system faces are adverse to conservation. As is discussed later in this chapter, there is the risk that growing scientific evidence could result in the imposition of measures to reduce emissions of carbon dioxide and other greenhouse gases thought to be contributing to global climate change. This risk was simulated by assuming taxes of $10, $25 and $40 per ton of carbon dioxide were implemented in 2005. Such measures could change the value of conservation to between $3.2 and $6.1 billion. Because these taxes raise the "cost-effectiveness limit" for conservation, they also increase the average amount of conservation developed in the region's least-cost portfolio by 130 to 350 average megawatts. Figures G-12, G-13 and G-14 show the distribution of the present value benefits across the 100 futures simulated in the ISAAC analysis for this sensitivity study for each level of carbon tax.

Figure G-12
Distribution of Present Value Benefits of Conservation with $10 per Ton Carbon Tax

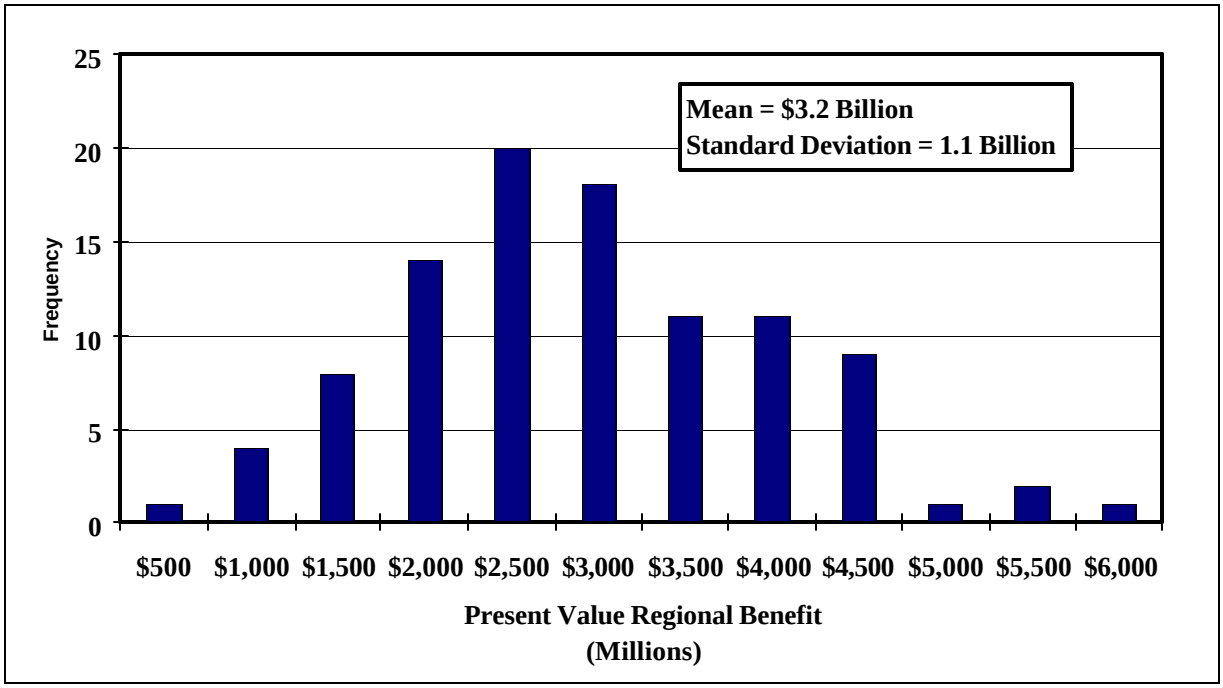


Figure G-13
Distribution of Present Value Benefit of Conservation with $25 per Ton Carbon Tax

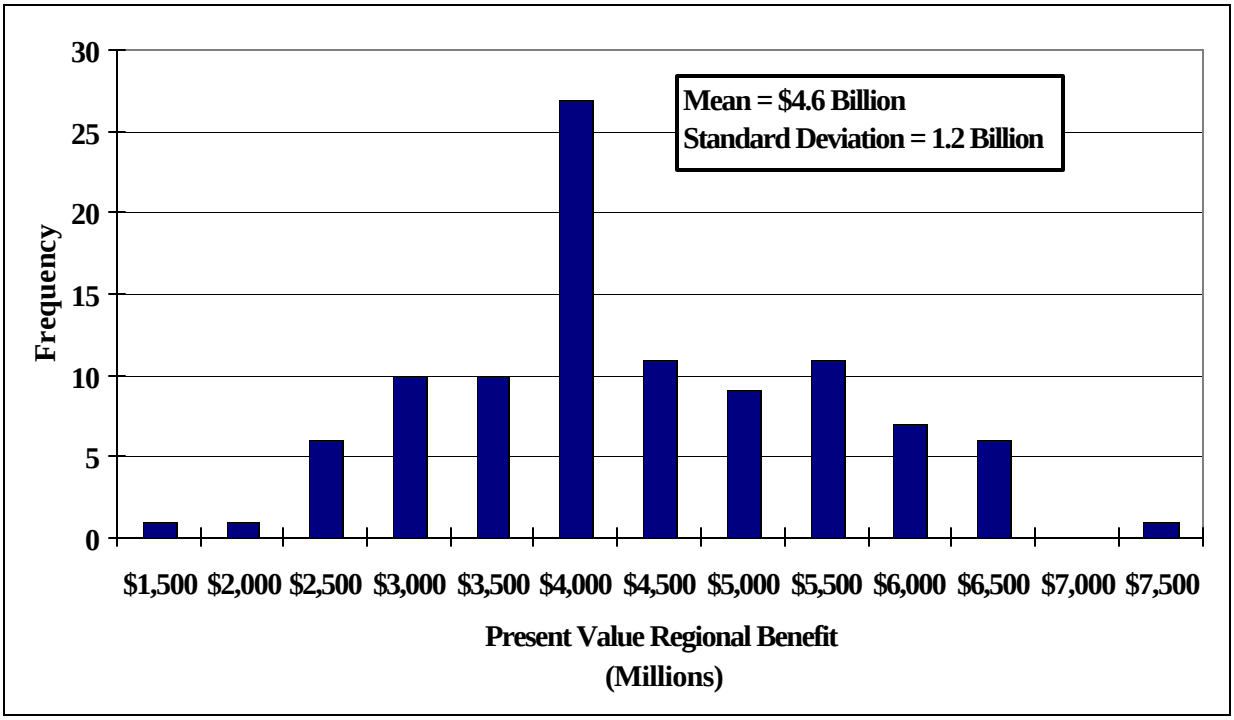
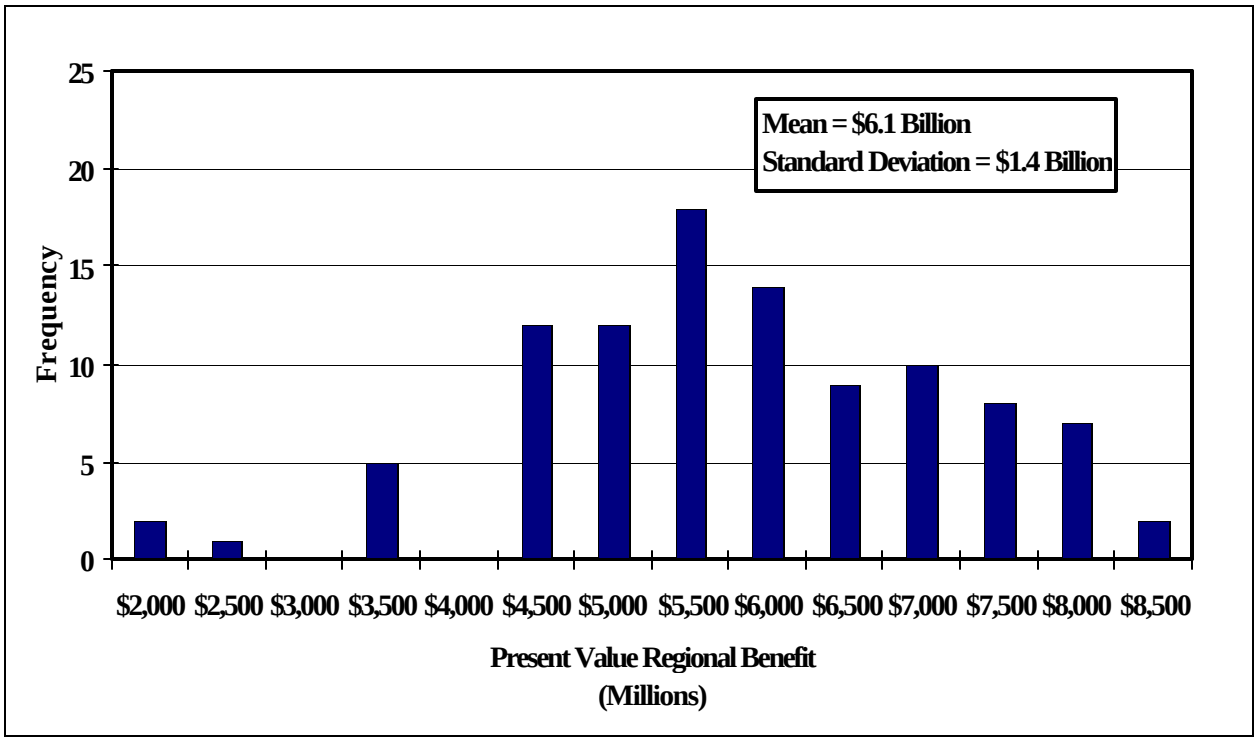


Figure G-14
Distribution of Present Value Benefit of Conservation with $40 per Ton Carbon Tax



Summary of Sensitivity Study Results

The effects of these various risks and uncertainties are summarized in Figure G-15. This figure shows the average present value benefits of pursuing conservation in the various sensitivity cases. In order to provide some measure of the robustness of these averages, Figure G-15 also shows one standard deviation above and below the average present value benefits. While clearly some of these risks reduce the average value of the conservation, in all cases there remains positive value that is generally significant. There are also risks that significantly increase the value of conservation, and many would argue that these risks are as likely as those risks that reduce the value of conservation.

Figure G-15
Summary of Conservation Sensitivity Study Results

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Assessing the Near-Term Financial Risks of Acquiring the Conservation Resource

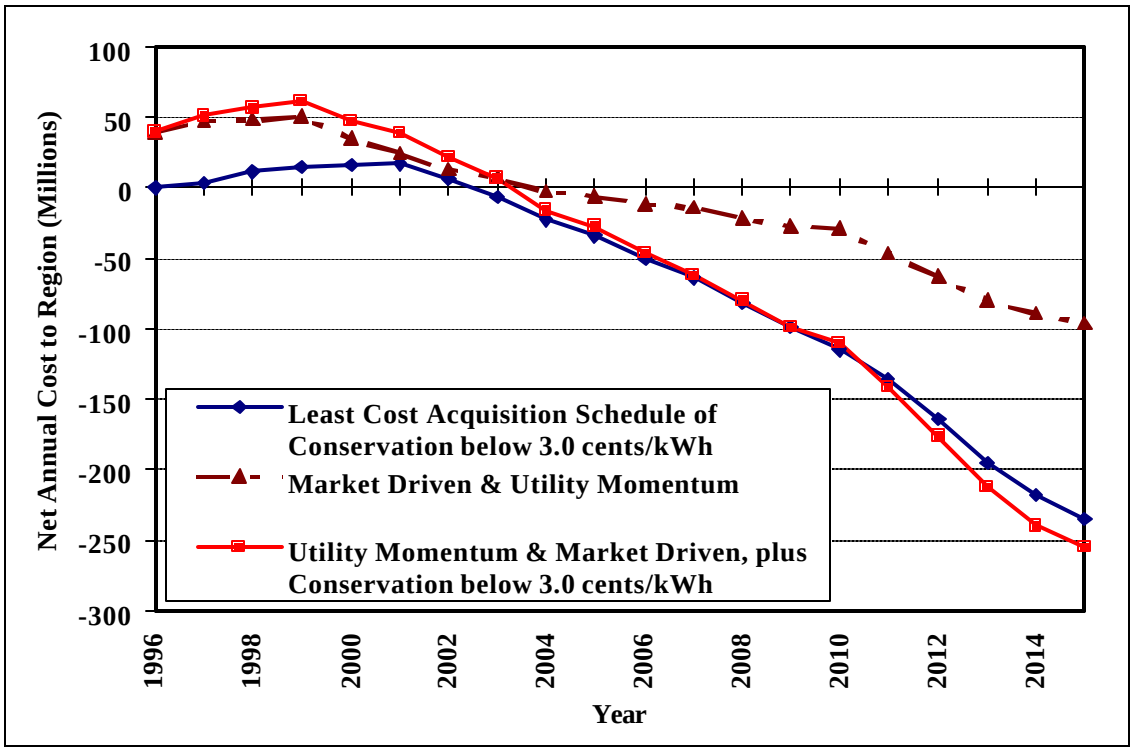
The reduction in the total present value of meeting the future electricity needs of the region with cost-effective conservation is not the only measure of its benefits and costs. The $2.3 billion in present value savings accrue as a result of investments made over the 20-year planning period. When comparing conservation with out-of-region power purchases or to the construction of new combustion turbines, some consideration should be given to the timing of the costs and benefits of these option. This is because the total cost of these resources is composed of markedly different proportions of capital and operating (i.e., fuel) costs. Virtually all of the total cost of acquiring conservation is represented by its capital cost. On the other extreme, an out-of-region power purchase contract has virtually no capital associated with it at all.

The risk the region takes in purchasing conservation (compared to a less capital intensive resource) is that once the capital is invested it can no longer be used for some other purpose. If fuel costs do not escalate as projected, or if a technological breakthrough occurs that dramatically lowers the cost of new electricity generation, some of the more expensive conservation measures may no longer be cost-effective. The sensitivity studies discussed above showed that over the long run conservation benefits largely outweigh its risks.

In addition to estimating the probability of attaining a net benefit to the region in the long run, the Council attempted to estimate the "cost-risk" of capturing conservation benefits within a shorter planning period. The Council compared the yearly cost of developing conservation versus buying power from the market in the near term and developing gas-fired generation in the longer term to assess the magnitude of the near-term risk created by purchasing conservation. Figure G-16 shows the annual net cost to the region of acquiring conservation by the year 2015 under three different acquisition schedules. The first schedule shows the annual net cost of acquiring the 515 average megawatts of conservation utilities are already planning to acquire plus the conservation the market might accomplish on its own. This is labeled "Market Driven & Utility Momentum." The second schedule, labeled "Utility Momentum and Market Driven, plus Conservation below 3.0 cents/kWh" adds the annual net cost of capturing the remaining cost-effective conservation to the 515 average megawatts developed in the first schedule. The third schedule, labeled "Least Cost Acquisition Schedule for Conservation below 3.0 cents/kWh" develops all conservation in least-cost order. The "zero" line represents the cost of relying on additional market purchases and new gas-fired generation in lieu of capturing any conservation. A positive figure represents net cost to the region while a negative figure represents a net savings. As can be seen from a review of Figure G-16, the region experiences a small "negative" cash flow between 1996 and the year 2003 when it invests in conservation. In the year 2004 and beyond, the region's investments in conservation result in lower annual costs as they offset more expensive power purchase and generation options.[15]

Figure G-16
Annual Net Cost of Conservation Resource Acquisitions
Compared to Reliance on Power Purchases and New Generating Resource Acquisitions

[15] The annual cost of acquiring conservation is assumed to be financed at a 4.75 percent real interest rate and repaid over 15 years. The "net cost" shown in Figure G-16 represents principal and interest payments minus the cost of power purchases after taking into account revenue produced by out-of-region sales.



As shown in Figure G-16, the combination of utility program momentum and consumer actions results in a pace of conservation acquisition that will require an investment of about $40 million annually more than the cost of relying on the current out-of-region market through the year 2000.[16] Developing the additional conservation needed to meet load growth would add only approximately $7 million per year in "new" investments beyond those anticipated to result from current utility plans and market expenditures.[17] The higher net cost in the early years is because so much of this conservation results from utility programs and contract commitments that have not fully adjusted to the lower avoided costs the region is now seeing. As a result, some of this conservation is more expensive than that which would be acquired on a least-cost basis. However, if the region's consumers and utilities are able to develop lower-cost conservation first, roughly the same amount of conservation is acquired, but at about one-third of the annual net cost. This can be seen by comparing the line labeled "Least Cost Acquisition Schedule for Conservation below 3.0 cents/kWh to the other two lines in Figure G-16.

Several features of Figure G-16 are significant. First, most of the "negative" cash flows in the years 1996 to 2000 are incurred by market-driven consumer actions and acquisitions resulting from the momentum created by current utility programs. The incremental cost of the residual conservation beyond the market-driven in these years is small, less than $10 million per year. Second, the "cross-over" point occurs around 2003 to 2004. This implies that the time horizon for significant cost risk to the system is within a fairly short period. Assuming no review of conservation acquisitions, fairly rapid reductions in generation costs would have to occur in order to drive the "negative" net cash flow of the region to a large number.

Figure G-17 illustrates the annual capital requirement for acquiring the 1,535 average megawatts of conservation resources and the annual amount of conservation acquired for each year in the planning period.

[16] Of the 700 average megawatts of conservation needed to meet load growth through the year 2003, approximately 335 average megawatts are anticipated to be developed by utilities and consumers without further market intervention.

[17] It should be noted that actual utility expenditures are expected to be only a portion of this amount due to consumer cost-sharing.

Figure G-17
Total Annual Conservation Capital Costs and Savings

Three factors should be taken into account in viewing Figure G-17. First, the level of conservation acquisitions from 1996 through the year 2000 is based on utility projections of conservation program activity levels described earlier. Second, the capital requirements shown in this figure represent conservation's total cost to the region. They are not directly comparable to past or projected utility expenditures because utility program participants usually pay a portion of these costs. Third, to put these costs in perspective, the region's current annual retail electricity bill (i.e., revenue requirement) is just under $8 billion. Thus, the annual total cost of securing the conservation contained in this draft plan is equivalent to about two percent of the region's annual electricity bill.

INDIVIDUAL SECTOR ANALYSIS

The following sections describe the analysis used to estimate the costs and savings for each sector:

1. Residential
2. Commercial
3. Industrial
4. Irrigated Agriculture
5. Transmission and Distribution

Each section provides the details of the analytical tools used and the resulting estimates of technical and achievable conservation potential and costs. Included is a discussion of the relevant changes in estimates since the 1991 Plan as well as new information that has been developed. For more background on a particular sector, Volume 2 of the 1991 Plan should be consulted.

The following narrative uses examples based on calculations from the Council's medium demand forecast. Throughout the remainder of this appendix, results for the medium forecast are used, unless specifically noted otherwise. Similar calculations were done for the low, medium-low, medium-high and high forecasts, but are not reported in this appendix for sake of brevity. As discussed above, the actual amount of conservation that is cost-effective to develop will depend on the combination of economic growth, fuel prices and hydroelectric conditions in the region over the next twenty years.

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RESIDENTIAL SECTOR

SUMMARY

In 1994, the region's residential sector consumed an estimated 6,443 average megawatts of electricity when adjusted for weather. This represented about 35 percent of the region's total firm electrical consumption. Space heating is the largest single category of consumption in the residential sector, using 35 percent of the total electricity sold to the sector.

The following sections will address the cost and savings of efficiency improvements in five end-uses in this sector:

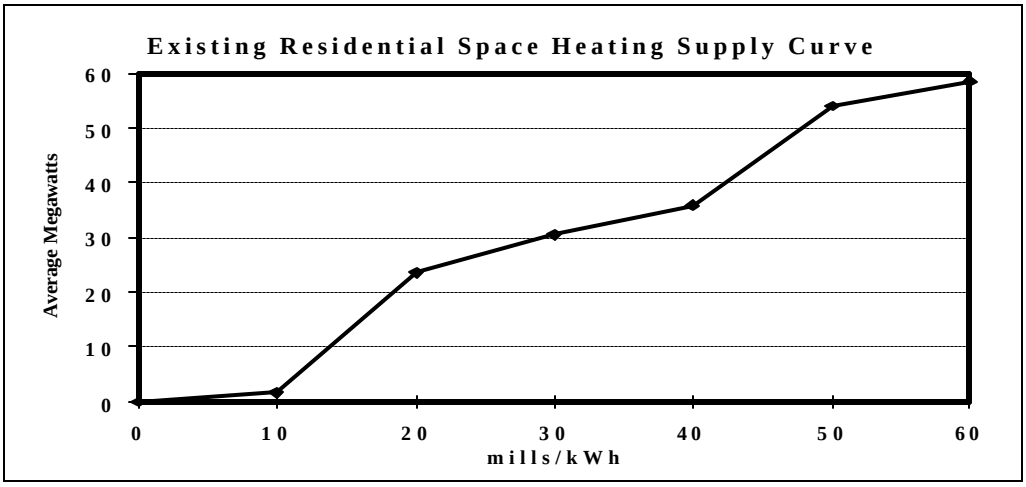
1. Space heating in existing residential buildings.
2. Space heating in new residentia l buildings.
3. Water Heating, including water heating systems, clothes washers and dryers, dishwashers, and showerheads.
4. Refrigeration, including refrigerator and freezer appliances.
5. Lighting.

The detailed nature of the analysis in each of these end-uses relies upon a great deal of reference material that has been developed over the 13 years since the first power plan was developed. Much of this material is fully detailed in Volume II of the 1991 Power Plan and is not repeated here for brevity's sake. In particular, a long list of appropriate references is not included here if it is adequately covered in the 1991 Plan. The focus in this section has been on information that has become available since the 1991 Plan and the implications for the development of this plan.

SPACE HEATING CONSERVATION IN EXISTING RESIDENTIAL BUILDINGS

Figure G-18 shows the estimated space heating savings available from existing single and multifamily residences at levelized cost up to 6.0 cents per kilowatt-hour. The technical conservation potential for all measures with benefit/cost ratios greater than 1.0 is 25 average megawatts. The estimated average levelized cost of insulating and weatherizing existing single family and multifamily residences is 1.6 cents per kilowatt-hour, including administrative costs of 20 percent and transmission and distribution cost adjustments.

Figure G - 18
Existing Residential Space Heating Supply Curve



The Council's assessment of the conservation potential for existing space heating involved four steps. These steps were to:

1. Estimate cost-effective thermal integrity changes that are available from insulating existing electrically heated single and multifamily dwellings;
2. Develop savings estimates and conservation supply functions consistent with the Council's forecasting model, and incorporate the forecasting model's estimate of the effect of consumer behavior on savings using the thermal integrity changes identified in Step 1 and accounting for historical retrofit activities;
3. Compare projected cost and savings estimates with historically observed cost and savings data; and,
4. Estimate achievable conservation potential.

The primary data sources used in this analysis have been drawn from the historical experience of Bonneville, the region's public and private utilities and low-income service agencies across this region. These sources are summarized in Table G-10.

Table G-10
Primary Data Sources for Existing Space Heating Conservation Assessment

Source	**Data Type**
Puget Sound Power and Light	Insulation and prime window replacement costs, weatherization program savings
Eugene Water and Electric Board	Insulation and prime window replacement costs
King County Housing Authority	Infiltration control costs and savings estimates
End-Use Load and Conservation Assessment	Typical insulation level of existing housing,
Project (ELCAP)	metered space heating consumption, load shapes
Bonneville Power Administration -	
Residential Standards Demonstration Program	Simulation model calibration
Pacific Northwest Residential Energy Surveys	Wood heat use, house size, space heating system
Evaluation of Weatherization Programs	Time series data on Pre/Post Program energy use
Data Gathering Project	Time series data on weatherization measure costs
"Super Window" Retrofit project	Cost and performance data on advanced windows

Step 1. Estimate Cost-Effective Thermal Integrity Improvements from Conservation Measures

The costs and savings of conservation measures are the primary determinants of the amount of conservation that is available from the supply curves. The Council's estimates of single- and multi-family home weatherization costs are based on information provided by Puget Sound Power and Light (Puget) and Eugene Water and Electric Board (EWEB) during 1993 and 1994. The actual costs of measures are shown Table G-11.

The costs of installing more energy efficient windows than are currently being installed in existing houses were developed separately. The costs of adding storm windows were derived from Bonneville's Data Gathering Project, because neither Puget nor EWEB reported cost information for this measure. Both Puget and EWEB did report the cost of replacing prime windows with better (Class 40) double-glazed windows. In order to determine the incremental cost of installing even more efficient double-glazed prime windows instead of a storm window, it was necessary to compare Bonneville's, Puget's and EWEB's costs with those collected from window manufacturers for high-performance glazings. The costs reported in Table G-11 reflect an assumption that the average labor and contractor margin to install a prime replacement window is $6.75 per square foot. This value was imputed from the difference observed between the cost of windows reported by manufacturers and the total installed cost reported by Puget and EWEB for class 40 windows. Table G-12 shows the incremental cost used to derive the cost of Class 35, Class 25 and Class 20 windows.

Each measure has its own average or expected lifetime, which is used in generating the levelized cost. The levelized costs displayed in these tables reflect financing costs and replacement costs for short-lived measures. Insulation and prime replacement windows last the lifetime of the residence, which for existing stock was expected to be an average of about 50 years in the 1991 Plan. This was reduced to 45 years in this plan to account for the aging of the stock over the past five years. Replacement doors are assumed to last an average of about 30 years. Infiltration reduction measures were assumed to last 10 years.

Table G-11

Residential Weatherization Measure Cost Data

Conservation Measure	Measure Life (Years)	Incremental Installed Cost ($/SF)
WALL R11	45	$ 0.65
ATTIC R11	45	$ 0.22
ATTIC R19	45	$ 0.16
ATTIC R30	45	$ 0.19
ATTIC R38	45	$ 0.10
ATTIC R49	45	$ 0.14
FLOOR R11	45	$ 0.64
FLOOR R19	45	$ 0.14
FLOOR R30	45	$ 0.18
FLOOR R38	45	$ 0.13
STORM WINDOW CL50[18]	30	$ 10.29
DG Low E WINDOW CL35	45	$ 5.11
TG Low E WINDOW CL25	45	$ 6.55
DOOR R5	30	$ 14.06
BSMT WALL R11	45	$ 0.33
BSMT WALL R21	45	$ 0.25
ACH @ 0.4	10	$ 125.00

[18] Due to economies of scale, multifamily storm window and prime window replacement costs appear to be less than for single family homes. The incremental installed cost for these windows in multifamily buildings was assumed to be as follows: Storm Windows - $7.83/sq ft, Class 35 prime replacement windows - $3.88/sq ft and Class 25 prime replacement windows - $4.98/sq ft.

Table G-12
Derivation of Window Cost Assumptions

	Single Family	Multifamily
Storm Window Cost	$ 10.29	$ 7.82
Incremental Cost Over Storm		
WINDOW CL65	$ 2.94	$ 2.23
WINDOW CL50	$ 3.08	$ 2.34
WINDOW CL40	$ 4.66	$ 3.54
WINDOW CL35	$ 5.11	$ 3.88
WINDOW CL25	$ 6.55	$ 4.97
WINDOW CL20	$ 11.18	$ 8.49

It is useful to distinguish between set-up and add-on costs to answer two different questions. Set-up costs are included when determining whether any insulation should be added to a building component, given that a certain level already exists. For example, if a ceiling is already insulated to R-30, it turns out that it is not cost-effective to the region to pay for a contractor to come to the house and increase the ceiling insulation level to R-38. Add-on costs determine how far a building component should be insulated, assuming the contractor is already set up and has installed some base insulation. If the contractor is already there, for example, it is cost-effective to increase ceiling insulation to R-38 from a base of R-19. Thus, the regional cost-effectiveness limit is R-38 in the ceiling, if anything less than about R-30 exists before weatherization.

In an ideal situation, where all measures can be installed in the building, the following measures would be recommended for installation in single-family houses and multifamily buildings: R-38 ceiling insulation, if the house has less than R-30; R-11 wall insulation, if no insulation currently exists; R-30 underfloor insulation if less than R-19 currently exists and there is space in the joist for the insulation. No window thermal upgrades were regionally cost-effective under the Council's current avoided cost projections. However, it should be noted that storm windows have benefit/cost ratios of above 0.95, and both storm windows and prime window replacements have substantial non-energy benefits (e.g., to increase the resale value of a home). Consequently, while these measures may not be cost-effective on the basis of the energy savings alone, they very well may make economic sense when their non-energy benefits are included.

In addition, because there is some uncertainty regarding the labor costs of prime replacement windows, the Council conducted a sensitivity analysis to see how low labor costs would have to be before Class 35 replacement windows would be cost-effective. A sensitivity done on the 1,350-square-foot prototype based on weighted average regional climate indicated that the labor costs would have to be about 45 percent of the current estimate before installation of a Class 35 prime window replacement (compared to existing single pane windows) could be cost-effective on the basis of its energy savings alone. Alternatively, class 35 windows would be cost-effective if their non-energy benefits were valued at approximately $3.75 per square foot – or about $60 for the average sized window.

Three typical building designs were used to estimate the retrofit potential for single-family houses in the region. The first is an 850-square-foot, single-story house built over an unheated basement. The second is a 1,350-square-foot house over a vented crawl space. The third is a 2,184-square-foot, two-story house with a

heated basement. The multifamily design is a three-story apartment house with four 840-square-foot units on each floor.

There are limitations on the number of houses that can reach full cost-effective weatherization levels. For example, if the house does not have room in the joist system to accommodate R-30 insulation, then given current data it does not appear cost-effective to add the increased joist space to accommodate the thicker insulation. Given this limitation, the current analysis of single-family residential weatherization savings uses R-30 floors on only two of the three prototypes. Less information is known about multifamily buildings. As a consequence, the multifamily prototypes were modeled with floors that could go to R-30 insulation without the increased joist cost. In addition, recent information on air change rates in multifamily units indicates that these dwellings have less air exchange with the outside air than single-family houses. The base case air change rate for multifamily dwellings is 0.4 air changes per hour in the current analysis. For single-family houses, the initial air change rate is assumed to be 0.5 air changes per hour. When some air infiltration reduction measures are taken, this is assumed to drop to 0.4 air changes per hour. This is a fairly small drop in infiltration, because costs taken from current programs represent only fairly small amounts of air infiltration reduction measures.

Savings from weatherization measures installed in all four house designs were estimated using a two-step process. This first step assesses the savings from each measure holding constant other determinants of space heating consumption, such as thermostat settings and room closure behavior. The second step is to take the aggregate efficiency improvement that is identified as cost-effective compared to a house with average insulation, and run it through the forecast to incorporate consumer behavior changes into the estimate of aggregate savings.

In the first step, the SUNDAY computer model,[19] which simulates a building's daily space heating energy needs, is used to evaluate a base case and the savings attributable to each conservation measure, holding behavior constant. This step determines which of the representative measures applied to the prototypes are cost-effective. At this stage, savings are evaluated using an average indoor temperature setting of 65° F (70° F for 10 hours/day and 62° F for 14 hours/day), internal gains consistent with the efficient appliances included in the Council's resource portfolio (2,000 British thermal units per hour), and no reduction in use from room closure and wood heat. This set of assumptions is referred to as the ``standard operating conditions'' of a residential building.

These values were selected based on analysis and judgment. They represent a house used at levels that are reasonable if efficiency measures are installed. Curtailment activities, such as room closure and reduced temperature settings, are less likely to continue after efficiency measures are installed since these measures significantly lower utility bills. If the house is actually operated in the long run at reduced amenity, then some measures may be included in the program that are not cost-effective. Conversely, if less than full amenity were assumed in this step of the analysis and consumers adopted higher levels in response to efficiency improvements, then measures that would have been cost-effective would be eliminated. The Council assumes in its analysis that consumers will chose higher amenity levels.

It is important to emphasize here that the SUNDAY model is used to determine which representative measures should be incorporated into a program, while holding behavior at pre-determined amenity levels. Once the relative efficiency change is determined, savings are re-estimated using the forecasting model to incorporate behavioral changes in response to price. In addition, because the forecast implicitly incorporates an estimate of wood heat and room closure, these are also accounted for in the average estimate of savings from weatherizing houses.

Tables G-13 through G-16 for single-family and Tables G-17 through G-20 for multifamily buildings show the installed costs, levelized cost in cents per kilowatt-hour, and the engineering savings assuming standard operating conditions from weatherizing the typical prototype houses in four representative climates

[19] The SUNDAY model simulates space heating needs based on heat loss rate, daily access to solar energy, daily inside and outside temperatures, thermal mass, and the amount of heat given off by lights, people and appliances.

in the region. The purpose of these tables is to show the expected reduction in space heating use as weatherization measures are installed in an uninsulated dwelling. The measures are assumed to be installed in the dwelling in a "least cost" order. That is, their location in the list is a function of which one has the least expected cost per unit savings. Since people often install measures out of order, the listings here must be considered as simply representative of the type of expected energy savings that would be secured as insulation is added.

Since each representative measure saves a different amount of energy in each house design and location, an aggregate supply curve must be developed to represent the weighted average efficiency change for all representative measures in the dwelling types. The use and cost from each climate zone were combined by weighting each location according to the proportion of electrically heated homes in the climate represented by that location. The weights used for single family homes were Portland/Zone1 - 37 percent, Seattle/Zone 1 - 48 percent, Spokane/Zone 2 - 11 percent and Missoula/Zone 3 - four percent. The multifamily weights were Portland/Zone1 - 30 percent, Seattle/Zone 1 - 50 percent, Spokane/Zone 2 -17 percent and Missoula/Zone 3 - three percent. The regional average thermal integrity curves for each typical house design appear in Table G-21 for single family homes and Table G-22 for multifamily buildings.

The cost and use for each of the three single-family houses were merged to estimate regional space heating consumption by cents per kilowatt-hour. The 1983 Pacific Northwest survey indicated that the average pre-1980 electrically heated house was approximately 1,600 square feet. The 850-square-foot, 1,350-square-foot, and 2184-square-foot houses were weighted to represent approximately 20, 38 and 42 percent, respectively, of the regional stock to achieve the appropriate average house size. These weights result in an average house size of 1,600 square feet and an average multifamily dwelling unit size of 840 square feet. Tables G-25 and G-26 show the curve of regionally weighted costs and space heating use for single-family and multifamily houses.

The vast majority of houses in the region, even those that are not retrofitted, already have some insulation. Therefore, the base case use on which a the remaining space heating conservation potential must represent the average insulation level of existing dwellings, rather than uninsulated case.

The Council, reviewed of the historical weatherization program data in Nutrak[20] to establish the base case insulation values for multifamily units. It appeared that approximately two-thirds of the multifamily units expected to survive until the year 2015 have already either undergone weatherization or cannot be economically retrofitted. An average heat loss rate per unit of 247 Btu/^{0}F was assumed to be representative of the multifamily units that remained to be insulated.[21] Under standard operating conditions, the space heating use these units is 3,320 kilowatt-hours per year. If all remaining cost-effective measures are added to the structure, the use under standard operating conditions drops to 2,900 kilowatt-hours per year for a savings 420 kilowatt-hours.

The best estimate of the average insulation level in pre-1979 vintage single-family houses that could be found is from a sample of 228 pre-1979 single-family houses in the End-Use Load and Conservation Assessment Program (ELCAP) where the average heat loss rate (specified in terms of UA) was determined from on-site surveys of the houses.[22] The UA value, after normalizing for the regional average square footage of existing houses used in this analysis and including the heat loss effect of infiltration, is approximately 550 Btu/^{o}F. In order to account for the weatherization actions that have occurred since the ELCAP data was collected, this average was reduced by approximately 20 percent to 505 Btu/^{o}F. Assuming standard operating

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[20] Nutrak is the Council's program for tracking utility conservation program activities.

[21] UA is the heat loss rate of a building (expressed as a U-value) times the area of the component. A U-value has units of Btu per Fahrenheit degree per square foot.

[22] Only about 13 percent of the houses on which the estimate is based participated in a weatherization program and took at least one major measure. If these houses were removed, the probable effect would be to raise the average UA. On the other hand, some self-weatherization has most likely occurred since the time the ELCAP houses were audited. The size of this action is unknown, but it would act to lower the UA. The judgment was to consider these as offsetting effects.

conditions, the average single family home would use approximately 10,900 kilowatt-hours per year for space heating prior to weatherization. This same home would be use about 9,200 kilowatt-hours per year for space heating after all regionally cost-effective measures had been installed, for a savings of 1,700 kilowatt-hours. These estimates are for efficiency changes only, and do not incorporate behavioral changes, since amenity and behavior are assumed to be constant as insulation was added. However, behavioral impacts on the estimate of savings are incorporated when the new thermal efficiency level is used in the forecasting model in the steps described below.

Table G-13

Existing Single Family Space Heating - Portland

850 sq ft	Portland - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	696	0	17266	0	45	0	0	0	N/A
ATTIC R11	522	$ 187	11622	5645	45	0.4	$ 3,078	$ 3,037	75.0
WALL R11	426	$ 527	8588	3034	45	6.7	$ 1,654	$ 1,249	4.1
ATTIC R19	409	$ 136	8062	526	45	10.6	$ 287	$ 176	2.6
FLOOR R11	351	$ 542	6296	1766	45	12.8	$ 963	$ 515	2.1
FLOOR R19	339	$ 117	5938	358	45	13.7	$ 195	$ 98	2.0
INFILTRATION @ O.4 ACH	327	$ 125	5576	362	10	16.1	$ 232	$ 97	1.7
ATTIC R30	312	$ 162	5150	426	45	21.4	$ 163	$ 36	1.3
FLOOR R30	302	$ 149	4850	300	45	33.6	$ 803	$ (178)	0.8
STORM WINDOW CL50	250	$ 967	3378	1473	30	35.8	$ 198	$ (60)	0.8
ATTIC R38	247	$ 85	3283	95	45	39.6	$ 52	$ (23)	0.7
ATTIC R49	243	$ 117	3164	119	45	43.6	$ 65	$ (38)	0.6
FLOOR R38	239	$ 106	3070	94	45	50.0	$ 51	$ (42)	0.5
DG Low E WINDOW CL35	226	$ 480	2712	358	45	59.8	$ 195	$ (229)	0.5
DOOR R5	215	$ 563	2413	299	15	118.7	$ 127	$ (422)	0.2
TG Low E WINDOW CL25	206	$ 616	2180	233	45	148.0	$ 163	$ (715)	0.2

1,350 sq ft	Portland - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	1036	0	27309	0	45	0	0	0	0
ATTIC R11	759	$ 297	18248	9061	45	0.4	$ 4,941	$ 4,878	78.4
WALL R11	639	$ 657	14391	3857	45	6.6	$ 2,103	$ 1,599	4.2
ATTIC R19	612	$ 216	13539	852	45	10.4	$ 465	$ 290	2.7
FLOOR R11	520	$ 861	10665	2874	45	12.5	$ 1,567	$ 857	2.2
FLOOR R19	501	$ 186	10079	586	45	13.2	$ 319	$ 166	2.1
INFILTRATION @ O.4 ACH	489	$ 125	9702	378	10	15.4	$ 384	$ 169	1.8
ATTIC R30	466	$ 257	8997	704	45	20.7	$ 268	$ 67	1.3
FLOOR R30	449	$ 236	8505	492	45	32.2	$ 1,327	$ (227)	0.9
STORM WINDOW CL50	368	$ 1,533	6072	2433	30	34.3	$ 206	$ (51)	0.8
ATTIC R38	362	$ 135	5916	157	45	38.0	$ 85	$ (33)	0.7
ATTIC R49	355	$ 186	5721	194	45	42.2	$ 106	$ (57)	0.7
FLOOR R38	350	$ 169	5566	155	45	48.3	$ 84	$ (64)	0.6

DG Low E WINDOW CL35	329	$ 761	4970	596	45	56.9	$ 325	$ (347)	0.5
DOOR R5	318	$ 563	4653	318	15	110.4	$ 217	$ (653)	0.2
TG Low E WINDOW CL25	304	$ 976	4255	397	45	139.2	$ 173	$ (704)	0.2

Table G-13 (Cont.)

Existing Single Family Space Heating - Portland

2,184 sq ft	**Portland - Zone 1**								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	**1408**	**$ -**	**35679**	**0**	**45**	**0.0**	**$ -**	**$ -**	**0.0**
ATTIC R11	1258	$ 160	30847	4833	45	0.4	$ 2,635	$ 2,600	74.9
BSMT WALL R11	1085	$ 281	25316	5531	45	1.2	$ 3,016	$ 2,888	23.6
WALL R11	904	$ 989	19616	5700	45	6.7	$ 3,108	$ 2,347	4.1
ATTIC R19	890	$ 116	19165	451	45	10.6	$ 246	$ 151	2.6
FLOOR R11	840	$ 464	17638	1527	45	12.7	$ 833	$ 449	2.2
FLOOR R19	830	$ 100	17326	312	45	13.4	$ 170	$ 87	2.0
INFILTRATION @ O.4 ACH	818	$ 125	16951	375	45	15.5	$ 206	$ 90	1.8
ATTIC R30	805	$ 138	16573	378	45	16.0	$ 313	$ 131	1.7
BSMT WALL R21	786	$ 216	16000	573	45	20.6	$ 145	$ 37	1.3
FLOOR R30	778	$ 127	15734	266	45	32.0	$ 2,819	$ (465)	0.9
STORM WINDOW CL50	605	$ 3,241	10565	5169	45	34.6	$ 204	$ (53)	0.8
ATTIC R38	602	$ 73	10480	85	45	47.5	$ 46	$ (34)	0.6
ATTIC R49	598	$ 100	10374	106	45	57.6	$ 58	$ (63)	0.5
FLOOR R38	595	$ 91	10289	84	45	58.9	$ 695	$ (792)	0.5
DG Low E WINDOW CL35	551	$ 1,610	9016	1274	45	77.5	$ 46	$ (84)	0.4
DOOR R5	540	$ 563	8696	319	45	117.1	$ 455	$ (1,482)	0.2
TG Low E WINDOW CL25	510	$ 2,063	7862	835	45	151.7	$ 174	$ (786)	0.2

Table G-14

Existing Single Family Space Heating - Seattle

850 sq ft	**Seattle - Zone 1**								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	696	0	19832	0	45	0	0	0	N/A
ATTIC R11	522	$ 187	13360	6472	45	0.2	$ 3,530	$ 3,507	157.6
WALL R11	426	$ 527	9852	3507	45	5.7	$ 1,913	$ 1,518	4.8
ATTIC R19	409	$ 136	9246	607	45	9.0	$ 331	$ 222	3.0
FLOOR R11	351	$ 542	7210	2036	45	10.9	$ 1,110	$ 668	2.5
FLOOR R19	339	$ 117	6799	411	45	11.8	$ 224	$ 128	2.3
INFILTRATION @ O.4 ACH	327	$ 125	6383	416	10	13.9	$ 266	$ 131	2.0
ATTIC R30	312	$ 162	5895	487	45	18.6	$ 186	$ 60	1.5
FLOOR R30	302	$ 149	5553	342	45	29.5	$ 912	$ (65)	0.9
STORM WINDOW CL50	250	$ 967	3881	1673	30	31.0	$ 227	$ (29)	0.9
ATTIC R38	247	$ 85	3774	107	45	35.0	$ 58	$ (16)	0.8
ATTIC R49	243	$ 117	3640	133	45	38.6	$ 73	$ (29)	0.7
FLOOR R38	239	$ 106	3534	106	45	44.3	$ 58	$ (35)	0.6

DG Low E WINDOW CL35	226	$ 480	3131	403	45	52.9	$ 220	$ (203)	0.5
DOOR R5	215	$ 563	2794	337	15	105.3	$ 143	$ (405)	0.3
TG Low E WINDOW CL25	206	$ 616	2531	263	45	131.3	$ 184	$ (693)	0.2

Table G-14 (Cont.)

Existing Single Family Space Heating - Seattle

1,350 sq ft	Seattle - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	1036	0	31322	0	45	0	0	0	0
ATTIC R11	759	$ 297	20962	10360	45	0.2	$ 5,650	$ 5,616	167.3
WALL R11	639	$ 657	16519	4444	45	5.6	$ 2,423	$ 1,932	4.9
ATTIC R19	612	$ 216	15530	989	45	8.8	$ 539	$ 367	3.1
FLOOR R11	520	$ 861	12217	3313	45	10.7	$ 1,807	$ 1,107	2.6
FLOOR R19	501	$ 186	11544	673	45	11.4	$ 367	$ 215	2.4
INFILTRATION @ O.4 ACH	489	$ 125	11110	434	10	13.3	$ 441	$ 229	2.1
ATTIC R30	466	$ 257	10301	809	45	17.8	$ 308	$ 108	1.5
FLOOR R30	449	$ 236	9736	565	45	28.0	$ 1,518	$ (27)	1.0
STORM WINDOW CL50	368	$ 1,533	6952	2784	30	29.7	$ 237	$ (19)	0.9
ATTIC R38	362	$ 135	6772	179	45	33.0	$ 98	$ (20)	0.8
ATTIC R49	355	$ 186	6550	222	45	36.8	$ 121	$ (41)	0.7
FLOOR R38	350	$ 169	6373	177	45	42.1	$ 97	$ (51)	0.7
DG Low E WINDOW CL35	329	$ 761	5694	679	45	49.8	$ 370	$ (300)	0.6
DOOR R5	318	$ 563	5334	360	15	98.0	$ 244	$ (625)	0.3
TG Low E WINDOW CL25	304	$ 976	4887	447	45	122.7	$ 196	$ (680)	0.2

2,184 sq ft	Seattle - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	1408	$ -	40989	0	45	0.0	$ -	$ -	0.0
ATTIC R11	1258	$ 160	35416	5573	45	0.2	$ 3,039	$ 3,020	164.1
BSMT WALL R11	1085	$ 281	29028	6388	45	0.9	$ 3,484	$ 3,375	32.0
WALL R11	904	$ 989	22454	6575	45	5.7	$ 3,585	$ 2,844	4.8
ATTIC R19	890	$ 116	21933	521	45	9.0	$ 284	$ 191	3.1
FLOOR R11	840	$ 464	20168	1764	45	10.8	$ 962	$ 584	2.5
FLOOR R19	830	$ 100	19808	360	45	11.5	$ 196	$ 114	2.4
INFILTRATION @ O.4 ACH	818	$ 125	19377	432	45	13.4	$ 236	$ 122	2.1
ATTIC R30	805	$ 138	18943	433	45	13.8	$ 357	$ 177	2.0
BSMT WALL R21	786	$ 216	18289	655	45	17.9	$ 165	$ 58	1.5
FLOOR R30	778	$ 127	17985	303	45	28.0	$ 3,214	$ (53)	1.0
STORM WINDOW CL50	605	$ 3,241	12092	5894	45	29.9	$ 235	$ (20)	0.9
ATTIC R38	602	$ 73	11995	96	45	41.8	$ 53	$ (27)	0.7
ATTIC R49	598	$ 100	11876	120	45	50.8	$ 65	$ (55)	0.5
FLOOR R38	595	$ 91	11780	95	45	52.4	$ 778	$ (705)	0.5
DG Low E WINDOW CL35	551	$ 1,610	10354	1426	45	68.7	$ 52	$ (78)	0.4

DOOR R5	540	$ 563	9995	359	45	103.0	$ 517	$ (1,419)	0.3
TG Low E WINDOW CL25	510	$ 2,063	9048	947	45	134.9	$ 196	$ (764)	0.2

Table G-15
Existing Single Family Space Heating - Spokane

850 sq ft	Spokane - Zone 2								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	696	0	26761	0	45	0	0	0	N/A
ATTIC R11	522	$ 187	18582	8179	45	-0.1	$ 4,461	$ 4,480	-226.9
WALL R11	426	$ 527	14123	4459	45	4.2	$ 2,432	$ 2,058	6.5
ATTIC R19	409	$ 136	13346	777	45	6.8	$ 424	$ 319	4.0
FLOOR R11	351	$ 542	10729	2616	45	8.3	$ 1,427	$ 998	3.3
FLOOR R19	339	$ 117	10196	533	45	8.8	$ 291	$ 198	3.1
INFILTRATION @ O.4 ACH	327	$ 125	9652	544	10	10.3	$ 349	$ 218	2.7
ATTIC R30	312	$ 162	9012	640	45	13.8	$ 246	$ 122	2.0
FLOOR R30	302	$ 149	8561	451	45	21.6	$ 1,225	$ 261	1.3
STORM WINDOW CL50	250	$ 967	6314	2247	30	23.5	$ 297	$ 43	1.2
ATTIC R38	247	$ 85	6169	146	45	25.4	$ 79	$ 6	1.1
ATTIC R49	243	$ 117	5987	182	45	28.0	$ 99	$ (2)	1.0
FLOOR R38	239	$ 106	5842	145	45	32.2	$ 79	$ (13)	0.9
DG Low E WINDOW CL35	226	$ 480	5291	551	45	38.4	$ 301	$ (119)	0.7
DOOR R5	215	$ 563	4826	465	15	75.1	$ 200	$ (346)	0.4
TG Low E WINDOW CL25	206	$ 616	4459	367	45	94.8	$ 254	$ (620)	0.3

1,350 sq ft	Spokane - Zone 2								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	1036	0	41403	0	45	0	0	0	0
ATTIC R11	759	$ 297	28344	13058	45	-0.1	$ 7,121	$ 7,154	-215.3
WALL R11	639	$ 657	22728	5617	45	4.2	$ 3,063	$ 2,598	6.6
ATTIC R19	612	$ 216	21481	1247	45	6.7	$ 680	$ 514	4.1
FLOOR R11	520	$ 861	17273	4208	45	8.1	$ 2,295	$ 1,615	3.4
FLOOR R19	501	$ 186	16414	858	45	8.7	$ 468	$ 320	3.2
INFILTRATION @ O.4 ACH	489	$ 125	15861	553	10	10.1	$ 564	$ 356	2.7
ATTIC R30	466	$ 257	14827	1034	45	13.6	$ 397	$ 200	2.0
FLOOR R30	449	$ 236	14100	727	45	21.2	$ 1,982	$ 456	1.3
STORM WINDOW CL50	368	$ 1,533	10465	3635	30	23.1	$ 301	$ 48	1.2
ATTIC R38	362	$ 135	10228	237	45	24.7	$ 129	$ 13	1.1
ATTIC R49	355	$ 186	9932	296	45	27.4	$ 161	$ 1	1.0
FLOOR R38	350	$ 169	9696	236	45	31.3	$ 129	$ (18)	0.9
DG Low E WINDOW CL35	329	$ 761	8790	906	45	37.0	$ 494	$ (171)	0.7
DOOR R5	318	$ 563	8308	482	15	72.5	$ 328	$ (537)	0.4
TG Low E WINDOW CL25	304	$ 976	7706	601	45	91.4	$ 263	$ (611)	0.3

Table G-15 (Cont.)

Existing Single Family Space Heating - Spokane

2,184 sq ft	Spokane - Zone 2								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	1408	$ -	54276	0	45	0.0	$ -	$ -	0.0
ATTIC R11	1258	$ 160	47295	6981	45	-0.1	$ 3,807	$ 3,823	-235.5
BSMT WALL R11	1085	$ 281	39247	8048	45	0.4	$ 4,389	$ 4,318	61.6
WALL R11	904	$ 989	30927	8320	45	4.3	$ 4,538	$ 3,835	6.5
ATTIC R19	890	$ 116	30263	664	45	6.8	$ 362	$ 272	4.0
FLOOR R11	840	$ 464	28009	2253	45	8.2	$ 1,229	$ 862	3.3
FLOOR R19	830	$ 100	27548	462	45	8.7	$ 252	$ 172	3.2
INFILTRATION @ O.4 ACH	818	$ 125	26994	554	45	10.1	$ 305	$ 193	2.7
ATTIC R30	805	$ 138	26434	559	45	10.4	$ 461	$ 286	2.6
BSMT WALL R21	786	$ 216	25588	846	45	13.6	$ 214	$ 108	2.0
FLOOR R30	778	$ 127	25196	392	45	21.2	$ 4,194	$ 967	1.3
STORM WINDOW CL50	605	$ 3,241	17505	7691	45	23.0	$ 302	$ 49	1.2
ATTIC R38	602	$ 73	17378	127	45	31.6	$ 69	$ (10)	0.9
ATTIC R49	598	$ 100	17221	158	45	38.3	$ 86	$ (34)	0.7
FLOOR R38	595	$ 91	17095	126	45	39.2	$ 1,033	$ (439)	0.7
DG Low E WINDOW CL35	551	$ 1,610	15201	1895	45	51.8	$ 68	$ (60)	0.5
DOOR R5	540	$ 563	14722	479	45	77.0	$ 689	$ (1,239)	0.4
TG Low E WINDOW CL25	510	$ 2,063	13458	1263	45	100.7	$ 261	$ (695)	0.3

Table G-16

Existing Single Family Space Heating - Missoula

850 sq ft	Missoula - Zone 3								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	696	0	31071	0	45	0	0	0	N/A
ATTIC R11	522	$ 187	21705	9366	45	-0.3	$ 5,108	$ 5,160	-97.6
WALL R11	426	$ 527	16570	5135	45	3.5	$ 2,800	$ 2,442	7.8
ATTIC R19	409	$ 136	15670	900	45	5.7	$ 491	$ 389	4.8
FLOOR R11	351	$ 542	12629	3040	45	7.0	$ 1,658	$ 1,239	4.0
FLOOR R19	339	$ 117	12009	621	45	7.4	$ 339	$ 247	3.7
INFILTRATION @ O.4 ACH	327	$ 125	11375	633	10	8.7	$ 406	$ 278	3.2
ATTIC R30	312	$ 162	10630	745	45	11.7	$ 286	$ 164	2.3
FLOOR R30	302	$ 149	10105	525	45	18.5	$ 1,420	$ 464	1.5
STORM WINDOW CL50	250	$ 967	7502	2603	30	20.0	$ 345	$ 94	1.4
ATTIC R38	247	$ 85	7334	168	45	21.8	$ 92	$ 19	1.3
ATTIC R49	243	$ 117	7124	210	45	24.1	$ 115	$ 14	1.1
FLOOR R38	239	$ 106	6956	167	45	27.7	$ 91	$ (1)	1.0
DG Low E WINDOW CL35	226	$ 480	6318	638	45	33.0	$ 348	$ (70)	0.8

DOOR R5	215	$ 563	5780	538	15	64.7	$ 231	$ (313)	0.4
TG Low E WINDOW CL25	206	$ 616	5355	424	45	81.7	$ 294	$ (579)	0.3

Table G-16 (Cont.)
Existing Single Family Space Heating - Missoula

1,350 sq ft	Missoula - Zone 3								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	1036	0	47955	0	45	0	0	0	0
ATTIC R11	759	$ 297	33028	14926	45	-0.3	$ 8,140	$ 8,225	-96.3
WALL R11	639	$ 657	26581	6447	45	3.5	$ 3,516	$ 3,070	7.9
ATTIC R19	612	$ 216	25139	1443	45	5.7	$ 787	$ 625	4.9
FLOOR R11	520	$ 861	20256	4883	45	6.9	$ 2,663	$ 1,998	4.0
FLOOR R19	501	$ 186	19257	999	45	7.3	$ 545	$ 400	3.8
INFILTRATION @ O.4 ACH	489	$ 125	18614	643	10	8.5	$ 656	$ 452	3.2
ATTIC R30	466	$ 257	17411	1203	45	11.5	$ 461	$ 268	2.4
FLOOR R30	449	$ 236	16565	846	45	18.1	$ 2,299	$ 786	1.5
STORM WINDOW CL50	368	$ 1,533	12348	4216	30	19.7	$ 351	$ 100	1.4
ATTIC R38	362	$ 135	12075	274	45	21.2	$ 149	$ 34	1.3
ATTIC R49	355	$ 186	11734	341	45	23.6	$ 186	$ 26	1.2
FLOOR R38	350	$ 169	11462	272	45	27.0	$ 148	$ 3	1.0
DG Low E WINDOW CL35	329	$ 761	10417	1045	45	31.9	$ 570	$ (92)	0.9
DOOR R5	318	$ 563	9861	557	15	62.5	$ 380	$ (483)	0.4
TG Low E WINDOW CL25	304	$ 976	9165	696	45	79.0	$ 304	$ (568)	0.3

2,184 sq ft	Missoula - Zone 3								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	1408	$ -	63081	0	45	0.0	$ -	$ -	0.0
ATTIC R11	1258	$ 160	55061	8021	45	-0.3	$ 4,374	$ 4,419	-97.6
BSMT WALL R11	1085	$ 281	45794	9267	45	0.2	$ 5,054	$ 5,010	115.3
WALL R11	904	$ 989	36178	9616	45	3.5	$ 5,244	$ 4,571	7.8
ATTIC R19	890	$ 116	35410	767	45	5.8	$ 418	$ 331	4.8
FLOOR R11	840	$ 464	32803	2608	45	6.9	$ 1,422	$ 1,063	4.0
FLOOR R19	830	$ 100	32267	536	45	7.3	$ 292	$ 214	3.7
INFILTRATION @ O.4 ACH	818	$ 125	31623	643	45	8.5	$ 354	$ 244	3.2
ATTIC R30	805	$ 138	30974	649	45	8.8	$ 537	$ 365	3.1
BSMT WALL R21	786	$ 216	29989	985	45	11.5	$ 249	$ 145	2.4
FLOOR R30	778	$ 127	29531	457	45	18.2	$ 4,836	$ 1,635	1.5
STORM WINDOW CL50	605	$ 3,241	20664	8867	45	19.7	$ 351	$ 100	1.4
ATTIC R38	602	$ 73	20518	146	45	27.2	$ 80	$ 1	1.0
ATTIC R49	598	$ 100	20336	182	45	33.0	$ 99	$ (20)	0.8
FLOOR R38	595	$ 91	20191	145	45	33.9	$ 1,189	$ (277)	0.8
DG Low E WINDOW CL35	551	$ 1,610	18011	2180	45	44.6	$ 79	$ (49)	0.6
DOOR R5	540	$ 563	17466	545	45	67.3	$ 786	$ (1,138)	0.4
TG Low E WINDOW CL25	510	$ 2,063	16024	1441	45	88.4	$ 297	$ (658)	0.3

Table G-17
Existing Multifamily Space Heating - Portland

	Portland - Zone 1			12 units @ 840 sq ft/dwelling unit					
Measure	**Building UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	4565	0	74479	0	45	0	$ -	$ -	N/A
ATTIC R11	3819	$ 801	54276	20203	45	0.7	$ 11,017	$ 10,752	41.5
WALL R11	3214	$ 3,305	38691	15585	45	8.5	$ 8,499	$ 5,876	3.2
ATTIC R19	3141	$ 582	36863	1828	45	13.3	$ 997	$ 514	2.1
INFILTRATION @ 0.35 ACH	2971	$ 1,500	32631	4232	10	16.5	$ 3,250	$ 1,296	1.7
FLOOR R11	2723	$ 2,321	26672	5960	45	18.0	$ 646	$ 222	1.5
FLOOR R19	2672	$ 501	25487	1184	45	20.8	$ 779	$ 189	1.3
ATTIC R30	2610	$ 692	24059	1429	45	34.3	$ 7,269	$ (1,790)	0.8
STORM WINDOW CL50	1983	$ 8,921	10729	13329	30	34.7	$ 440	$ (115)	0.8
FLOOR R30	1940	$ 637	9922	807	45	36.8	$ 2,308	$ (782)	0.7
ATTIC R38	1925	$ 364	9656	267	45	60.8	$ 145	$ (176)	0.5
ATTIC R49	1907	$ 501	9322	333	45	67.0	$ 182	$ (261)	0.4
DG Low E WINDOW CL35	1747	$ 4,418	6712	2610	45	75.7	$ 1,423	$ (2,493)	0.4
FLOOR R38	1733	$ 455	6500	212	45	96.1	$ 116	$ (289)	0.3
DOOR R5	1699	$ 1,688	6010	490	15	171.2	$ 815	$ (4,256)	0.2
TG Low E WINDOW CL25	1591	$ 5,672	4516	1494	45	272.0	$ 267	$ (2,375)	0.1

Table G-18
Existing Multifamily Space Heating - Seattle

	Seattle - Zone 1		12 units @ 840 sq ft/dwelling unit						
Measure	**Building UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	4565	0	85199	0	45	0	$ -	$ -	N/A
ATTIC R11	3819	$ 801	62139	23060	45	0.4	$ 12,575	$ 12,375	62.6
WALL R11	3214	$ 3,305	44451	17689	45	7.3	$ 9,646	$ 7,071	3.7
ATTIC R19	3141	$ 582	42412	2039	45	11.8	$ 1,112	$ 634	2.3
INFILTRATION @ 0.35 ACH	2971	$ 1,500	37699	4713	10	14.6	$ 3,651	$ 1,714	1.9
FLOOR R11	2723	$ 2,321	31004	6695	45	15.8	$ 731	$ 311	1.7
FLOOR R19	2672	$ 501	29664	1340	45	18.3	$ 880	$ 293	1.5
ATTIC R30	2610	$ 692	28051	1613	45	30.3	$ 8,189	$ (833)	0.9
STORM WINDOW CL50	1983	$ 8,921	13036	15015	30	30.5	$ 499	$ (54)	0.9
FLOOR R30	1940	$ 637	12121	915	45	33.0	$ 2,570	$ (509)	0.8
ATTIC R38	1925	$ 364	11819	302	45	53.6	$ 165	$ (156)	0.5
ATTIC R49	1907	$ 501	11442	377	45	59.1	$ 206	$ (236)	0.5
DG Low E WINDOW CL35	1747	$ 4,418	8369	3073	45	64.1	$ 1,676	$ (2,230)	0.4
FLOOR R38	1733	$ 455	8115	254	45	80.2	$ 138	$ (265)	0.3
DOOR R5	1699	$ 1,688	7529	586	15	142.2	$ 980	$ (4,084)	0.2
TG Low E WINDOW CL25	1591	$ 5,672	5733	1796	45	227.3	$ 319	$ (2,321)	0.1

Table G-19
Existing Multifamily Space Heating - Spokane

	Spokane - Zone 2			12 units @ 840 sq ft/dwelling unit					
Measure	**Building UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	4565	0	125083	0	45	0	$ -	$ -	N/A
ATTIC R11	3819	$ 801	95129	29954	45	0.1	$ 16,335	$ 16,290	359.2
WALL R11	3214	$ 3,305	71550	23579	45	5.2	$ 12,859	$ 10,416	5.3
ATTIC R19	3141	$ 582	68779	2771	45	8.4	$ 1,511	$ 1,049	3.3
INFILTRATION @ 0.35 ACH	2971	$ 1,500	62371	6409	10	10.4	$ 4,965	$ 3,082	2.6
FLOOR R11	2723	$ 2,321	53266	9105	45	11.3	$ 999	$ 590	2.4
FLOOR R19	2672	$ 501	51433	1832	45	13.1	$ 1,205	$ 632	2.1
ATTIC R30	2610	$ 692	49224	2210	45	19.3	$ 772	$ 231	1.4
STORM WINDOW CL50	1983	$ 8,921	27818	21405	30	20.9	$ 11,673	$ 2,796	1.3
FLOOR R30	1940	$ 637	26402	1416	45	23.9	$ 3,495	$ 454	1.1
ATTIC R38	1925	$ 364	25931	471	45	34.0	$ 257	$ (60)	0.8
ATTIC R49	1907	$ 501	25343	588	45	37.5	$ 321	$ (116)	0.7
DG Low E WINDOW CL35	1747	$ 4,418	20289	5054	45	38.5	$ 2,756	$ (1,106)	0.7
FLOOR R38	1733	$ 455	19843	445	45	45.2	$ 243	$ (157)	0.6
DOOR R5	1699	$ 1,688	18816	1027	15	78.6	$ 1,760	$ (3,272)	0.3
TG Low E WINDOW CL25	1591	$ 5,672	15589	3227	45	129.1	$ 560	$ (2,070)	0.2

Table G-20
Existing Multifamily Space Heating - Missoula

	Missoula - Zone 3			12 units @ 840 sq ft/dwelling unit					
Measure	**Building UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	4565	0	147079	0	45	0	$ -	$ -	N/A
ATTIC R11	3819	$ 801	111828	35251	45	-0.1	$ 19,224	$ 19,314	-212.8
WALL R11	3214	$ 3,305	84333	27495	45	4.3	$ 14,994	$ 12,640	6.4
ATTIC R19	3141	$ 582	81088	3245	45	7.0	$ 1,770	$ 1,319	3.9
INFILTRATION @ 0.35 ACH	2971	$ 1,500	73572	7516	10	8.7	$ 5,836	$ 3,988	3.2
FLOOR R11	2723	$ 2,321	62871	10701	45	9.3	$ 1,186	$ 785	3.0
FLOOR R19	2672	$ 501	60696	2175	45	10.8	$ 1,433	$ 870	2.5
ATTIC R30	2610	$ 692	58069	2627	45	16.8	$ 881	$ 344	1.6
STORM WINDOW CL50	1983	$ 8,921	33025	25043	30	17.7	$ 13,657	$ 4,862	1.6
FLOOR R30	1940	$ 637	31410	1615	45	20.2	$ 4,099	$ 1,083	1.4
ATTIC R38	1925	$ 364	30874	536	45	29.7	$ 292	$ (23)	0.9
ATTIC R49	1907	$ 501	30205	670	45	32.8	$ 365	$ (70)	0.8
DG Low E WINDOW CL35	1747	$ 4,418	24476	5729	45	33.9	$ 3,124	$ (722)	0.8
FLOOR R38	1733	$ 455	23966	510	45	39.4	$ 278	$ (120)	0.7
DOOR R5	1699	$ 1,688	22789	1177	15	68.5	$ 2,017	$ (3,004)	0.4
TG Low E WINDOW CL25	1591	$ 5,672	19090	3699	45	112.6	$ 642	$ (1,985)	0.2

Table G-21

Existing Single Family Space Heating - Regional Average

850 sq ft	Region								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	696	0	20094	0	45	0	0	0	N/A
ATTIC R11	522	$ 187	13625	6470	45	0.2	$ 3,528	$ 3,506	157.1
WALL R11	426	$ 527	10123	3502	45	5.7	$ 1,910	$ 1,515	4.8
ATTIC R19	409	$ 136	9516	607	45	9.0	$ 331	$ 222	3.0
FLOOR R11	351	$ 542	7476	2040	45	10.9	$ 1,112	$ 671	2.5
FLOOR R19	339	$ 117	7063	414	45	11.7	$ 226	$ 130	2.4
INFILTRATION @ O.4 ACH	327	$ 125	6643	419	10	13.8	$ 268	$ 134	2.0
ATTIC R30	312	$ 162	6152	492	45	18.4	$ 188	$ 62	1.5
FLOOR R30	302	$ 149	5806	345	45	29.0	$ 927	$ (50)	0.9
STORM WINDOW CL50	250	$ 967	4107	1699	30	30.8	$ 229	$ (27)	0.9
ATTIC R38	247	$ 85	3998	109	45	34.2	$ 59	$ (15)	0.8
ATTIC R49	243	$ 117	3862	136	45	37.8	$ 74	$ (28)	0.7
FLOOR R38	239	$ 106	3753	108	45	43.3	$ 59	$ (34)	0.6
DG Low E WINDOW CL35	226	$ 480	3341	412	45	51.7	$ 225	$ (198)	0.5
DOOR R5	215	$ 563	2996	345	15	102.5	$ 147	$ (401)	0.3
TG Low E WINDOW CL25	206	$ 616	2726	270	45	128.2	$ 188	$ (689)	0.2

1350 sq ft	Region								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	1036	0	31611	0	45	0	0	0	0
ATTIC R11	759	$ 297	21253	10359	45	0.2	$ 5,649	$ 5,615	167.2
WALL R11	639	$ 657	16817	4436	45	5.6	$ 2,419	$ 1,927	4.9
ATTIC R19	612	$ 216	15832	985	45	8.8	$ 537	$ 365	3.1
FLOOR R11	520	$ 861	12520	3312	45	10.7	$ 1,806	$ 1,106	2.6
FLOOR R19	501	$ 186	11846	674	45	11.4	$ 368	$ 216	2.4
INFILTRATION @ O.4 ACH	489	$ 125	11412	435	10	13.2	$ 442	$ 230	2.1
ATTIC R30	466	$ 257	10601	811	45	17.8	$ 309	$ 110	1.5
FLOOR R30	449	$ 236	10034	567	45	27.8	$ 1,530	$ (15)	1.0
STORM WINDOW CL50	368	$ 1,533	7229	2805	30	29.7	$ 237	$ (19)	0.9
ATTIC R38	362	$ 135	7047	181	45	32.7	$ 99	$ (19)	0.8
ATTIC R49	355	$ 186	6823	225	45	36.4	$ 123	$ (39)	0.8
FLOOR R38	350	$ 169	6644	179	45	41.6	$ 98	$ (50)	0.7
DG Low E WINDOW CL35	329	$ 761	5956	688	45	49.1	$ 375	$ (295)	0.6
DOOR R5	318	$ 563	5590	366	15	96.1	$ 248	$ (620)	0.3
TG Low E WINDOW CL25	304	$ 976	5135	455	45	120.8	$ 199	$ (677)	0.2

Table G-21 (Cont.)

Existing Single Family Space Heating - Missoula

2184 sq ft	Region								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	1408	$ -	41370	0	45	0.0	$ -	$ -	0.0
ATTIC R11	1258	$ 160	35818	5552	45	0.2	$ 3,028	$ 3,009	159.4
BSMT WALL R11	1085	$ 281	29449	6369	45	0.9	$ 3,473	$ 3,364	31.8
WALL R11	904	$ 989	22885	6565	45	5.7	$ 3,580	$ 2,838	4.8
ATTIC R19	890	$ 116	22364	521	45	9.0	$ 284	$ 191	3.1
FLOOR R11	840	$ 464	20600	1764	45	10.8	$ 962	$ 584	2.5
FLOOR R19	830	$ 100	20239	360	45	11.5	$ 197	$ 115	2.4
INFILTRATION @ O.4 ACH	818	$ 125	19807	432	45	13.3	$ 237	$ 123	2.1
ATTIC R30	805	$ 138	19372	435	45	13.7	$ 359	$ 180	2.0
BSMT WALL R21	786	$ 216	18713	659	45	17.8	$ 167	$ 59	1.5
FLOOR R30	778	$ 127	18407	306	45	27.7	$ 3,240	$ (26)	1.0
STORM WINDOW CL50	605	$ 3,241	12465	5942	45	29.8	$ 236	$ (20)	0.9
ATTIC R38	602	$ 73	12368	98	45	41.3	$ 53	$ (27)	0.7
ATTIC R49	598	$ 100	12246	121	45	50.2	$ 66	$ (54)	0.5
FLOOR R38	595	$ 91	12150	97	45	51.5	$ 792	$ (691)	0.5
DG Low E WINDOW CL35	551	$ 1,610	10698	1452	45	67.7	$ 53	$ (77)	0.4
DOOR R5	540	$ 563	10333	365	45	101.6	$ 524	$ (1,411)	0.3
TG Low E WINDOW CL25	510	$ 2,063	9373	960	45	132.6	$ 199	$ (760)	0.2

Table G-22

Existing Multifamily Space Heating - Regional Average

	Region			12 units @ 840 sq ft/dwelling unit					
Measure	**Building UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	4565	0	90620	0	45	0	$ -	$ -	N/A
ATTIC R11	3819	$ 801	66879	23740	45	0.4	$ 12,947	$ 12,761	69.8
WALL R11	3214	$ 3,305	48526	18353	45	7.0	$ 10,009	$ 7,448	3.9
ATTIC R19	3141	$ 582	46390	2136	45	11.2	$ 1,165	$ 689	2.4
INFILTRATION @ 0.35 ACH	2971	$ 1,500	41449	4941	10	13.9	$ 3,820	$ 1,889	2.0
FLOOR R11	2723	$ 2,321	34445	7004	45	15.1	$ 765	$ 346	1.8
FLOOR R19	2672	$ 501	33043	1402	45	17.4	$ 921	$ 337	1.6
ATTIC R30	2610	$ 692	31353	1689	45	28.1	$ 539	$ (12)	1.0
STORM WINDOW CL50	1983	$ 8,921	15457	15897	30	28.6	$ 8,669	$ (332)	1.0
FLOOR R30	1940	$ 637	14468	989	45	31.4	$ 2,694	$ (380)	0.9
ATTIC R38	1925	$ 364	14141	327	45	49.4	$ 178	$ (142)	0.6
ATTIC R49	1907	$ 501	13732	409	45	54.4	$ 223	$ (218)	0.5
DG Low E WINDOW CL35	1747	$ 4,418	10381	3351	45	58.7	$ 1,827	$ (2,073)	0.5
FLOOR R38	1733	$ 455	10100	282	45	72.2	$ 154	$ (250)	0.4
DOOR R5	1699	$ 1,688	9450	650	15	127.2	$ 1,094	$ (3,965)	0.2

TG Low E WINDOW CL25	1591	$ 5,672	7444	2006	45	204.8	$ 354	$ (2,284)	0.1

Step 2. Develop Conservation Savings Estimates that are Consistent with the Council's Forecast, and Incorporate Behavioral Impacts

The Council's supply curve for the total amount of conservation available in existing residential buildings was developed for the year 2015. This was done for three reasons. First, the supply of energy available through conservation in existing buildings is constrained by the rates at which measures can be implemented. Second, these rates are constrained by the need for additional energy supplies. Third, some existing houses will be torn down by the year 2015, and others may change their primary heating fuel. As a result, the conservation savings from existing buildings diminish with time because of removal and can also change due to altered selections of heating fuel. By developing its retrofit supply function for the year 2015, the Council was able to account for demolitions and set deployment schedules based on the need for additional supplies, which is done in the Integrated Systems for Analysis of Acquisitions model.

The estimates are based on the size of the existing housing stock and savings per house that will be expected in the year 2015. These estimates will vary from savings expected in the near term, not only because electricity prices change over this time period, but also because of expected equipment changes in residential households. For example, over this period, it is expected that residential appliances, such as refrigerators and freezers, will become much more efficient. During cold periods, the space heating equipment must then make up for the lack of heat that was once given off by the less efficient appliance. For residential space heating, these factors act to make savings look larger at the end of the forecast period. However, the magnitude of this effect is small. In addition, the savings expected in the year 2015 are consistent with the pre-conservation consumption used in the forecast.

The forecast model, combined with information from utility weatherization programs, was used to determine the number of electrically heated houses built before 1979 that would survive to 2015 and could still be retrofitted. Houses built after 1979 are not included as weatherization potential. These houses represent a lost-opportunity for conservation because they are insulated well enough that additional weatherization is generally not cost-effective, yet they are not insulated to the full level that is cost-effective for new homes. Houses that have electric heating systems, but heat primarily with wood, are also not included in the stock remaining to be weatherized. The retrofit savings in this chapter are based only on houses primarily heated with electricity.

In 1979, the stock of primarily electric space-heated single-family houses totaled 871,600. For multifamily units the number was 322,300. The existing housing stock is estimated to have an average lifetime of approximately 80 years. Today, the average age of the existing stock is approximately 25 years. By the year 2015, a number of these existing houses will have been removed from the housing stock because of such things as fire and decay. In addition, some houses may have changed their primary heating fuel either into, or away from, electricity over this period, as modeled in the forecast. Consequently, the remaining pre-1980 vintage stock in 2015, given the Council's average lifetime estimates and fuel choice, is approximately 825,000 single-family houses and 265,000 multifamily units.

In determining the number of weatherized houses that will survive until 2015 it has been assumed weatherized houses are not as likely to be removed from the housing stock between now and 2015 as units that are not weatherized. It seems likely that houses that are considered valuable enough to invest in for weatherization are probably not the houses that will decay out of the housing stock first.

A number of the houses that will survive to 2015 have already been weatherized through either utility-sponsored weatherization programs or by their owners. Therefore, the remaining conservation potential consists only of those houses that 1) have not yet been fully weatherized, 2) will survive in 2015; and, 3) have electric space heating in 2015. Using data supplied to the Council by Bonneville and the region's electric

utilities it was estimated that approximately 125,000 single-family dwellings and 85,000 multifamily units remain to be weatherized.

Once the remaining number of houses to be weatherized is established, then the engineering model's estimate of the level of thermal integrity improvement that is regionally cost-effective can be modeled in the load forecast. This is done by running the load forecast model under the assumption that all remaining homes and multifamily units are completely retrofitted with all cost-effective measures. Table G-23 compares the results of the engineering model with those produced by the load forecasting model. The difference in post-retrofit savings for both single family and multifamily are quite small, indicating that the magnitude of the efficiency improvements does not significantly shift consumer behavior.

The remaining conservation potential can then be derived by multiplying the "calibrated" regional average cost effective savings per unit by the remaining units. For multifamily units, the technical potential equals 413 kilowatt-hours per year x 85,000 units /8,760,000 kilowatt-hours per average megawatt = 4 Average megawatts. For single family the technical potential equals 1770 kilowatt-hour per year x 125,000 units / 8,760,000 kilowatt-hours per average megawatt = 25 average megawatts.

Table G-23
Load Forecast Calibration Results

	Forecast Model	Engineering Model	Difference
Housing Type	(kWh/Year)	(kWh/Year)	(kWh/yr)
Pre-Retrofit Single Family	11294	10923	
Post-Retrofit Single Family	9524	9211	
Savings	1770	1712	58
Pre-Retrofit Multifamily	3269	3322	
Post-Retrofit Multifamily	2857	2903	
Savings	413	419	-7

Step 3. Compare Savings and Costs Estimates with Observed Savings and Costs

As discussed under Step 1, the measure costs used in this analysis were taken from actual utility program experience. The most recent (1991 program year) evaluation results from Bonneville's residential weatherization program indicate that average savings per retrofitted home are about 2,445 kilowatt-hours per year. These savings are not directly comparable to the findings of this analysis because not all of the measures installed in the program are regionally cost-effective given today's much lower avoided costs. A comparison of the evaluation's savings estimate to one that includes all of the measures that were regionally cost-effective at the avoided cost being used in 1991 (6.0 cents per kilowatt-hour in 1995 dollars), shows reasonable agreement (2,370 kilowatt-hours vs. 2,445 kilowatt-hours). No comparable evaluation data were available for multifamily dwellings that reflect the more limited set of measures that have been identified as regionally cost-effective in this analysis.

Step 4. Estimate Achievable Potential

The Council has assumed that 85 percent of the remaining technically available and regionally cost-effective space heating conservation potential is achievable over the next 20 years. This amounts to approximately 25 average megawatts in the Council's medium forecast. The assumption that 85 percent of the potential can be achieved represents actions by utilities and potentially other parties. Even with utility restructuring, some utilities will continue to offer residential weatherization services to their customers, although it is expected that program "participants" will be asked to shoulder more of the cost of retrofitting

their homes. Table G-24 shows the technically available and achievable resource potential in existing single and multifamily buildings by levelized cost.

Table G-24
Existing Space Heating - Supply Curve

Resource Costs (Mills/kWh)	Technical Potential (AMW)	Achievable Potential (AMW)
0	0	0
10	2	2
20	25	20
30	30	25
40	35	30
50	55	45
60	60	50

SPACE HEATING CONSERVATION IN NEW RESIDENTIAL BUILDINGS

Figures G-19, G-20, and G-21 show the technical space heating savings available under the Council's medium forecast from new single-family and multifamily residences and from new manufactured houses at various costs. If the prevailing codes and building practices in the region had not changed since 1983, new single-family and multifamily homes would have represented approximately 430 average megawatts of technical potential if savings costing less than 2.8 cents per kilowatt-hour could be achieved in all new electrically heated dwellings built between 1997 and 2015. Since 1983, when the Council adopted its first plan, the states of Oregon and Washington, and other jurisdictions in Idaho and Montana, have adopted energy codes equivalent to the Council's model conservation standards for new electrically heated residences. These code changes are anticipated to secure about 310 average megawatts of this technical potential, if they are effectively enforced.[23] This leaves 120 average megawatts of technical potential yet to be secured through further energy efficiency improvements in site-built residential construction practices.

Similarly, if the energy efficiency of new manufactured homes had not changed since 1983, they would represent about 425 average megawatts of technical potential between 1997 and 2015. However, due to changes in the federal standards regulating the thermal efficiency of manufactured homes and the efforts of Bonneville and the region's utilities to transform this market, all but 100 average megawatts of this potential will be captured.

The average cost of improving the thermal efficiency of new buildings beyond current codes is about 1.9 cents per kilowatt-hour when administrative costs and transmission and distribution adjustments are included. Figure G-22 illustrates how improved building practices since 1983 have reduced the amount of remaining cost-effective conservation to be secured. The height of each bar represents the cost-effective savings potential in new electrically heated residential buildings compared to practices in 1983 and 1995. These estimates assume the number of units constructed between 1997 and 2015 under the Council's medium forecast. The remaining potential beyond 1995 building codes/practices that requires further action is represented by the height of third bar.

[23] The state of Washington began enforcing an energy code equivalent to the Council's model conservation standards for new electrically heated residences in July 1991. The State of Oregon began enforcing an energy code equivalent to the Council's model conservation standards for new electrically heated residences in January 1992.

Figure G-19
New Single Family Space Heating Supply Curve

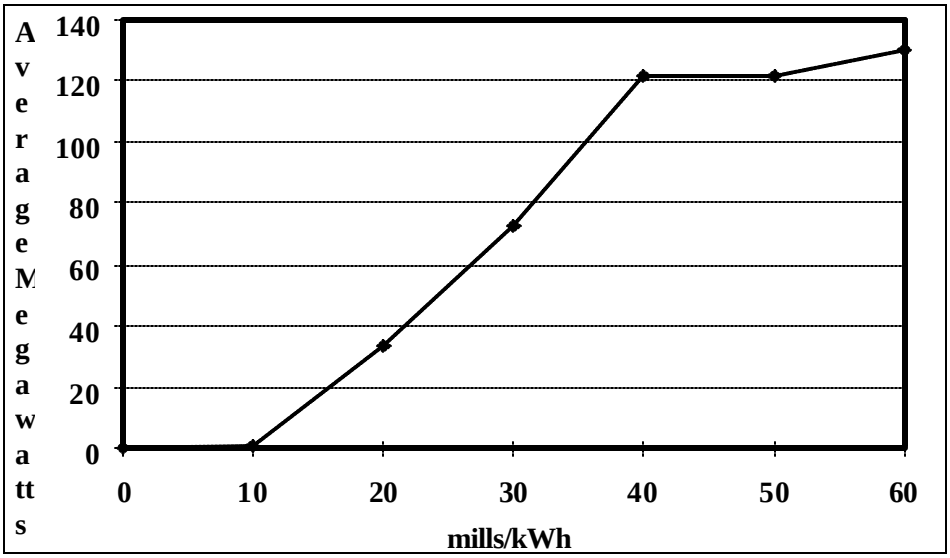


Figure G-20
New Multifamily Space Heating Supply Curve

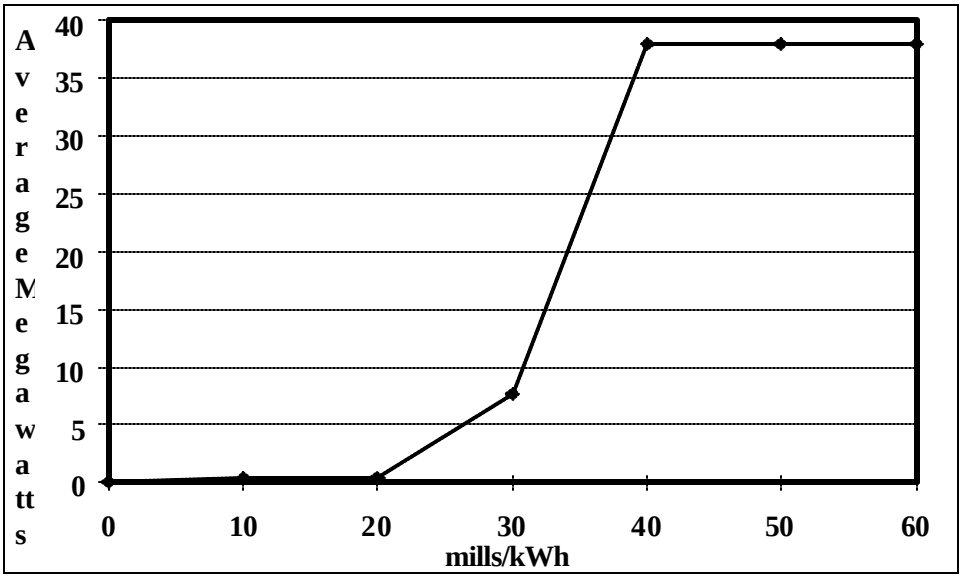


Figure G-21
New Manufactured Housing Space Heating Supply Curve

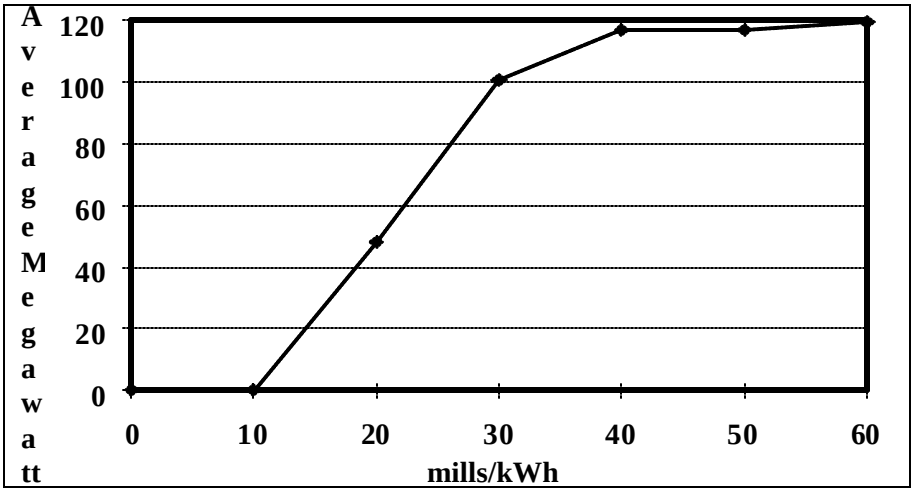
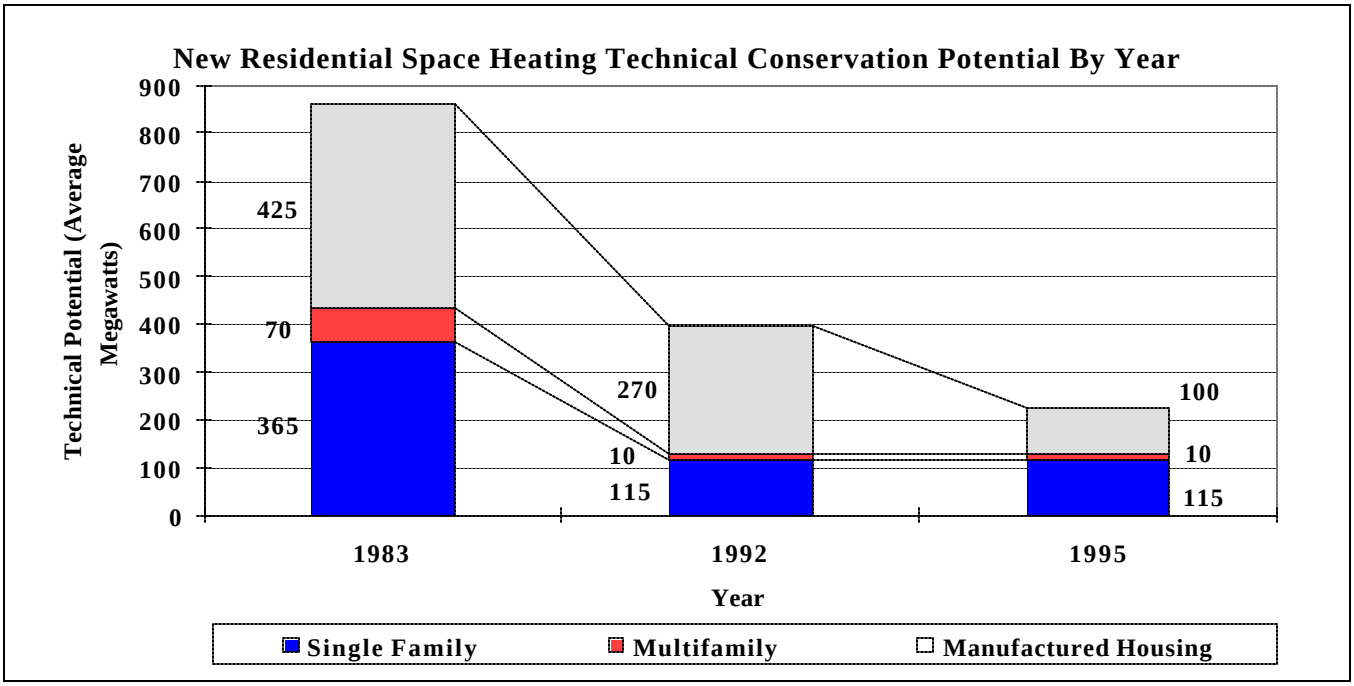


Figure G-22
New Residential Space Heating Technical Conservation Potential By Year



The Council's estimate of conservation potential available through improving the energy efficiency of space heating in new residential buildings was developed in five steps. These steps were to:

1. Establish the characteristics of current new residential construction.
2. Develop construction cost estimates for space heating conservation measures in new dwellings.
3. Assess the cost-effectiveness of space heating energy savings produced by efficiency improvements in new residential buildings.
4. Estimate the technical potential available from space heating energy conservation in new dwellings.
5. Estimate the achievable conservation potential available from space heating energy conservation in new dwellings.

The key sources of information used in this section come from research and programs operated in the region. Table G-24 summarizes these data sources.

Table G-24
Primary Data Source for New Residential Space Heating Analysis

Data Source	Data Type
Bonneville Regional Energy Measure Cost Project	Current insulation practices and measure costs
Washington State Energy Office Residential Energy Conservation Evaluation	Current measure costs
Manufactured Home Acquisition Program - Performance of Homes Sited in the First Year	Manufactured housing measure costs and space heating performance
Bonneville's Super GOOD CENTS Sub-metering project	Single family space heating performance
Northwest Residential Infiltration Study	Air change rates in new dwellings
Residential Construction Demonstration Program	Measure cost, space heating performance and air change rates

Separate estimates were prepared for single-family dwellings (up to four units and less than four stories), multifamily dwellings (five-plex and larger) and manufactured housing (e.g., mobile homes). A description of each of these steps, the data and major assumptions used and their sources follows.

Step 1. Establish the Characteristics of New Residential Construction

To determine the potential for improving the energy efficiency of new residential structures, it was first necessary to establish their current level of efficiency. In addition to identifying the level of insulation and type of windows commonly installed in new housing, other new home characteristics had to be ascertained, such as average floor area heated, number of stories, window area, "tightness'' of the dwelling and foundation type. These characteristics significantly affect the amount of energy needed for space heating.

Table G-25 shows by building type the 1995 "base case'' insulation levels assumed by the Council in its assessment of space heating conservation potential in new dwellings. The information on 1995 single-family and multifamily housing characteristics shown in Table G-25 represent the Council's assessment of current building practices. For those areas in the region that enforce an energy code, the requirements of such codes served to establish the minimum thermal efficiency levels found in typical new single-family and multifamily

dwellings. In other areas of the region that have not adopted an energy code, the Council used information from a survey ofconstruction practices prepared for Bonneville by the Washington State Energy Office. [24]

Table G-25

New Residential Buildings - Current Building Practice Assumptions [25]

Building Component	Single Family	Multifamily	Manufactured Home
Wall	R-19 Standard	R-19 Standard	R-19 Advanced
Attic	R-38 Standard	R-38 Standard	R-19 Standard
Vault	R-30	R-30	R-19
Floor over crawlspace	R-19	R-25	R-22
Windows	Class 40 (U-0.40)	Class 50 (U-0.50)	Class 50 (U-0.50)
Exterior Doors	R-5 (Metal Insulated)	R-5 (Metal Insulated)	R-5 (Metal Insulated)
Slab Edge	R-10 (2 ft. down)	R-10 (2 ft. down)	Not Applicable
Below Grade Wall	R-19 Interior	R-19 Interior	Not Applicable
Air Leakage	0.35 air changes per hour	0.35 air changes per hour	0.35 air changes per hour
Average UA (Btu/F)	392	2114	360
Average House Size (Sq. Ft.)	1700	1040	1465
Average Use (kWh/yr)	7140	2120	8940
Average Use (kWh/sq ft/yr)	4.2	2.0	6.1
Average Heating Degree Days	5525	5400	5900

Information on the air tightness of new dwellings was obtained from the Northwest Residential Infiltration Study (NORIS) sponsored by Bonneville. The NORIS research indicated that the average infiltration rates for single-family detached housing built between 1980 and 1986 was approximately 0.40 to 0.45 air changes per hour. Research carried out under NORIS also found that the average infiltration rates for houses built under Bonneville's Super Good Cents program was approximately 0.30 air changes per hour in site-built homes and 0.25 air changes per hour in manufactured homes. The NORIS project found that, depending on the criteria used, from 20 to 50 percent of all of the homes tested, whether built to the Super Good Cents standards or not, would not meet the most current American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. standard for acceptable ventilation rates (ASHRAE Standard 62-89). Given these findings and the adoption of energy codes in Oregon and Washington that are equivalent to the Council's model standards, the Council will continue to assume the ASHRAE rate of 0.35 air changes per hour for current (1995) practice homes.

The base-case characteristics for new manufactured housing, shown in G-25, were derived from discussions with state energy office personnel who are providing design approval services for the industry's Super Good Cents program. These levels exceed the requirements of the U.S. Department of Housing and Urban Development's revised rules concerning the eligibility of manufactured homes for mortgage insurance under Title II of the National Housing Act. However, it should be noted that preliminary results from a Bonneville study of the market transformation impacts of the Manufactured Housing Acquisition Program (MAP) appear to indicate that over 90 percent of new electrically heated manufactured homes continue to be built at levels that contain all regionally cost-effective measures. If these results are confirmed, the final plan will assume that there are no further savings available from improving the building envelop. This will reduce

[24] Lubliner, M. etal, Costs of New Residential Conservation Measures in the Pacific Northwest. (Draft Report) September 31, 1995.

[25] Practice represents the weighted average across all climate zones and states.

regional load growth and new residential space heating conservation potential by approximately 95 average megawatts.

Once the general characteristics of new dwellings had been identified, "typical'' building designs were developed for detailed analysis of space heating conservation potential. Three typical single-family detached dwelling designs were developed to represent the mixture of house sizes and foundation types being constructed in the region. A single multifamily building design was chosen to represent new multifamily construction larger than four-plexes. Two manufactured home designs were selected to represent those typically being sold in the region. Table G-26 summarizes the basic characteristics of the new dwellings used in the Council's assessment. These designs were selected as representative, based on features primarily related to their space heating requirements, such as foundation type, and secondarily on their architectural styles.

Table G-26
Prototype Characteristics for New Residential Construction

Single Family			
Total Floor Area (Square Feet)	1,344	2,200	2,283
Wall (Square Feet	1,231	2,122	1,817
Attic (Square Feet)	960	802	1,198
Vault (Square Feet)	405	802	0
Floor over crawlspace (Square Feet)	1,344	1,721	104
Windows (Square Feet)	176	366	200
Exterior Doors (Square Feet)	38	55	89
Slab Edge (Linear Feet)	0	0	140
Below Grade Wall (Square Feet)	0	0	560
Multifamily			
Total Floor Area (Square Feet)	12,492		
Wall (Square Feet	8,432		
Attic (Square Feet)	2,148		
Vault (Square Feet)	1,851		
Floor over crawlspace (Square Feet)	0		
Windows (Square Feet)	1,247		
Exterior Doors (Square Feet)	240		
Slab Edge (Linear Feet)	276		
Below Grade Wall (Square Feet)	575		

Table G-26 (Cont.)
Prototype Characteristics for New Residential Construction

Manufactured Home		
Total Floor Area (Square Feet)	924	1568
Wall (Square Feet	1048	1026
Attic (Square Feet)	400	908
Vault (Square Feet)	524	660
Floor over crawlspace (Square Feet)	924	1568

Windows (Square Feet)	116	196
Exterior Doors (Square Feet)	38	38

Step 2. Develop Construction Cost Estimates for Space Heating Conservation Measures in New Dwellings

In the development of the 1983 Power Plan, the Council conducted an extensive survey of conservation costs in new residential buildings. Pursuant to the Council's plan, Bonneville, in cooperation with the four Northwest states, initiated a regionwide demonstration program on energy-efficient new home construction called the Residential Standards Demonstration Program (RSDP). The Council analyzed the cost reports submitted by builders in this program. Except for one measure, infiltration control with mechanical ventilation, the median costs reported by participating builders generally agreed with those used by the Council in the 1983 Plan. The conservation analysis presented here makes use of three additional sources of conservation measure cost in addition to the RSDP cost data. Recent data on single family and multifamily construction costs were taken from two studies prepared by the Washington State Energy Office for Bonneville.[26] The cost data used to estimate conservation potential in new manufactured homes were taken from a report prepared by Ecotope for Bonneville on the cost-effectiveness of the Manufactured Housing Acquisition Program.[27] A markup on direct costs of 36 percent was assumed to cover overhead, profits and fees for single-family and multifamily housing. The costs of measures installed in new manufactured homes reflect a 35-percent markup for dealer overhead and profit.

Not all space heating conservation measures have similar useful lives. Insulation and infiltration control measures (i.e., air/vapor barriers) installed in new single-family and multifamily dwellings are anticipated to last at least 70 years (i.e., about the life of the structure). These same measures installed in new manufactured houses are also expected to last the life of the building (i.e., 45 years). However, the Council has assumed that two measures, insulated doors and energy-efficient windows, must be repaired or replaced before the end of the life of the structure. The Council included the cost of repairing and/or replacing these two space heating conservation measures when calculating their levelized cost. Based on data obtained during the process of revising the Oregon energy code, it appears that, with modern sealants and manufacturing techniques, approximately 25 percent of the windows installed in new housing can be expected to fail during the first 70 years. The cost of replacing these windows was converted to present value. It was then determined that a 60-year measure life would provide the same present value. Insulated doors in new residential structures were assumed to be replaced at 30-year intervals at a cost equivalent to their initial capital cost. The incremental installed cost of the measures considered in this analysis is shown in Table G-27 for single and multifamily homes and Table G-28 for manufactured housing.

[26] See: Frankel, M. et al., Residential Energy Conservation Evaluation - Cost Effectiveness of Energy Conservation Measures in New Residential Construction in Washington State. (Draft Report) March 31, 1995. Washington State Energy Office, Olympia. and Lubliner, M. etal. Costs of New Residential Conservation Measures in the Pacific Northwest. (Draft Report) September 31, 1995. Washington State Energy Office, Olympia.

[27] Baylon, D. Manufactured Home Acquisition Program - Performance of Homes Sited in the First Year. (Draft Report) March 16, 1995. Ecotope, Seattle, WA.

Table G-27

Incremental Installed Cost of New Space Heating Conservation Measures

Single and Multifamily Housing

Conservation Measure	Incremental Installed Cost (1995$)	
WALL R-19 Standard	Base Case	
WALL R-21 Advanced	$ 0.14	
WALL R-26 Advanced	$ 0.78	
WALL R-30 8” Stress Skin Panel	$ 1.06	
WALL R-33 Double wall	$ 0.54	
ATTIC R-38 Standard	Base Case	
ATTIC R-49 Advanced Truss	$ 0.64	
ATTIC R-60 Advanced Truss	$ 0.37	
VAULT R-30 High Density Batts	Base Case	
VAULT R38 High Density Batts	$ 0.56	
VAULT R-49 10” Stress Skin Panel	$ 1.94	
FLOOR R-19	Base Case Single Family	
FLOOR R-25	$ 0.14	< = Base Case Multifamily
FLOOR R-30	$ 0.08	
FLOOR R-38 w/12” truss	$ 0.37	
WINDOW Class 50	Base Case Multifamily	
WINDOW Class 40	$ 2.15	< = Base Case Multifamily
WINDOW Class 35	$ 0.65	
WINDOW Class 30	$ 2.20	
WINDOW Class 20	$ 6.01	
DOOR R-5	Base Case	
SLAB R-10 @ 2 Ft Depth	Base Case	
SLAB R-10 @ 4 ft Depth	$ 2.28	
SLAB R-10 Under full slab	$ 4.57	
Below Grade Wall R-19	Base Case	
Below Grade Wall R-22 Foam Blocks	$ (0.98)	
All costs are in $/square foot of component area, except slab insulation		
measures which are reported in $/linear foot.		

Table G-28
Incremental Installed Cost of New Space Heating Conservation Measures

Manufactured Housing

Conservation Measure	Incremental Installed Cost (1995$)
WALL R-19	Base Case
WALL R-21 Advanced	$ 0.15
ATTIC R-19	Base Case
ATTIC R-25	$ 0.11
ATTIC R-30	$ 0.09
ATTIC R-38	$ 0.13
ATTIC R-49	$ 0.19
VAULT R-19	Base Case
VAULT R-25	$ 0.11
VAULT R-30	$ 0.09
VAULT R-38	$ 0.13
FLOOR R-22	Base Case
FLOOR R-33	$ 0.15
FLOOR R-44	$ 0.15
WINDOW Class 50	Base Case
WINDOW Class 40	$ 2.04
WINDOW Class 35	$ 0.86
DOOR R-5	Base Case
All costs are in $/square foot of component area.	

Step 3. Estimate the Cost-Effectiveness of Space Heating Energy Savings Produced by Efficiency Improvements in New Residential Buildings

Once typical new dwelling designs were selected, the Council used a computer simulation model to estimate potential space heating energy savings that could be produced by each conservation measure. This model, SUNDAY, is also used to estimate savings from weatherization measures (see discussion above in residential weatherization section).

The absolute value (in kilowatt-hours per year) of the space heating energy savings produced by adding an individual conservation measure is a function of the existing thermal efficiency level of the building. The less efficient the existing building, the larger the savings that will be obtained from installing the same measure.

To assess the savings that could be produced by installing each space heating conservation measure, it is necessary to take into account the interaction of all of the measures. This was done by determining each measure's benefit (i.e., change in heat loss rate) and cost (i.e., present-value dollars per square foot). The savings produced by each potentially cost-effective measure were then analyzed under the assumption that all measures with higher benefit-to-cost ratios had already been installed in the house.

When determining the electrical savings of measures applied to a current-practice house, at least the following three policy considerations must be evaluated: the treatment of wood heating, internal temperature settings for the whole house, and internal gains.[28] The Council assumed no wood heating when evaluating measure savings in new residential buildings. The Council used a constant thermostat setting of 65 degreesF for the whole house to represent a combination of higher temperatures when the house was occupied and the occupants active, and a lower nighttime setback. Finally, the Council assumed a cadre of efficient appliances, reflecting appliances that would be in place for most of the life of the house, and are present in the region throughout most of the Council's plan. Appliances currently in place in houses are less efficient than new appliances, but contribute more usable heat to the house, and thus cut space heating loads.

The Council reassessed the planning assumptions described above and feels that these assumptions should be maintained for the following reasons. First, there is no assurance that occupants of houses built to the standards will continue to use wood heat. Changing wood prices, income levels, wood availability and environmental regulations all could reduce the use of wood heating, leaving the electrical system vulnerable to mass "fuel switching" to electricity, an action that would be difficult if not impossible to plan resources for. Second, the Northwest Power Act defines conservation as an efficiency improvement, not a change in lifestyle. Current behavior of consumers to close off rooms or lower thermostats may represent curtailment rather than conservation as defined in the Act. Such behavior is not expected to continue after cost-effective efficiency improvements are made. Third, more efficient appliances are clearly cost-effective resources and will be the norm in the next decade, especially in new houses. Appliance manufacturers have testified that, even without appliance standards such as those adopted in 1987 by Congress, new appliances will be much more efficient. Therefore, the Council's estimates reflect less heat escaping from these appliances to heat the house. Finally, the adoption of planning assumptions different from these would subject the region to greater planning uncertainties than the present set of assumptions. If the energy-efficiency requirements of the standards are made less stringent, because it is assumed consumers will continue to close off rooms and heat with wood, the degree of uncertainty the region must plan for increases.

Tables G-29 through G-40 show the levelized cost, annual energy use and energy savings produced by the addition of each measure for each dwelling type, building design and for representative climate types found in the region (Zone 1-Portland and Seattle, Zone 2-Spokane and Zone 3-Missoula). The levelized costs shown for single-family and multifamily buildings are based on a 70-year physical life and a financing cost of 4.75 percent in real dollars. Levelization was done using a 4.75 percent real discount rate over 15 years. The levelized cost shown for manufactured housing is based on a 45-year economic life and levelization at the same real financing and discount rate used for single-family and multifamily housing.

[28] These items are discussed here in terms of the calculated savings per measure. Under Step 5, these items are discussed in terms of differences between the demand forecast estimates of space heating loads and estimates from the engineering model.

Table G-29
New Single Family Space Heating Cost-Effectiveness

1,344 sq ft	Portland - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	322	0	4521	0	70	0	0	0	N/A
WALL R21ADV	308	$ 167	4148	373	70	13.6	$ 329	$ 171	2.1
WINDOW CL35	300	$ 115	3918	230	60	16.0	$ 203	$ 88	1.8
FLOOR R25 STD	289	$ 183	3632	287	70	19.7	$ 253	$ 77	1.4
FLOOR R30 STD	284	$ 110	3491	141	70	24.3	$ 124	$ 18	1.2
WINDOW CL25	267	$ 345	3057	434	60	26.1	$ 384	$ 29	1.1
VAULT R38 SCI	266	$ 44	3025	31	70	44.7	$ 28	$ (16)	0.6
FLOOR R38STD w/12”Truss	256	$ 494	2784	241	70	65.5	$ 213	$ (281)	0.4
ATTIC R49 ADVrh	246	$ 614	2517	267	70	73.7	$ 236	$ (380)	0.4
WALL R21A+R5	232	$ 954	2181	336	70	91.2	$ 297	$ (663)	0.3
VAULT 10” SS Panel	227	$ 650	2044	137	70	152.9	$ 121	$ (536)	0.2
ATTIC R60 ADVrh	224	$ 353	1975	69	70	165.7	$ 61	$ (296)	0.2
WINDOW CL20	215	$ 1,108	1777	198	60	190.7	$ 175	$ (1,006)	0.1
WALL 8” SSPANEL	204	$ 1,624	1529	248	70	211.5	$ 220	$ (1,425)	0.1
WALL R33DBL	203	$ 670	1502	27	70	808.1	$ 24	$ (657)	0.0

2,200 sq ft	Portland - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	520	$ -	8166	0	70	0.0	$ -	$ -	N/A
WALL R21ADV	496	$ 289	7518	648	70	13.4	$ 573	$ 301	2.1
WINDOW CL35	479	$ 239	7038	480	60	16.0	$ 424	$ 184	1.8
FLOOR R25 STD	465	$ 234	6665	373	70	19.4	$ 329	$ 103	1.5
FLOOR R30 STD	458	$ 140	6481	185	70	23.7	$ 163	$ 26	1.2
WINDOW CL25	423	$ 717	5561	919	60	25.6	$ 813	$ 75	1.1
VAULT R38 SCI	421	$ 74	5508	54	70	44.1	$ 47	$ (27)	0.6
FLOOR R38STD w/12”Truss	409	$ 632	5196	312	70	64.8	$ 276	$ (357)	0.4
ATTIC R49 ADVrh	400	$ 513	4968	227	70	72.2	$ 201	$ (313)	0.4
WALL R21A+R5	377	$ 1,645	4372	596	70	88.6	$ 527	$ (1,127)	0.3
VAULT 10” SS Panel	368	$ 1,098	4129	242	70	146.2	$ 214	$ (895)	0.2
ATTIC R60 ADVrh	365	$ 294	4069	60	70	157.5	$ 53	$ (244)	0.2
WINDOW CL20	348	$ 2,305	3632	437	60	179.4	$ 386	$ (2,067)	0.2
WALL 8” SSPANEL	328	$ 2,799	3175	457	70	198.2	$ 404	$ (2,430)	0.1
WALL R33DBL	326	$ 1,154	3127	49	70	765.5	$ 43	$ (1,130)	0.0

Table G-29 (Cont.)

New Single Family Space Heating Cost-Effectiveness

2,283 sq ft	Portland - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	460	$ -	7758	0	70	0.0	$ -	$ -	0.0
BGWALL R22 FOAM BLOCK	457	$ (548)	7676	82	70	-268.5	$ 72	$ 757	-0.1
WALL R21ADV	437	$ 247	7096	580	70	12.8	$ 512	$ 280	2.2
WINDOW CL35	428	$ 131	6821	276	60	15.1	$ 244	$ 113	1.9
FLOOR R25 STD	427	$ 14	6797	24	70	18.4	$ 21	$ 7	1.5
FLOOR R30 STD	426	$ 8	6785	12	70	22.2	$ 10	$ 2	1.3
WINDOW CL25	407	$ 392	6248	538	60	23.9	$ 475	$ 73	1.2
SLAB R10-4FT	399	$ 320	6013	235	70	43.2	$ 208	$ (110)	0.7
SLAB R10-FULL	382	$ 642	5545	468	70	43.5	$ 414	$ (223)	0.6
BGWALL R21	380	$ 76	5498	47	70	51.9	$ 41	$ (35)	0.5
FLOOR R38STD w/12”Truss	380	$ 38	5478	20	70	60.8	$ 18	$ (20)	0.5
ATTIC R49 ADVrh	367	$ 766	5120	357	70	68.6	$ 316	$ (452)	0.4
WALL R21A+R5	347	$ 1,409	4584	536	70	84.3	$ 474	$ (942)	0.3
ATTIC R60 ADVrh	343	$ 440	4488	96	70	147.4	$ 85	$ (359)	0.2
WINDOW CL20	333	$ 1,259	4231	257	60	166.7	$ 227	$ (1,113)	0.2
WALL 8” SSPANEL	317	$ 2,397	3797	434	70	178.4	$ 384	$ (2,041)	0.2
WALL R33DBL	315	$ 988	3749	48	70	666.9	$ 43	$ (962)	0.0

Table G-30

New Single Family Space Heating Cost-Effectiveness

1,344 sq ft	Seattle - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	322	0	5189	0	70	0	0	0	N/A
WALL R21ADV	308	$ 167	4770	419	70	11.9	$ 370	$ 214	2.4
WINDOW CL35	300	$ 115	4512	258	60	14.2	$ 228	$ 113	2.0
FLOOR R25 STD	289	$ 183	4189	323	70	17.4	$ 285	$ 110	1.6
FLOOR R30 STD	284	$ 110	4028	161	70	21.1	$ 142	$ 36	1.3
WINDOW CL25	267	$ 345	3535	493	60	22.9	$ 436	$ 83	1.2
VAULT R38 SCI	266	$ 44	3500	35	70	39.8	$ 31	$ (13)	0.7
FLOOR R38STD w/12”Truss	256	$ 494	3229	271	70	58.1	$ 240	$ (254)	0.5
ATTIC R49 ADVrh	246	$ 614	2927	302	70	65.0	$ 267	$ (347)	0.4
WALL R21A+R5	232	$ 954	2546	381	70	80.3	$ 337	$ (622)	0.4
VAULT 10” SS Panel	227	$ 650	2391	155	70	135.1	$ 137	$ (519)	0.2
ATTIC R60 ADVrh	224	$ 353	2313	78	70	146.3	$ 69	$ (287)	0.2
WINDOW CL20	215	$ 1,108	2089	224	60	168.0	$ 198	$ (981)	0.2
WALL 8” SSPANEL	204	$ 1,624	1803	285	70	183.9	$ 252	$ (1,391)	0.2
WALL R33DBL	203	$ 670	1772	31	70	695.1	$ 28	$ (653)	0.0

Table G-30 (Cont.)

New Single Family Space Heating Cost-Effectiveness

2,200 sq ft	Seattle - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	520	$ -	9367	0	70	0.0	$ -	$ -	N/A
WALL R21ADV	496	$ 289	8629	738	70	11.7	$ 652	$ 383	2.4
WINDOW CL35	479	$ 239	8084	545	60	13.9	$ 482	$ 244	2.0
FLOOR R25 STD	465	$ 234	7662	422	70	17.0	$ 373	$ 149	1.7
FLOOR R30 STD	458	$ 140	7451	211	70	20.6	$ 186	$ 50	1.4
WINDOW CL25	423	$ 717	6411	1040	60	22.5	$ 920	$ 186	1.3
VAULT R38 SCI	421	$ 74	6351	60	70	39.0	$ 53	$ (20)	0.7
FLOOR R38STD w/12”Truss	409	$ 632	5998	352	70	57.2	$ 311	$ (320)	0.5
ATTIC R49 ADVrh	400	$ 513	5741	257	70	63.9	$ 227	$ (286)	0.4
WALL R21A+R5	377	$ 1,645	5069	672	70	78.5	$ 594	$ (1,057)	0.4
VAULT 10” SS Panel	368	$ 1,098	4797	272	70	130.3	$ 240	$ (868)	0.2
ATTIC R60 ADVrh	365	$ 294	4729	68	70	139.6	$ 60	$ (237)	0.2
WINDOW CL20	348	$ 2,305	4237	493	60	159.0	$ 435	$ (2,016)	0.2
WALL 8” SSPANEL	328	$ 2,799	3713	524	70	172.6	$ 463	$ (2,368)	0.2
WALL R33DBL	326	$ 1,154	3656	57	70	662.2	$ 50	$ (1,123)	0.0

2,283 sq ft	Seattle - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	460	$ -	8895	0	70	0.0	$ -	$ -	0.0
BGWALL R22 FOAM BLOCK	457	$ (548)	8804	91	70	-240.6	$ 80	$ 766	-0.1
WALL R21ADV	437	$ 247	8157	647	70	11.4	$ 572	$ 342	2.5
WINDOW CL35	428	$ 131	7849	309	60	13.4	$ 273	$ 143	2.1
FLOOR R25 STD	427	$ 14	7822	27	70	16.3	$ 23	$ 10	1.7
FLOOR R30 STD	426	$ 8	7809	13	70	19.7	$ 12	$ 4	1.4
WINDOW CL25	407	$ 392	7204	605	60	21.1	$ 534	$ 135	1.3
SLAB R10-4FT	399	$ 320	6938	266	70	38.1	$ 235	$ (82)	0.7
SLAB R10-FULL	382	$ 642	6410	528	70	38.4	$ 467	$ (169)	0.7
BGWALL R21	380	$ 76	6358	52	70	46.1	$ 46	$ (29)	0.6
FLOOR R38STD w/12”Truss	380	$ 38	6335	23	70	53.7	$ 20	$ (18)	0.5
ATTIC R49 ADVrh	367	$ 766	5928	407	70	60.0	$ 360	$ (406)	0.5
WALL R21A+R5	347	$ 1,409	5314	614	70	73.6	$ 542	$ (871)	0.4
ATTIC R60 ADVrh	343	$ 440	5204	110	70	129.0	$ 97	$ (347)	0.2
WINDOW CL20	333	$ 1,259	4914	290	60	147.2	$ 257	$ (1,082)	0.2
WALL 8” SSPANEL	317	$ 2,397	4428	486	70	159.4	$ 429	$ (1,994)	0.2
WALL R33DBL	315	$ 988	4375	53	70	601.9	$ 47	$ (957)	0.0

Table G-31
New Single Family Space Heating Cost-Effectiveness

1,344 sq ft	Spokane - Zone 2								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	322	0	8122	0	70	0	0	0	N/A
WALL R21ADV	308	$ 167	7556	566	70	8.6	$ 501	$ 349	3.3
WINDOW CL35	300	$ 115	7204	351	60	10.1	$ 310	$ 199	2.8
FLOOR R25 STD	289	$ 183	6761	443	70	12.4	$ 392	$ 220	2.3
FLOOR R30 STD	284	$ 110	6541	220	70	15.1	$ 195	$ 90	1.9
WINDOW CL25	267	$ 345	5861	680	60	16.3	$ 601	$ 254	1.7
VAULT R38 SCI	266	$ 44	5812	49	70	28.1	$ 43	$ 0	1.0
FLOOR R38STD w/12”Truss	256	$ 494	5434	379	70	41.3	$ 335	$ (155)	0.7
ATTIC R49 ADVrh	246	$ 614	5014	420	70	46.5	$ 371	$ (240)	0.6
WALL R21A+R5	232	$ 954	4486	528	70	57.7	$ 466	$ (487)	0.5
VAULT 10” SS Panel	227	$ 650	4269	217	70	96.5	$ 191	$ (463)	0.3
ATTIC R60 ADVrh	224	$ 353	4160	109	70	103.9	$ 97	$ (259)	0.3
WINDOW CL20	215	$ 1,108	3843	317	60	118.4	$ 281	$ (896)	0.2
WALL 8” SSPANEL	204	$ 1,624	3433	409	70	127.9	$ 362	$ (1,277)	0.2
WALL R33DBL	203	$ 670	3388	45	70	481.5	$ 40	$ (640)	0.1

2,200 sq ft	Spokane - Zone 2								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	520	$ -	13847	0	70	0.0	$ -	$ -	N/A
WALL R21ADV	496	$ 289	12869	977	70	8.5	$ 864	$ 602	3.3
WINDOW CL35	479	$ 239	12142	727	60	10.2	$ 643	$ 411	2.8
FLOOR R25 STD	465	$ 234	11579	563	70	12.5	$ 497	$ 278	2.3
FLOOR R30 STD	458	$ 140	11300	280	70	15.3	$ 247	$ 114	1.9
WINDOW CL25	423	$ 717	9908	1392	60	16.6	$ 1,230	$ 509	1.7
VAULT R38 SCI	421	$ 74	9827	81	70	28.7	$ 72	$ (1)	1.0
FLOOR R38STD w/12”Truss	409	$ 632	9351	476	70	42.1	$ 421	$ (207)	0.7
ATTIC R49 ADVrh	400	$ 513	9004	346	70	47.1	$ 306	$ (204)	0.6
WALL R21A+R5	377	$ 1,645	8095	909	70	57.8	$ 804	$ (840)	0.5
VAULT 10” SS Panel	368	$ 1,098	7728	367	70	96.2	$ 324	$ (781)	0.3
ATTIC R60 ADVrh	365	$ 294	7637	91	70	103.9	$ 81	$ (216)	0.3
WINDOW CL20	348	$ 2,305	6977	660	60	118.5	$ 583	$ (1,863)	0.2
WALL 8” SSPANEL	328	$ 2,799	6269	708	70	127.4	$ 626	$ (2,199)	0.2
WALL R33DBL	326	$ 1,154	6191	78	70	480.6	$ 69	$ (1,103)	0.1

Table G-31 (Cont.)

New Single Family Space Heating Cost-Effectiveness

2,283 sq ft	Spokane - Zone 2								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	460	$ -	13154	0	70	0.0	$ -	$ -	0.0
BGWALL R22 FOAM BLOCK	457	$ (548)	13032	122	70	-179.8	$ 108	$ 795	-0.2
WALL R21ADV	437	$ 247	12165	868	70	8.2	$ 767	$ 544	3.4
WINDOW CL35	428	$ 131	11752	413	60	9.8	$ 365	$ 239	2.9
FLOOR R25 STD	427	$ 14	11716	36	70	11.9	$ 31	$ 18	2.4
FLOOR R30 STD	426	$ 8	11698	18	70	14.5	$ 16	$ 8	2.0
WINDOW CL25	407	$ 392	10890	808	60	15.5	$ 714	$ 321	1.8
SLAB R10-4FT	399	$ 320	10535	356	70	28.2	$ 314	$ 0	1.0
SLAB R10-FULL	382	$ 642	9826	709	70	28.4	$ 627	$ (3)	1.0
BGWALL R21	380	$ 76	9755	71	70	33.9	$ 63	$ (13)	0.8
FLOOR R38STD w/12”Truss	380	$ 38	9724	31	70	39.5	$ 27	$ (11)	0.7
ATTIC R49 ADVrh	367	$ 766	9172	552	70	44.0	$ 488	$ (273)	0.6
WALL R21A+R5	347	$ 1,409	8345	828	70	54.3	$ 731	$ (675)	0.5
ATTIC R60 ADVrh	343	$ 440	8197	147	70	95.9	$ 130	$ (313)	0.3
WINDOW CL20	333	$ 1,259	7804	393	60	108.5	$ 347	$ (988)	0.3
WALL 8” SSPANEL	317	$ 2,397	7139	665	70	116.0	$ 588	$ (1,829)	0.2
WALL R33DBL	315	$ 988	7065	74	70	435.0	$ 65	$ (938)	0.1

Table G-32

New Single Family Space Heating Cost-Effectiveness

1,344 sq ft	Missoula - Zone 3								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	322	0	9676	0	70	0	0	0	N/A
WALL R21ADV	308	$ 167	9020	656	70	7.2	$ 580	$ 432	3.9
WINDOW CL35	300	$ 115	8612	408	60	8.6	$ 360	$ 251	3.3
FLOOR R25 STD	289	$ 183	8099	513	70	10.5	$ 453	$ 284	2.7
FLOOR R30 STD	284	$ 110	7844	255	70	12.9	$ 225	$ 122	2.2
WINDOW CL25	267	$ 345	7056	788	60	13.9	$ 697	$ 353	2.0
VAULT R38 SCI	266	$ 44	7000	57	70	24.3	$ 50	$ 7	1.2
FLOOR R38STD w/12”Truss	256	$ 494	6563	436	70	35.7	$ 386	$ (102)	0.8
ATTIC R49 ADVrh	246	$ 614	6079	485	70	40.1	$ 428	$ (180)	0.7
WALL R21A+R5	232	$ 954	5466	613	70	49.6	$ 541	$ (409)	0.6
VAULT 10” SS Panel	227	$ 650	5213	253	70	82.4	$ 224	$ (429)	0.3
ATTIC R60 ADVrh	224	$ 353	5085	128	70	88.5	$ 113	$ (241)	0.3
WINDOW CL20	215	$ 1,108	4713	372	60	100.8	$ 329	$ (846)	0.3
WALL 8” SSPANEL	204	$ 1,624	4230	483	70	108.3	$ 427	$ (1,210)	0.3
WALL R33DBL	203	$ 670	4176	53	70	406.3	$ 47	$ (633)	0.1

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Table G-32 (Cont.)
New Single Family Space Heating Cost-Effectiveness

2,200 sq ft	Missoula - Zone 3								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	520	$ -	16489	0	70	0.0	$ -	$ -	N/A
WALL R21ADV	496	$ 289	15348	1141	70	7.2	$ 1,009	$ 753	3.9
WINDOW CL35	479	$ 239	14494	853	60	8.5	$ 754	$ 527	3.3
FLOOR R25 STD	465	$ 234	13829	665	70	10.4	$ 588	$ 372	2.7
FLOOR R30 STD	458	$ 140	13499	330	70	12.8	$ 292	$ 160	2.2
WINDOW CL25	423	$ 717	11844	1655	60	13.8	$ 1,463	$ 750	2.1
VAULT R38 SCI	421	$ 74	11747	97	70	23.9	$ 86	$ 13	1.2
FLOOR R38STD w/12”Truss	409	$ 632	11183	564	70	35.4	$ 499	$ (126)	0.8
ATTIC R49 ADVrh	400	$ 513	10774	408	70	39.8	$ 361	$ (147)	0.7
WALL R21A+R5	377	$ 1,645	9705	1069	70	49.0	$ 945	$ (694)	0.6
VAULT 10” SS Panel	368	$ 1,098	9273	432	70	81.5	$ 382	$ (721)	0.3
ATTIC R60 ADVrh	365	$ 294	9166	107	70	88.2	$ 95	$ (201)	0.3
WINDOW CL20	348	$ 2,305	8388	778	60	100.3	$ 688	$ (1,755)	0.3
WALL 8” SSPANEL	328	$ 2,799	7550	838	70	107.5	$ 741	$ (2,080)	0.3
WALL R33DBL	326	$ 1,154	7458	92	70	408.9	$ 81	$ (1,091)	0.1

2,283 sq ft	Missoula - Zone 3								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	460	$ -	15525	0	70	0.0	$ -	$ -	0.0
BGWALL R22 FOAM BLOCK	457	$ (548)	15387	139	70	-158.4	$ 123	$ 810	-0.2
WALL R21ADV	437	$ 247	14399	987	70	7.1	$ 873	$ 654	4.0
WINDOW CL35	428	$ 131	13927	472	60	8.4	$ 417	$ 293	3.4
FLOOR R25 STD	427	$ 14	13886	41	70	10.2	$ 36	$ 23	2.8
FLOOR R30 STD	426	$ 8	13866	20	70	12.4	$ 18	$ 10	2.3
WINDOW CL25	407	$ 392	12934	931	60	13.3	$ 823	$ 435	2.1
SLAB R10-4FT	399	$ 320	12525	409	70	24.3	$ 362	$ 50	1.2
SLAB R10-FULL	382	$ 642	11717	808	70	24.8	$ 714	$ 88	1.1
BGWALL R21	380	$ 76	11637	80	70	29.7	$ 71	$ (4)	0.9
FLOOR R38STD w/12”Truss	380	$ 38	11602	35	70	34.6	$ 31	$ (7)	0.8
ATTIC R49 ADVrh	367	$ 766	10975	627	70	38.6	$ 555	$ (204)	0.7
WALL R21A+R5	347	$ 1,409	10030	945	70	47.4	$ 835	$ (567)	0.6
ATTIC R60 ADVrh	343	$ 440	9860	169	70	83.4	$ 150	$ (292)	0.3
WINDOW CL20	333	$ 1,259	9408	452	60	94.2	$ 400	$ (934)	0.3
WALL 8” SSPANEL	317	$ 2,397	8641	768	70	100.5	$ 678	$ (1,736)	0.3
WALL R33DBL	315	$ 988	8556	85	70	379.0	$ 75	$ (928)	0.1

Table G-33
New Multifamily Space Heating Cost-Effectiveness

	Portland - Zone 1			12 units @ 1040 sq ft/dwelling unit					
Measure	**Building UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	2114	0	21418	0	70	0	$ -	$ -	N/A
BGWALL R22 FOAM BLOCK*	2111	$ (641)	21345	73	70	-445.6	$ 44	$ 751	-0.1
WALL R21INT	2044	$ 1,147	19645	1700	70	26.9	$ 1,025	$ 32	1.0
WINDOW CL35	1869	$ 3,443	15369	4276	60	33.1	$ 2,578	$ (498)	0.8
WINDOW CL25	1750	$ 2,442	12730	2639	60	38.2	$ 1,591	$ (600)	0.7
VAULT R38 SCI	1744	$ 201	12612	119	70	69.2	$ 72	$ (107)	0.4
WALL R21A+R5	1626	$ 4,358	10191	2420	70	73.4	$ 1,459	$ (2,407)	0.4
SLAB R10-4FT	1610	$ 631	9872	320	70	80.6	$ 193	$ (368)	0.3
SLAB R10-FULL	1577	$ 1,265	9247	624	70	82.8	$ 377	$ (748)	0.3
ATTIC R49 ADVrh	1553	$ 1,373	8804	443	70	127.1	$ 267	$ (958)	0.2
VAULT 10” SS Panel	1527	$ 2,970	8322	482	70	253.9	$ 291	$ (2,372)	0.1
ATTIC R60 ADVrh	1521	$ 789	8203	119	70	272.2	$ 72	$ (635)	0.1
WINDOW CL20	1460	$ 7,852	7122	1081	60	306.8	$ 652	$ (6,563)	0.1
WALL 8” SSPANEL	1410	$ 11,123	6261	860	70	533.9	$ 519	$ (9,473)	0.1
WALL R33DBL	1401	$ 4,587	6120	142	70	1339.6	$ 85	$ (4,040)	0.0

Table G-34
New Multifamily Space Heating Cost-Effectiveness

	Seattle - Zone 1			12 units @ 1040 sq ft/dwelling unit					
Measure	**Building UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	2114	0	25071	0	70	0	$ -	$ -	N/A
BGWALL R22 FOAM BLOCK*	2111	$ (641)	24989	82	70	-395.7	$ 50	$ 757	-0.1
WALL R21INT	2044	$ 1,147	23092	1896	70	24.0	$ 1,143	$ 155	1.2
WINDOW CL35	1869	$ 3,443	18311	4782	60	29.5	$ 2,883	$ (181)	0.9
WINDOW CL25	1750	$ 2,442	15180	3130	60	32.0	$ 1,887	$ (292)	0.9
VAULT R38 SCI	1744	$ 201	15039	141	70	57.9	$ 85	$ (93)	0.5
WALL R21A+R5	1626	$ 4,358	12096	2943	70	60.2	$ 1,775	$ (2,080)	0.5
SLAB R10-4FT	1610	$ 631	11702	394	70	65.2	$ 237	$ (321)	0.4
SLAB R10-FULL	1577	$ 1,265	10925	777	70	66.3	$ 468	$ (652)	0.4
ATTIC R49 ADVrh	1553	$ 1,373	10383	542	70	103.8	$ 327	$ (897)	0.3
VAULT 10” SS Panel	1527	$ 2,970	9801	582	70	210.1	$ 351	$ (2,309)	0.1
ATTIC R60 ADVrh	1521	$ 789	9657	144	70	226.2	$ 87	$ (620)	0.1
WINDOW CL20	1460	$ 7,852	8365	1292	60	256.5	$ 779	$ (6,431)	0.1
WALL 8” SSPANEL	1410	$ 11,123	7322	1043	70	440.0	$ 629	$ (9,358)	0.1
WALL R33DBL	1401	$ 4,587	7153	168	70	1125.6	$ 102	$ (4,023)	0.0

Table G-35
New Multifamily Space Heating Cost-Effectiveness

	Spokane - Zone 2			12 units @ 1040 sq ft/dwelling unit					
Measure	**Building UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	2114	0	43534	0	70	0	$ -	$ -	N/A
BGWALL R22 FOAM BLOCK*	2111	$ (641)	43420	114	70	-284.8	$ 69	$ 778	-0.1
WALL R21INT	2044	$ 1,147	40736	2684	70	16.6	$ 1,618	$ 648	1.7
WINDOW CL35	1869	$ 3,443	33857	6879	60	20.2	$ 4,148	$ 1,131	1.4
WINDOW CL25	1750	$ 2,442	29353	4504	60	21.9	$ 2,716	$ 568	1.3
VAULT R38 SCI	1744	$ 201	29146	207	70	39.3	$ 125	$ (52)	0.7
WALL R21A+R5	1626	$ 4,358	24836	4311	70	40.8	$ 2,599	$ (1,224)	0.7
SLAB R10-4FT	1610	$ 631	24248	588	70	43.3	$ 354	$ (200)	0.6
SLAB R10-FULL	1577	$ 1,265	23085	1163	70	44.0	$ 701	$ (411)	0.6
ATTIC R49 ADVrh	1553	$ 1,373	22277	808	70	69.2	$ 487	$ (730)	0.4
VAULT 10” SS Panel	1527	$ 2,970	21408	869	70	140.3	$ 524	$ (2,129)	0.2
ATTIC R60 ADVrh	1521	$ 789	21195	214	70	151.8	$ 129	$ (576)	0.2
WINDOW CL20	1460	$ 7,852	19229	1965	60	168.3	$ 1,185	$ (6,010)	0.2
WALL 8” SSPANEL	1410	$ 11,123	17604	1625	70	282.1	$ 980	$ (8,994)	0.1
WALL R33DBL	1401	$ 4,587	17337	268	70	707.7	$ 161	$ (3,961)	0.0

Table G-36
New Multifamily Space Heating Cost-Effectiveness

	Missoula - Zone 3			12 units @ 1040 sq ft/dwelling unit					
Measure	**Building UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	2114	0	53051	0	70	0	$ -	$ -	N/A
BGWALL R22 FOAM BLOCK*	2111	$ (641)	52919	132	70	-246.0	$ 80	$ 789	-0.1
WALL R21INT	2044	$ 1,147	49828	3091	70	14.3	$ 1,864	$ 903	1.9
WINDOW CL35	1869	$ 3,443	41882	7946	60	17.3	$ 4,791	$ 1,799	1.6
WINDOW CL25	1750	$ 2,442	36615	5267	60	18.6	$ 3,176	$ 1,045	1.5
VAULT R38 SCI	1744	$ 201	36373	242	70	33.3	$ 146	$ (30)	0.8
WALL R21A+R5	1626	$ 4,358	31261	5112	70	34.2	$ 3,082	$ (722)	0.8
SLAB R10-4FT	1610	$ 631	30548	713	70	35.6	$ 430	$ (122)	0.8
SLAB R10-FULL	1577	$ 1,265	29128	1421	70	35.8	$ 857	$ (249)	0.8
ATTIC R49 ADVrh	1553	$ 1,373	28120	1007	70	55.3	$ 607	$ (605)	0.5
VAULT 10” SS Panel	1527	$ 2,970	27025	1095	70	111.2	$ 660	$ (1,988)	0.2
ATTIC R60 ADVrh	1521	$ 789	26754	271	70	119.2	$ 164	$ (540)	0.2
WINDOW CL20	1460	$ 7,852	24247	2507	60	131.7	$ 1,511	$ (5,671)	0.2
WALL 8” SSPANEL	1410	$ 11,123	22170	2077	70	220.5	$ 1,252	$ (8,711)	0.1
WALL R33DBL	1401	$ 4,587	21826	344	70	550.7	$ 207	$ (3,913)	0.1

Table G-37

New Manufactured Home Space Heating Cost-Effectiveness

924 sq ft	Portland -Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	252	$ -	3836	0	45	0	0	0	N/A
FLOOR R33	241	$ 140	3481	355	45	16.8	$ 194	$ 75	1.6
ATTIC R25	238	$ 43	3380	101	45	18.3	$ 55	$ 18	1.5
VAULT R25	234	$ 57	3248	132	45	18.4	$ 72	$ 24	1.5
ATTIC R30	232	$ 35	3184	63	45	23.8	$ 34	$ 5	1.2
VAULT R30	229	$ 45	3103	82	45	24.1	$ 45	$ 6	1.1
WINDOW CL35	213	$ 336	2609	494	45	29.9	$ 269	$ (23)	0.9
WALL R21 ADV	206	$ 156	2423	186	45	36.9	$ 101	$ (35)	0.7
ATTIC R38	204	$ 52	2364	59	45	39.1	$ 32	$ (13)	0.7
VAULT R38	203	$ 68	2318	46	45	65.9	$ 25	$ (35)	0.4
ATTIC R49	201	$ 78	2271	47	45	74.3	$ 26	$ (43)	0.4
FLOOR R44	199	$ 140	2218	54	45	116.6	$ 29	$ (95)	0.2

1,568 sq ft	Portland -Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	380	$ -	9597	0	45	0	0	0	N/A
FLOOR R33	361	$ 237	8798	799	45	12.4	$ 436	$ 239	2.2
ATTIC R25	354	$ 98	8493	305	45	13.5	$ 166	$ 85	2.0
VAULT R25	349	$ 71	8272	221	45	13.6	$ 121	$ 61	2.0
ATTIC R30	344	$ 78	8082	189	45	17.8	$ 75	$ 27	1.5
VAULT R30	341	$ 57	7945	137	45	17.8	$ 103	$ 36	1.5
WINDOW CL35	313	$ 568	6824	1121	45	22.0	$ 612	$ 123	1.3
WALL R21 ADV	307	$ 152	6576	248	45	26.9	$ 135	$ 3	1.0
ATTIC R38	303	$ 118	6394	182	45	28.3	$ 99	$ (3)	1.0
VAULT R38	301	$ 86	6314	79	45	47.9	$ 43	$ (32)	0.6
ATTIC R49	297	$ 177	6170	145	45	54.3	$ 79	$ (77)	0.5
FLOOR R44	294	$ 237	6045	125	45	85.2	$ 68	$ (143)	0.3

Table G-38

New Manufactured Home Space Heating Cost-Effectiveness

924 sq ft	Seattle - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	252	$ -	4414	0	45	0	0	0	N/A
FLOOR R33	241	$ 140	4014	400	45	14.8	$ 218	$ 101	1.9
ATTIC R25	238	$ 43	3900	114	45	16.2	$ 62	$ 25	1.7

VAULT R25	234	$ 57	3752	148	45	16.3	$ 81	$ 33	1.7
ATTIC R30	232	$ 35	3682	71	45	21.2	$ 39	$ 9	1.3
VAULT R30	229	$ 45	3590	92	45	21.3	$ 50	$ 11	1.3
WINDOW CL35	213	$ 336	3030	559	45	26.2	$ 305	$ 14	1.0
WALL R21 ADV	206	$ 156	2818	213	45	32.1	$ 116	$ (20)	0.9
ATTIC R38	204	$ 52	2750	67	45	33.9	$ 37	$ (9)	0.8
VAULT R38	203	$ 68	2698	53	45	57.3	$ 29	$ (31)	0.5
ATTIC R49	201	$ 78	2644	54	45	64.6	$ 29	$ (40)	0.4
FLOOR R44	199	$ 140	2582	62	45	101.4	$ 34	$ (91)	0.3

Table G-38 (Cont.)

New Manufactured Home Space Heating Cost-Effectiveness

1,568 sq ft	Seattle - Zone 1								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	380	$ -	9597	0	45	0	0	0	N/A
FLOOR R33	361	$ 237	8798	799	45	12.4	$ 436	$ 239	2.2
ATTIC R25	354	$ 98	8493	305	45	13.5	$ 166	$ 85	2.0
VAULT R25	349	$ 71	8272	221	45	13.6	$ 121	$ 61	2.0
ATTIC R30	344	$ 78	8082	189	45	17.8	$ 75	$ 27	1.5
VAULT R30	341	$ 57	7945	137	45	17.8	$ 103	$ 36	1.5
WINDOW CL35	313	$ 568	6824	1121	45	22.0	$ 612	$ 123	1.3
WALL R21 ADV	307	$ 152	6576	248	45	26.9	$ 135	$ 3	1.0
ATTIC R38	303	$ 118	6394	182	45	28.3	$ 99	$ (3)	1.0
VAULT R38	301	$ 86	6314	79	45	47.9	$ 43	$ (32)	0.6
ATTIC R49	297	$ 177	6170	145	45	54.3	$ 79	$ (77)	0.5
FLOOR R44	294	$ 237	6045	125	45	85.2	$ 68	$ (143)	0.3

Table G-39

New Manufactured Home Space Heating Cost-Effectiveness

924 sq ft	Spokane - Zone 2								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	252	$ -	7228	0	45	0	0	0	N/A
FLOOR R33	241	$ 140	6682	546	45	10.6	$ 298	$ 183	2.6
ATTIC R25	238	$ 43	6526	156	45	11.5	$ 85	$ 50	2.4
VAULT R25	234	$ 57	6321	204	45	11.5	$ 111	$ 65	2.4
ATTIC R30	232	$ 35	6224	97	45	15.0	$ 53	$ 24	1.8
VAULT R30	229	$ 45	6097	127	45	15.1	$ 69	$ 31	1.8
WINDOW CL35	213	$ 336	5316	781	45	18.5	$ 426	$ 139	1.5
WALL R21 ADV	206	$ 156	5016	300	45	22.5	$ 164	$ 30	1.2
ATTIC R38	204	$ 52	4921	95	45	23.7	$ 52	$ 7	1.2
VAULT R38	203	$ 68	4846	75	45	40.2	$ 41	$ (19)	0.7
ATTIC R49	201	$ 78	4770	76	45	45.4	$ 41	$ (27)	0.6
FLOOR R44	199	$ 140	4682	87	45	71.5	$ 48	$ (76)	0.4

1,568 sq ft	Spokane - Zone 2								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	380	$ -	9597	0	45	0	0	0	N/A
FLOOR R33	361	$ 237	8798	799	45	12.4	$ 436	$ 239	2.2
ATTIC R25	354	$ 98	8493	305	45	13.5	$ 166	$ 85	2.0

VAULT R25	349	$ 71	8272	221	45	13.6	$ 121	$ 61	2.0
ATTIC R30	344	$ 78	8082	189	45	17.8	$ 75	$ 27	1.5
VAULT R30	341	$ 57	7945	137	45	17.8	$ 103	$ 36	1.5
WINDOW CL35	313	$ 568	6824	1121	45	22.0	$ 612	$ 123	1.3
WALL R21 ADV	307	$ 152	6576	248	45	26.9	$ 135	$ 3	1.0
ATTIC R38	303	$ 118	6394	182	45	28.3	$ 99	$ (3)	1.0
VAULT R38	301	$ 86	6314	79	45	47.9	$ 43	$ (32)	0.6
ATTIC R49	297	$ 177	6170	145	45	54.3	$ 79	$ (77)	0.5
FLOOR R44	294	$ 237	6045	125	45	85.2	$ 68	$ (143)	0.3

Table G-40
New Manufactured Home Space Heating Cost-Effectiveness

924 sq ft	Missoula - Zone 3								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	252	$ -	8614	0	45	0	0	0	N/A
FLOOR R33	241	$ 140	7981	633	45	9.0	$ 345	$ 233	3.1
ATTIC R25	238	$ 43	7799	181	45	9.8	$ 99	$ 64	2.8
VAULT R25	234	$ 57	7563	237	45	9.8	$ 129	$ 83	2.8
ATTIC R30	232	$ 35	7450	113	45	12.8	$ 62	$ 33	2.1
VAULT R30	229	$ 45	7302	147	45	12.9	$ 80	$ 43	2.1
WINDOW CL35	213	$ 336	6401	901	45	15.9	$ 492	$ 208	1.7
WALL R21 ADV	206	$ 156	6057	344	45	19.5	$ 187	$ 55	1.4
ATTIC R38	204	$ 52	5949	108	45	20.6	$ 59	$ 15	1.3
VAULT R38	203	$ 68	5864	85	45	35.1	$ 46	$ (13)	0.8
ATTIC R49	201	$ 78	5777	87	45	39.6	$ 47	$ (21)	0.7
FLOOR R44	199	$ 140	5677	100	45	62.4	$ 54	$ (69)	0.4

1,568 sq ft	Missoula - Zone 3								
Measure	**UA**	**Installed Cost (1995$)**	**Annual Use (kWh)**	**Annual Savings (kWh)**	**Physical Life (yrs)**	**Levelized Cost (mills / kWh)**	**PV Benefits (1995$)**	**Net Benefits**	**B/C Ratio**
Base	380	$ -	9597	0	45	0	0	0	N/A
FLOOR R33	361	$ 237	8798	799	45	12.4	$ 436	$ 239	2.2
ATTIC R25	354	$ 98	8493	305	45	13.5	$ 166	$ 85	2.0
VAULT R25	349	$ 71	8272	221	45	13.6	$ 121	$ 61	2.0
ATTIC R30	344	$ 78	8082	189	45	17.8	$ 75	$ 27	1.5
VAULT R30	341	$ 57	7945	137	45	17.8	$ 103	$ 36	1.5
WINDOW CL35	313	$ 568	6824	1121	45	22.0	$ 612	$ 123	1.3
WALL R21 ADV	307	$ 152	6576	248	45	26.9	$ 135	$ 3	1.0
ATTIC R38	303	$ 118	6394	182	45	28.3	$ 99	$ (3)	1.0
VAULT R38	301	$ 86	6314	79	45	47.9	$ 43	$ (32)	0.6
ATTIC R49	297	$ 177	6170	145	45	54.3	$ 79	$ (77)	0.5
FLOOR R44	294	$ 237	6045	125	45	85.2	$ 68	$ (143)	0.3

Step 4. Estimate the Regional Conservation Potential Available from Space Heating Conservation in New Dwellings

The next step in the Council's development of a regional supply curve for space heating conservation potential requires combining the engineering estimates of individual house savings by climate zone to establish a regional total. Because each measure saves a different amount of energy in each house design and

in each location, an aggregate supply curve must be developed that represents the weighted average savings for all measures in comparable dwelling types.

Each of the three single-family dwelling designs was assigned a weight based on its foundation type, size and window area. The specific weight assigned to each design approximately reflects that design's share of the new housing stock additions expected over the forecast period. This was also done for the two manufactured housing designs. Building type weighting was unnecessary for multifamily space heating, because only one multifamily design was used. It should be noted that the Council's forecasting model defines all units up to and including four-plexes as "single-family dwellings.'' Consequently, the weights selected are designed more to achieve an average size for new single-family houses (i.e., 1,700 square feet of floor area) than if they been selected on the basis of the more conventional definition of a single-family home (one- and two-family dwellings).

Once each building design's weight was established, the average savings by climate type were calculated for all designs. These savings then were aggregated to the regional level based on the share of new electrically heated dwellings expected to be constructed in each climate over the forecast period. Table G-41 shows the weight assigned each building design and climate type.

Table G-41
Climate Zone and Prototype Weights

Single Family				
Prototype Size Weights			**Climate Weights**	
1344	60%		Portland	19%
2200	25%		Seattle	68%
2283	15%		Spokane	10%
Average = 1700 square feet			Missoula	3%
Multifamily				
Prototype Size Weights			**Climate Weights**	
12492	100%		Portland	20%
Average = 1040 square feet/unit			Seattle	75%
			Spokane	3%
			Missoula	2%
Manufactured Housing				
Prototype Size Weights			**Climate Weights**	
924	16%		Portland	20%
1568	84%		Seattle	40%
Average = 1465 square feet			Spokane	36%
			Missoula	4%

Step 5. Estimate the Realizable Conservation Potential from New Residential Space Heating Efficiency Improvements

In order to establish the proportion of technically available space heating conservation that realistically can be achieved, the engineering savings estimates must be calibrated to the Council's forecasting model. This is accomplished by adjusting the conservation resource estimates based on engineering models of space

heating energy use and savings to the forecasting model's estimates. This ensures that current and projected consumer behavioral responses to electricity prices are accounted for in the Council's savings estimates. The forecast model's estimates shown here assume higher consumer amenity levels in the year 2015 than are present today. This is consistent with the Council's forecast, which projects that consumers will increase their amenity levels by the year 2015. Table G-42 compares the average space heating energy use by dwelling type for houses built to 1995 practice, as estimated by the Council's forecasting model for the year 2015 in the medium forecast and the engineering estimate. The engineering estimates and the forecasting model estimates of space heating use in new homes agree reasonably well.

Table G-42

Engineering Estimate versus Forecasting Model Estimates for Space Heating Use and Savings

	Forecast Model	Engineering Model	Difference
Housing Type	(kWh/Year)	(kWh/Year)	(kWh/yr)
Single Family-Current Practice	7228	7140	
Single Family-All Cost-effective	5158	5095	
Savings	2070	2045	25
Multifamily-Current Practice	2150	2121	
Multifamily-All Cost-effective	1983	1956	
Savings	168	166	2
Manufactured Housing-Current Practice	8990	8938	
Manufactured Housing-All Cost-effective	6184	6148	
Savings	2806	2790	16

The Council's engineering estimates of space heating energy use in new dwellings and the forecasting model contain similar underlying assumptions regarding appliance efficiency and family size. In order to match current (1995) consumption, the forecasting model must use current (1995) appliance efficiencies. However, because the Council anticipates further efficiency improvements in appliance energy use within the next five to 10 years, the Council's engineering and forecast model estimates of space heating use in 2015 assumes the presence of more efficient appliances. The forecasting model's estimate of current space heating use shown in Table G-42 reflect appliance efficiency levels expected to be present in 2015, and therefore are higher than actual space heating use today.

Because waste heat offsets the need for space heating, more efficient appliances mean larger space heating energy requirements. Had the Council assumed less efficient appliances in its engineering and forecasting model estimates, the regional average space heating energy used in new single-family houses built in 2015 would fall about 1.0 kilowatt-hours per square foot. Thus, failure to recognize the installation of efficient appliances in this same house by the year 2010 would result in an underestimate of space heating energy needs by 1,600 kilowatt-hours per year in the average single-family house.[29]

[29] Due to the decreased need for space heating in houses built with all regionally cost-effective space heat conservation measures, increases in appliance efficiency would result in a smaller increase in space heating needs. This is estimated to be just over 1,100 kilowatt-hours per year.

Table G-43 shows the technical achievable conservation potential in the Council's medium forecast from improvements in space heating efficiency in new single-family and multifamily dwellings and manufactured houses from a 1995 code/construction practice at levelized costs up to 6.0 cents per kilowatt-hour. Achievable potential is assumed to be 85 percent.

Table G-43
New Residential Space Heating Supply Curve

	Single Family	Multifamily	Manufactured Housing	Total	Total
Resource Costs (Cents/kWh)	**Technical Potential (AMW)**	**Technical Potential (AMW)**	**Technical Potential (AMW)**	**Technical Potential (AMW)**	**Achievable Potential**
0	0	0	0	0	0
1.0	1	0	0	1	1
2.0	35	0	50	85	70
3.0	75	10	100	185	155
4.0	120	40	115	275	235
5.0	120	40	115	280	240
6.0	130	40	120	285	240

WATER HEATING

The following sections describe the costs and savings of measures affecting the efficiency of domestic hot water heating (water heating systems) and the end-use (clothes washing, dish washing, and showerheads) that use hot water.

Electric Water Heaters

This section describes the energy use and savings potential from electric water heaters. All appliances that consume or use hot water are described next, with a summary of all water heating measures following in the summary section.

Base Use of Electric Water Heaters

The amount of energy consumed for water heating depends on two factors: standby losses and variable use. Standby losses refer to the energy that is used during storage to keep the water hot. They are determined by the temperature of the water relative to the air temperature surrounding the tank, and the insulation levels of the hot water storage tank and supply piping as well as the temperature of cold water that enters the tank. Variable use is the amount of hot water actually used in the household. Variable use differs substantially among households, depending on the habits and number of occupants, and the stock of appliances that use hot water (such as clothes washers and dish washers).

Temperature Assumptions

Table G-43 indicates the values used to determine key water and air temperatures that determine hot water energy consumption. They are compared to temperatures used by the U.S. Department of Energy (DOE) in testing the efficiency of water heater tanks.

- Inlet temperature is taken from Seattle water data and represents an eight-year average.

- The set point for new tanks has been lowered relative to prior plan assumptions due to the fact that manufacturers must now deliver tanks with the temperature set at 120 degrees Fahrenheit. The 120° set point was raised by the judgment that some plumbers will install the tanks and set the temperature higher to avoid call-backs.
- The weighted ambient temperature assumes about 50 percent of the tanks are located at a 66 degree inside temperature, and 50 percent are at a 55-degree "untempered" (garage, unheated basement, etc) ambient temperature. Inside values are for heated spaces, including heated basements as estimated by Portland Energy Conservation, Inc.[30] using data from the End-Use Load and Conservation Assessment Project. Outdoor ambient temperatures are weighted at 30 percent indoor (66 degrees) and 70 percent outdoor (50 degrees) temperature to represent the fact that most of the tanks would be in somewhat tempered (although technically "unheated") spaces, such as garages.

The temperature differences from the regionally based estimates are virtually identical to the temperature differences used by DOE, and as a result, the temperature differences used by DOE were adopted for this analysis.

Table G-43

Set point, Inlet and Ambient Temperatures for Electric Water Heaters

(in Degrees Fahrenheit)

	Regionally-Derived	**U.S. DOE**
Inlet Temperature	49	58
Set Point for New Tanks	126	135
Weighted Ambient Air Temperature	60	67.5
Temperature Difference:		
Inlet to Set Point	77	77
Set Point to Ambient Air	66	67.5

Base Case Standby Losses

Standby Losses were estimated from a frozen efficiency base case with an energy factor[31] of 0.86[32] for the standard 52-gallon electric water heater. This is the level of federal standards that have been in place since 1990. If a base case were used that reflected the current energy factor for all water heaters sold in the market, the base would be closer to 0.87 or 0.88, as indicated from Washington State Energy Office[33] work done in 1990. The base at the federal standards was selected because it was consistent with the assumptions in the load forecast; however, this will be revised between the draft and final. If the more efficient base were used, it would lower the forecast and the savings estimated in this chapter by about 50 kWh per water heater or about 20 achievable average megawatts in the medium forecast.

[30] Portland Energy Conservation, Inc, "Evaluation of the Efficient Water Heater Program", for Bonneville Power Administration, July 15, 1994.

[31] An energy factor, or EF, is used by DOE to rate the energy use of an electric water heater. It is the daily load (4,391 kilowatt-hours per year) divided by the average daily consumption.

[32] Note that the testing procedure for water heater tanks changed in about 1988. The new test meant that water heaters tested about 0.02 EF points lower than they would in the previous test. As a result, a 0.88 EF water heater performed at a 0.86 EF with the new test. All references in this document refer to a water heater under the new testing procedure.

[33] Mark Hamilton and Shelley Rudeen, Washington State Energy Office, "The Market for Water Heater Insulation Kits in the Northwest," for Bonneville Power Administration, February, 1991. See also, Lois Gordon, Grian Lagerberg, Charles Murray and Shelley Rudeen, Washington State Energy Office, "Water Heater Market Analysis," for Bonneville Power Administration, June 1991.

More Efficient Tanks

Standby losses for a 0.86 tank with the temperature differences shown in table 1, are about 700 kilowatt-hours per year. Savings from this base line are estimated to be about 50 kilowatt-hours for each 0.01 change in energy factor based on analysis done by U.S. Department of Energy in support of the 1990 standard. Utility programs have historically operated efficient tank programs that use 0.93 tanks. In addition, it is possible that U.S. Department of Energy will adopt 0.93 tanks in its new round of standards for electric water heaters. A 0.93 energy factor was used to represent the savings available from making water heater tanks more efficient. At 50 kilowatt-hours per 0.01 change in energy factor, the overall savings per tank is 350 kilowatt-hours, before the interaction of the savings with space heating are taken into account. (See section in this chapter on "interaction with space heating").

Costs for tanks were taken from the U.S Department on Energy work on evaluating more efficient water heaters in an effort to look at strengthened appliance efficiency standards. Department of Energy found that the cost for a 0.93 water heater was an extra $42 in 1990 dollars compared to a 0.86 tank. $50 was used after escalation to 1995 dollars.

The lifetime of electric water heaters is expected to average 12 years.

Base Case Hot Water Demand

Prior work on the question of how much hot water is consumed each day, discussed in volume 2 of the 1991 Plan, indicates that a linear relationship of consumption and persons per household results in consumption of about 19 gallons per person per day. With 2.6 persons per household, this results in about 49 gallons per household per day. U.S. DOE uses 64.4 gallons per household per day for a four-person household, or 16 gallons per person per day. Pratt,[34]analyzing ELCAP data, found that the relationship of hot water use to number of occupants was not linear. He found that the second adult in a household consumes much less than the first adult, and that children under 6 and adults over 65 also consume less. However, using his equation, and an average household size of 2.6 persons, resulted in approximately 17 gallons per person per day. A study of heat pump water heaters in single family houses indicated about 20 gallons per person per day. After discussion with the conservation resources advisory committee, it was decided to use 19 gallons per person per day. Using the temperature differences cited above, this results in a total kilowatt-hour consumption for demand in the base case of almost 3,100 kilowatt-hours.[35] This base case demand has not accounted for very high penetration of energy efficient showerheads or other significant conservation measures.

If this is added to the 700 kilowatt-hours estimated for standby use, total base case use for the average electric water heater is approximately 3800 kilowatt-hours per year.

Bottom Boards

Savings from installing rigid insulation under new water heaters at the time they are installed were estimated from Pratt[36], using ELCAP data. These results, about 70 kilowatt-hours, confirmed prior laboratory work done at Bonneville Power Administration. Because many new water heaters are expected to be located in semi-tempered spaces, savings from the bottom boards are estimated at approximately 60 kilowatt-hours per water heater. If the savings are reduced to account for the interaction with space heating (described elsewhere), the savings are about 50 kilowatt-hours.

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[34]R.G. Pratt and B.A. Ross, "Measured Electric Hot Water Standby and Demand Loads from Pacific Northwest Homes", Pacific Northwest Laboratories for Bonneville Power Administration and the Northwest Power Planning Council, November, 1991, PNL-7889/UC-350.

[35]While 2.6 persons per household is the correct number for the mid-1990s, 2.4 persons per household is the expected occupancy for the year 2015. The values in this chapter are based on 2.4 persons per household.

[36]ibid.

Costs were estimated to be $12, if done at the time of new water heater installation. The lifetime is also expected to be the life of the water heater or 12 years.

Wraps on Efficient Tanks (EF=~0.93)

Bonneville's laboratory study of efficient tanks also tried to ascertain the savings from wrapping efficient tanks. This study indicated savings of about 96 kilowatt-hours per year for completely wrapping a 0.93 tank. We estimated savings from wrapping new electric water heaters in new houses only, so it would be possible to locate them with sufficient space to wrap the entire heater. These savings are estimated to be 95 kilowatt-hours per year, which was reduced to 79 kilowatt-hours per year if the interaction with space heating (described later) is taken into account.

Costs were estimated to be about $20 for the insulation and $10 in labor, or a total of $30. The cost for the wrap was taken from a Washington State Energy Office report done for Bonneville [37], which indicated a cost: $15 in 1990 dollars. This was escalated to 1995 dollars and then rounded up to $20. Labor was estimated to be fairly small because a plumber would be installing the water heater anyway at the time of construction.

The average lifetime is expected to be the length of the water heater or 12 years.

Efficient Clothes Washers

Federal standards for this appliance currently require an energy factor (EF) of 1.18 cubic feet per kilowatt per cycle. The higher the number, the more efficient the appliance. Standards were expected to be updated in 1996 but have been delayed by Congress. The most promising way to conserve electricity and water in clothes washers is to change the configuration of the appliance from the traditional "vertical axis" to a "horizontal axis" design. The horizontal axis design uses much less water since the clothes are cycled through a partially filled drum, rather an entirely filled drum. Since hot water use accounts for most of the use of the washing machine, cutting that use can result in dramatic savings. In addition, new designs of washing machines have the potential to remove more moisture from the clothes by increasing the spin speed. This is a much more efficient way to remove moisture from the clothes than using warm air in the dryer. As a result, dryer savings would result from the higher moisture extraction.

Savings for this appliance were estimated by assuming that horizontal axis machines could increase the EF from the base of 1.18 to 3.25. This is the level advocated by joint comments of key laundry machine manufacturers and environmental groups to the U.S. Department of Energy for consideration of the next level of standards. This level includes high speed spin to remove more moisture at the time the clothes are in the washing machine, so savings also accrue from the dryer. Savings are based on DOE test procedures, [38] which include estimates of the weighted average water temperature used for clothes washing, and the number of washing cycles per year in a typical household. Prior information from surveys in the Northwest indicate fewer washing cycles than the national average (300 compared to 380 cycles per year), and so savings were scaled downward to reflect the regional survey information.

Table G-44 indicates the baseline use and savings for washers with electric water heating and electric dryers. This table is taken from work done by Seattle City Light.[39] Use and savings have been scaled for fewer cycles per year in the Northwest than the national average. Savings are expected to be about 500

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[37] Mark Hamilton and Shelley Rudeen, Washington State Energy Office, "The Market for Water Heater Insulation Kits in the Northwest," for Bonneville Power Administration, February 1991.

[38] During the development of these plan estimates, the Department of Energy changed the test procedure for clothes washers. The effect of this will be to reduce savings from the 500 kilowatts here to about 480 kilowatts. We were unable to incorporate this change in the current draft.

[39] Since the development of these numbers, the Constorium for Energy Efficiency has developed numbers based on information collected for U.S. Department of Energy by the Association of Home Appliance Manufacturers and LBL. These newer numbers will be incorporated into the final plan, but do not change the conclusion that these efficiency improvements are cost-effective.

kilowatt-hours. Currently, only imported washers meet an EF of about 3.2. However, key U.S. manufacturers are expected to come out in mid-1996 with a washer that exceeds an EF of 3, and are likely to be 3.25. In addition, this is the level that manufacturers and environmental groups advocated for the next level of national standard. Finally, the Consortium for Energy Efficiency is working with utilities, including some from the Northwest, to encourage the production of laundry equipment that meets a level similar to this standard. For these reasons, it was selected as the efficiency level to target.

Table G-44

Water and Electricity Savings from Horizontal Axis Clotheswashers

Efficiency Factor	Water Used (gallons per year)	Cumulative Water Saved (gallons per year)	Washer Use (kWh/yr.)	Dryer Use (kWh/yr.)	kWh Use per year	Cumulative kWh savings per year
Baseline:EF=1.18	11,251	0	532	658	1,190	0
EF=2.5	8,580	2671	250	658	908	282
Higher moisture removal EF=2.5	8,580	2671	250	493	743	447
EF=3.25	7,020	4231	193	493	686	504
Higher moisture removal EF=3.25	7,020	4231	193	411	604	586

Costs are estimated from the Association of Home Appliance Manufacturers, which indicate that if produced in large quantities, the machine with an Energy Factor of 3.25 will have an incremental cost of approximately $175.[40]

In addition, horizontal axis clotheswashers have significant non-energy benefits in the form of reduced water use. Most water charges in cities include some charge for the volume of water used and/or put through the sewer system. Table G-45 lists the water and sewer charges for Portland, Seattle and Spokane. The clothes washers are expected to save about 4,000 gallons of water per year. Also shown in Table G-45 are the dollar savings from reducing consumption and sewage treatment by 4,000 gallons per year. The average for these three cities is $13 per year. These were yearly non-energy cost savings that were included in the average levelized cost of the clotheswashers. It should be noted that the non-energy benefits for this product are quite large, and it offers the chance to collaborate with non-electric utility and other parties to try and secure savings for all benefiting parties.

[40] Personal communication with Ted Pope, Seattle City Light, November 15, 1995. Since the estimates for this Plan were done, DOE has developed consensus estimates of costs and savings for making clothes washers efficient. These revised numbers would indicate costs of about $210, for savings of about 630 kWh. These new numbers would not have changed the conclusion that clothes washers are cost-effective. (From: Proposed Rulemaking Regarding Energy Conservation Standards for Three Cleaning Products, Docket # EE-RM-94-403, Comment #40 from Peter Biermeyer, Lawrence Berkeley Laboratories. Conveyed by Marc LaFrance, U.S. DOE, (202) 586-8423.)

Table G-45
Yearly Savings from Reduction in Water Use Due to Horizontal Axis Clothes washers

	Water Use Charge	Sewer Charge	Yearly $ Savings (for 4,000 gallon reduction)
Portland	$1.10 per 1,000 gallons	$2.30 per gallon	$13.60
Seattle	$5.92 per 1,000 gallons (water and sewer combined)		$23.68
Spokane	$0.67 per 1,000 gallons (water and sewer combined)		$ 2.68
Average			$13.32

Efficient Clothes Dryers

The 1991 Power Plan found microwave clothes dryers marginally cost-effective and heat pump clothes dryers not cost-effective. There is no new information on which to base updated estimates. In addition, savings from these appliances will be reduced if the clothes washer has a greater ability to remove moisture during the spin cycle, as envisioned in the prior savings estimate for clothes washers. As a result, these appliances are not considered cost-effective in this plan.

Efficient Dishwashers

Federal appliance standards for this appliance currently require standard dishwashers to meet an Energy Factor of 0.46. This factor is expressed in terms of kilowatt-hours per cycle. The higher the energy factor, the more efficient the dishwasher. Data from E-Source[41] indicates that a number of dishwashers are available that exceed the current federal standard by 10 to 30 percent. Many of these are manufactured by U.S. manufacturers. In addition, information from the technical documentation that set the standards level show further savings were available at a cost of about $11.50.[42] A value of $25 was used as the cost of improving the efficiency level by 10 percent in this draft plan, and the savings were not found cost-effective. However, correcting this value to $11.50 brings the cost of this efficiency improvement below the cost-effectiveness threshold. This would mean an additional 10 average megawatts would be available in the medium forecast. Unless further information becomes available between the draft and final plan, the $11.50 number will be used

Efficient Showerheads

In the 1991 Power Plan, very little research had been done on the base use of the current stock of showerheads. Since 1991, multiple studies have been completed that evaluated both the efficiency of the current stock of showerheads, but also the performance of energy-efficient showerheads. In addition, a large number of showerheads have been retrofit into various houses due to utility programs. Most showerheads in the regional program have performed at 2.5 gallons per minute or better. Effective in 1994 the federal government adopted a showerhead standard of 2.5 gallons per minute as the maximum usage for this appliance. As a result, as new showerheads are installed in new and existing houses, very efficient 2.5 gallon per minute showerheads will slowly infiltrate the market. After discussion with the Conservation Resources Advisory Committee, it was decided that further savings from showerheads beyond this level were not likely to be acceptable to consumers, and they are not represented in this plan.

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[41] E-Source, Residential Appliances Technology Atlas, October 1994 Edition.

[42] DOE work is cited in R.J. Hwang, F.X. Johnson, R.E. Brown, J.W. Hanford, and J.G. Koomey, "Residential Appliance Data, Assumptions and Methodology for End-Use Forecasting with EPRI-REEPS 2.1", Lawrence Berkeley Laboratory, LBL-34046, page 63, May 1994.

The lifetime of showerheads is an average of 12 years.[43]

Heat Pump Water Heaters

Since the 1991 Power Plan, there have been developments in the area of reducing the size of heat pumps and improving their performance. Because some of these units are still in the prototype stage, it is difficult to ascertain just how well they will perform. This analysis assumes that these units can meet their performance challenge. However, even under this assumption, heat pump water heaters were not found to be cost-effective. The analysis that was done follows.

The estimates of costs and savings for exhaust-air heat-pump water heaters[44] were primarily taken from two sources: a monitoring and evaluation study done by Bonneville of thirty exhaust air heat pumps installed in the field,[45] and estimates used by the U.S. Department of Energy in evaluating revised water heater performance standards.[46] Another document that compiles some of this information is the Council's comments to the U.S. DOE on the water heater standards.[47]

Research conducted by Bonneville found that the total incremental installed cost of an integrated heat pump water heater employed as an exhaust-air-heat-recovery ventilation device was approximately $1,800 (1992 dollars). The heat pump water heater and its controls comprised $1,450 of this cost with the installation costs (labor, ductwork, grills, make-up air vents, etc.) representing the $350 balance. This analysis assumes a non-integrated heat pump water heater (such as E-tech/Crispaire) substituting for the integrated unit. The non-integrated heat pump is anticipated to be available for about $400 as production increases. This means that the total incremental installed cost of such devices is in the range of $745 to $945 (1992 dollars). The mid point of this range was used and escalated to 1995 dollars. The assumed coefficient of performance for these units is a coefficient of performance of 2.0, given that they will be operating some of the time off warm indoor air being exhausted from the house.

Heat pump water heaters would be most cost-effective in households with high water use, typically houses with more occupants. This analysis assumes that heat pump water heaters are installed only in new single family houses and new manufactured homes. This also keeps the cost of installation down, especially since the exhaust-air systems modeled here must include duct work. The anticipated savings from heat pump water heaters depends on the total amount of water heating use. Savings will vary by the occupancy of the house, but are estimated to be about 1,500 kilowatt-hours per year for an average house size (single family and manufactured home) of 3.2 occupants. These savings were derived after other more cost-effective water/energy savings devices (such as efficient tanks and efficient clotheswashers) have been applied. They also account for the interaction with space heating, because the exhaust ventilation in the house will increase space heating use.

Maintenance costs are expected to be $5 per year, and lifetimes are anticipated to be 15 years.

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43 This is the median lifetime. This is discussed fully in: Memorandum to multiple parties, November 10, 1994 from Margie Gardner, Northwest Power Planning Council, entitled "Showerhead Lifetime".

44 Exhaust air heat pumps recover the waste heat in air exhausted from the home using the hot air and heat pump to heat water in the water tank.

45 Pacific Science and Technology, Inc., "Exhaust Air Heat Pump Monitoring Study" July 1994, prepared for Bonneville Power Administration and Idaho Department of Water Resources.

46 U.S. DOE, "Technical Support Document: Energy Efficiency Standards for Consumer Products: Room Air Conditioners, Water heaters, ...", November 1993, DOE/EE-0009, Volumes 1-3.

47 Council letter to U.S. DOE in Docket no. EE-RM-90-201, July 15, 1994, plus its attachments.

Summary of Electric Water Heating Measures

The assumptions described above for each measure led to the data in Table G-46, which includes levelized costs and the benefit/cost (b/c) ratio. If the ratio is larger than 1, then benefits exceed costs. Base consumption is 3,880 kilowatt-hours per year for an average size household with 2.4 occupants. The column labeled "shape pointer" is used by the cost-effectiveness model to point to the correct load shape for water heaters. Cost-effective measures are: bottom boards, efficient tanks, and efficient clothes washers.

Table G-46

Data for Cost and Savings for Electric Water Heating Measures

Measure Name	Measure Applies to:	Savings with interaction (kwh/yr.)	Phys Life (yrs)	Capital Cost ($)	Annual O&M ($)	Shape Pointer	Non-E Value ($/yr.)	O&M Cost	O&M period (year)	Levlz'd Cost (c/kWh)	B/C Ratio
Eff Tank .86 to .93	new electric WH	291	12	$50	$	whpriv	0	0		15.3	1.67
Bottom Bd	new electric WH	50	12	$12	$	whpriv	0	0		21.7	1.18
Eff Clothesdryer 1.18 to 3.25	new Clotheswashers	500	12	$175	$	whpriv	$13	0		10.1	2.54
Wrap .93 tank (No partls)	New houses	79	12	$30	$	whpriv	0	0		34.7	0.74
Eff Dishwasher, .46 to .51	new Dishwashers	50	12	$25	$	whpriv	0	0		45.8	0.56
HPWH (@3.2 occup)	New SF & MH	1511	15	$910	$5	whpriv	0	$5	1	52.2	0.49
HPWH @ 2 occup	New SF & MH	965	15	$910	$5	whpriv	0	$5	1	82.2	0.31
HPWH @ 3 occup	New SF & MH	1401	15	$910	$5	whpriv	0	$5	1	56.4	0.45
HPWH @ 4 occup	New SF & MH	1929	15	$910	$5	whpriv	0	$5	1	40.8	0.63
HPWH @ 5 occup	New SF & MH	2388	15	$910	$5	whpriv	0	$5	1	32.8	0.78
HPWH @ 6 occup	New SF & MH	2824	15	$910	$5	whpriv	0	$5	1	27.6	0.93

Further information necessary to translate measure savings into average megawatts are shown in Table G-47. Cost-effective measures result in achievable savings of about 290 average megawatts in the medium forecast, not including line loss savings.

Table G-47

Information Used to Derive Average Megawatt Savings for Electric Water Heating Measures

50%	Saturation of dishwashers
78%	Saturation of clothes washers
85%	Achievable penetration: all measures except heat pumps
70%	Achievable penetration for heat pumps
4,099,000	Technical number of electric water heaters, medium forecast

REFRIGERATORS AND FREEZERS

Refrigerators and freezers have had significant changes in efficiency improvements over the last two decades, partially in response to initial standards for the state of California, and more recently due to federal appliance efficiency standards. U.S. Department of Energy adopted standards for refrigerators and freezers manufactured after 1993 that resulted in typical units consuming about 690 kilowatt-hours per year and 480 kilowatt-hours per year respectively.

Since that time, a consortium of utilities conducted a contest, alternately know as the Super Efficient Refrigerator Project (SERP) or the Golden Carrot, where manufacturers bid for $30 million to produce a refrigerator that beat the 1993 standard by about 30 percent using environmentally friendly technologies. The bid was won by Whirlpool and the units are now being produced and sold around the United States.

One important result of this contest was the demonstration it provided to U.S. Department of Energy and manufacturers that refrigerators could be made 30 percent more efficient than the existing standard by a major U.S. manufacturer. This information was used in hearings on upgrading refrigerator and freezer efficiency standards for 1996 (effective in 1999) and beyond. The prospect of standards resulted in the submission to DOE of joint comments between environmental and energy groups and major refrigerator manufacturers. The joint comments supported a level about 30 percent more efficient than existing standards, or about the level produced by the SERP competition, for refrigerators, and a level about 10-15 percent more efficient for freezers. These levels, and an additional 15 percent beyond these levels, were analyzed for the power plan for refrigerators and freezers. Savings ultimately were reduced by 20 percent for refrigerators and 13 percent for freezers to reflect the interaction of savings with space heating loads, described below.

Costs were taken from two sources. First, an Environmental Protection Agency document[48] that identified the manufacturer's cost of making refrigerators and freezers more efficient was consulted. It identified multiple pathways of achieving efficiency for refrigerators. These multiple pathways were averaged together for the efficiency change that was recommended in the joint comments and for 15 percent beyond the joint comments. This resulted in $17.75 being added to the manufacturer's cost of the refrigerator. To escalate this cost to the retail level, U.S. Department of Energy's technical support document was used,[49] which indicated that the ratio of consumer (retail) costs to manufacturer's costs was about 2.3 to 1. So the $17.75 was multiplied by 2.3 to get a consumer cost of about $41. These costs were very similar to the costs Department of Energy found in its proceeding on refrigerator standards.

However, this number was checked with one of the parties that was heavily involved with the negotiations with manufacturers on the joint comments.[50] He indicated that the negotiated number for the consumer cost of the 30-percent efficiency change was $75. The $41 and the $75 were averaged, resulting in a cost of $58 for the first level of efficiency change (30 percent savings). The costs found in the Environmental Protection Agency document for the additional 15 percent change beyond the joint comments were escalated by a similar factor to represent their costs.

Freezer costs were not developed specifically by Environmental Protection Agency or parties to the joint comments. However, the Environmental Protection Agency estimated costs for refrigerators that were very similar to costs developed by DOE in their last proceeding on refrigerator and freezer standards. As a result, the Department of Energy costs for freezer efficiency improvements were used, after escalating for a similar factor that was used in refrigerators ($58/$41 DOE freezer costs). The costs and savings that were used in the plan, along with levelized costs and benefit cost ratios, appear in Tables G-48 and G-49.

Table G-48

Costs and Savings for Refrigerator Efficiency Improvements

Volume: 18 cubic feet; Adjusted volume: 20.9 cubic feet; Space heating interaction: 0.8						
	Use (kWh/yr.)	**Savings (kWh/yr.)**	**Savings w/ Interaction**	**Cumulative Cost**	**Incremental Cost**	**B/C Ratio**
1993 Std =	689	0	0	0	0	0
Joint Comment level (~30% savings)	481	208	166	$41	$41	1.3
Another 15% off Joint Comment	409	72	58	$78	$37	0.4

[48] U.S. Environmental Protection Agency, "Multiple Pathways to Super-Efficient Refrigerators," June 1993, EPA-430-R-93-008.

[49] U.S. DOE, "Technical Support Document: Energy Conservation Standards for Consumer Products: Refrigerators, Furnaces and Television Sets", November, 1988, DOE/CE-0239.

[50] Personal communication 7/21/95, Howard Geller, American Council for an Energy Efficient Economy.

Table G-49
Costs and Savings for Freezer Efficiency Improvements

Average (50% Chest and 50% Upright)					
	Use (kWh/yr.)	**Incremental Savings (kWh/yr.)**	**Saving with Interaction**	**Cumulative Cost**	**B/C Ratio**
1993 Std =	481	0	0	0	0
Joint Comment level (~30% more efficient)	422	60	52	$12.31	2.0
Another 15% off Joint Comment	358	63	55	$32.70	0.1

Only the joint comment level was cost-effective. A total of 4,787,000 refrigerators and 2,609,000 freezers are expected to be added in the medium forecast from 1999 to 2015, resulting in a total savings of 88 and 16 average megawatts, using a 90 percent penetration rate. Lifetimes are estimated to be 22 years.

RESIDENTIAL LIGHTING

The estimates for costs and savings of individual compact fluorescent light bulbs were largely taken from a consensus memo, produced in 1994, by the Oregon Department of Energy, Bonneville, Washington State Energy Office, Seattle City Light, and the Power Planning Council.[51] While that memo discusses costs and savings for various program types, the program approach adopted here reflects an approach known as the "manufacturer buy-down." In this type of program, utility dollars go directly to manufacturers for the delivery of qualifying bulbs to stores in the service territory of the utilities. This reduces the administrative cost of the program because individual rebates are not required. It also leverages the utility contributions because the retailer's mark-up on the wholesale price is reduced because the wholesale price is lower due to the manufacturer payment from the utilities. This type of program also has the feature of competing manufacturers against each other for the largest portion of utility funds.

The key data used in the analysis appears in Table G-50. The joint memo cited above should be referenced for further information. The costs of the bulbs were adjusted from the memo to reflect more recent information from the regional program, described next. The weighted average savings per bulb used here were 50 kilowatts per year, at a levelized cost of 2.4 cents per kilowatt-hour and a cost-benefit ratio of 1.0. Assuming three bulbs per house in 50 percent of the houses by the year 2015, results in a total of 44 average megawatts by 2015, not including line losses.

[51] Stephens, Charlie, et al "Residential Compact Fluroescent Lighting, A Re-examination of Cost-Effectiveness Issues", April 12, 1994.

Table G-50
Key Assumptions and Levelized Costs for Compact Fluorescent Bulbs

	INTERIOR	EXTERIOR
Weights	70%	30%
Hours On/Day	3	5
Lifetime (Hours)	7000	8000
Lifetime (months) with given on-time	78	53
Initial Measure Cost (Total)	$ 11.50	$ 11.50
Utility Measure Cost	$ 5.00	$ 5.00
Watts Displaced	50	50
Removal	12%	12%
Take-back	5%	20%
Space heat interact.	22%	0%
Incandescent cost	$ 0.50	$ 0.50
# inc and replacmts (at 750 hrs life/bulb)	9	11
Monthly cost of incan (for PV)	$0.06	$0.10
KWh/yr savings w takeback	33.40	62.05
kWh/yr w/out takeback	36.14	80.30
Administrative Costs (Mfg. prog)	$0.60	$0.60

Washington Water Power, Portland General Electric, PacifiCorp, Puget Power and Bonneville Power Administration started a program in 1996 that is a buy-down approach. The idea with this program is to help transform the market for compact fluorescent lights by competing manufacturers in the program against each other, and by competing the highly reduced cost of bulbs in the program with non-program manufacturers. Bulbs in the program are expected to cost less than $10 in the store, compared with prices in the range of $18-$20 for non-participating manufacturer's bulbs. This program is expected to take a few years before its effects can be measured. However, the program may cause significant shifts in the price or rebate offers from manufacturers not in the program. Any spillover of this type will act to reduce the levelized costs of the program because more bulbs at a lower cost were secured than were counted directly in the program. This additional benefit is not included in the estimates in this plan.

INTERACTION OF APPLIANCE SAVINGS WITH SPACE HEATING USE

A house is warmed by a combination of internal and external heat sources. Internal heat comes from incidental or waste heat given off by appliances and people (usually called "internal gains") and from the space heater. The external source of heat is primarily radiant energy from the sun (usually called "solar gains"). These heating sources are in balance, and if the heat produced by any one of them decreases, more heat must be added from the other components to keep the house at the same temperature. This section explains the interaction between the waste heat given off by appliances and the heat supplied by the space heater.[52]

If the efficiency of an appliance, such as a refrigerator located inside the heated space, improves, the unit both uses less energy and gives off less waste heat. This change in turn causes the space heater to use more electricity, in order to keep the house at the same temperature it was before the improvement in the refrigerator's efficiency occurred.

The balance between the decrease in electricity consumption by the refrigerator and the increase in use for extra space heating depends on many factors. One prominent factor is the insulation level of the house. The better insulated a dwelling, the less useful is the waste heat from the appliance. For example, the space

[52] Solar gains are considered constant in this discussion.

heater must produce about an additional 5 kilowatt-hours per year for every 10 kilowatt-hours per year saved by the appliance efficiency improvement, assuming all of the following: the appliance is located in the heated space, electricity is the space heating fuel, no air conditioning is installed, and the house is not fully insulated. In other words, only 50 percent of the savings from improving appliance efficiency would be realized. This estimate accounts for periods of the year, such as summer, when additional space heat is not necessary.

This estimate must be tempered by other intervening variables to calculate the average expected impact on the Northwest electrical system from improved appliance efficiencies. First, the appliance must be one that produces internal gains. Many do not. For example, about half the electric freezers in the region are located outside heated areas. Waste heat generated from freezers (and other appliances) that are outside the heated shell of the house would be fully realized as 100-percent energy savings and would not require that additional heat be provided by the furnace.

Second, a number of electrical appliances that do produce internal gains, such as refrigerators, are located in houses that do not use electricity for their space heating. In this case, the full amount of electricity saved by improving the appliance's efficiency is realized by the region's electrical system.

Finally, the reduction of internal gains benefits the house if air-conditioning equipment is installed. In this case, less cooling needs to be provided in the summer to offset the internal gains from inefficient appliances. For water heaters, only the standby use of hot water held in the tank (for units located in the house) is an internal gain. Variable hot water demand does not contribute significantly to internal gains, even though it uses electricity.[53] Consequently, only efficiency improvements in standby use for tanks located in the house increase the heat needed from the space heater.

When all of these factors are considered, electricity used for space heating must make up, on average in the region, about 17 percent, 20 percent, 13 percent and 22 percent of the savings from standby losses on water heaters, refrigerators, freezers and lights, respectively. These figures were used to devalue the saving obtainable from these appliances in the preceding cost-effectiveness evaluations.

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[53] A recent American Society of Heating, Refrigerating and Air-Conditioning Engineers' publication suggests that the minor internal gain from variable use should be ignored. The gain from the hot water in the pipes is offset by heat used to heat cold water brought inside the heated shell through other pipes.

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COMMERCIAL SECTOR

SUMMARY

Savings

The combined total of achievable conservation potential for the sector is over 451 average megawatts for measures with benefits exceeding costs. This amounts to 8 percent of the projected commercial electric energy demand in the year 2015. The resource is split roughly 40 to 60 percent between existing buildings with 138 average megawatts and new commercial buildings at 241-273. The total also includes 72 average megawatts of potential savings available if all of the existing stock that undergoes a full renovation during the next twenty years were brought up to the same efficiency levels as new buildings.

Costs

Savings from all measures that have benefits exceeding costs are available at an average cost of 13.27 mills per kilowatt-hour in existing buildings and 11.86 mills per kilowatt-hour in new buildings. Across the subsectors, these costs range from 0.9 to 1.6 cents per kilowatt-hour in existing and 0.4 to 2.0 cents per kilowatt-hour in new buildings. These costs include administrative costs computed at 20 percent of the first cost of the measure as well as a 10-percent credit from the Northwest Power Act computed on the total present value of the measures.

Figure G-23 shows the amount of commercial sector conservation available at various costs in existing commercial buildings and figure G-24 shows the amount of conservation available in new and renovated commercial buildings.

Figure G-23
Conservation Supply in Existing Commercial Buildings

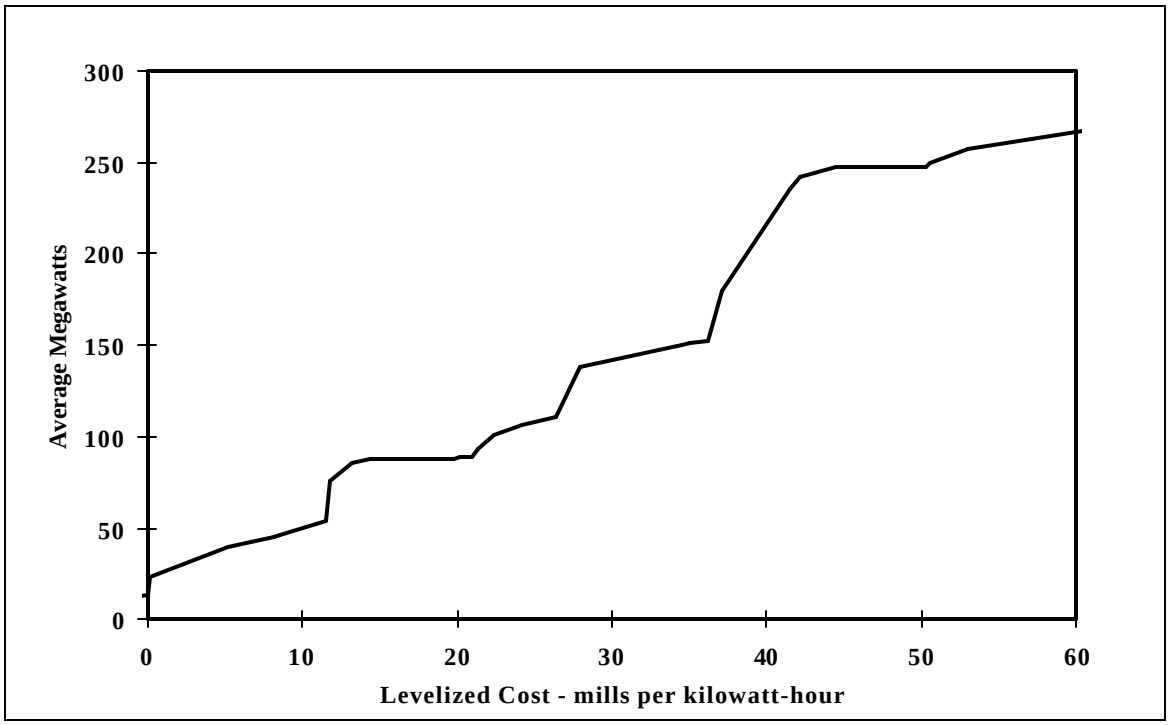
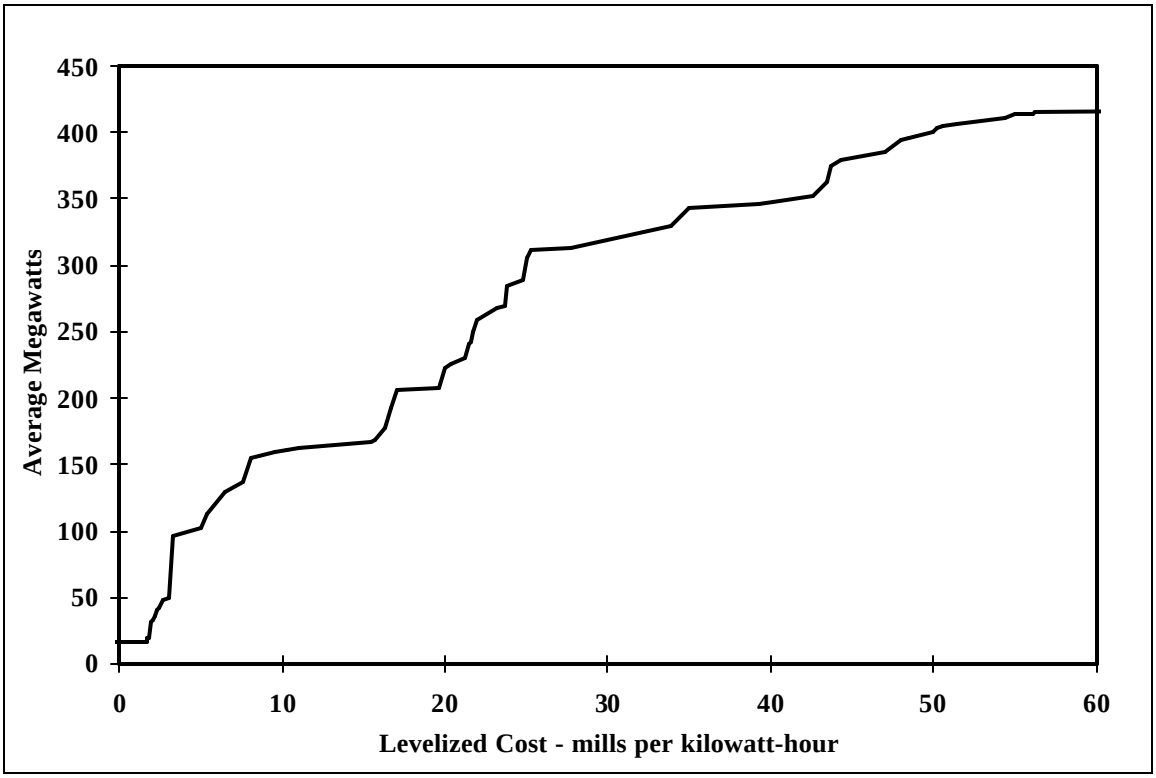


Figure G-24
Conservation Supply in New and Renovated Commercial Buildings



CHANGES FROM THE 1991 PLAN

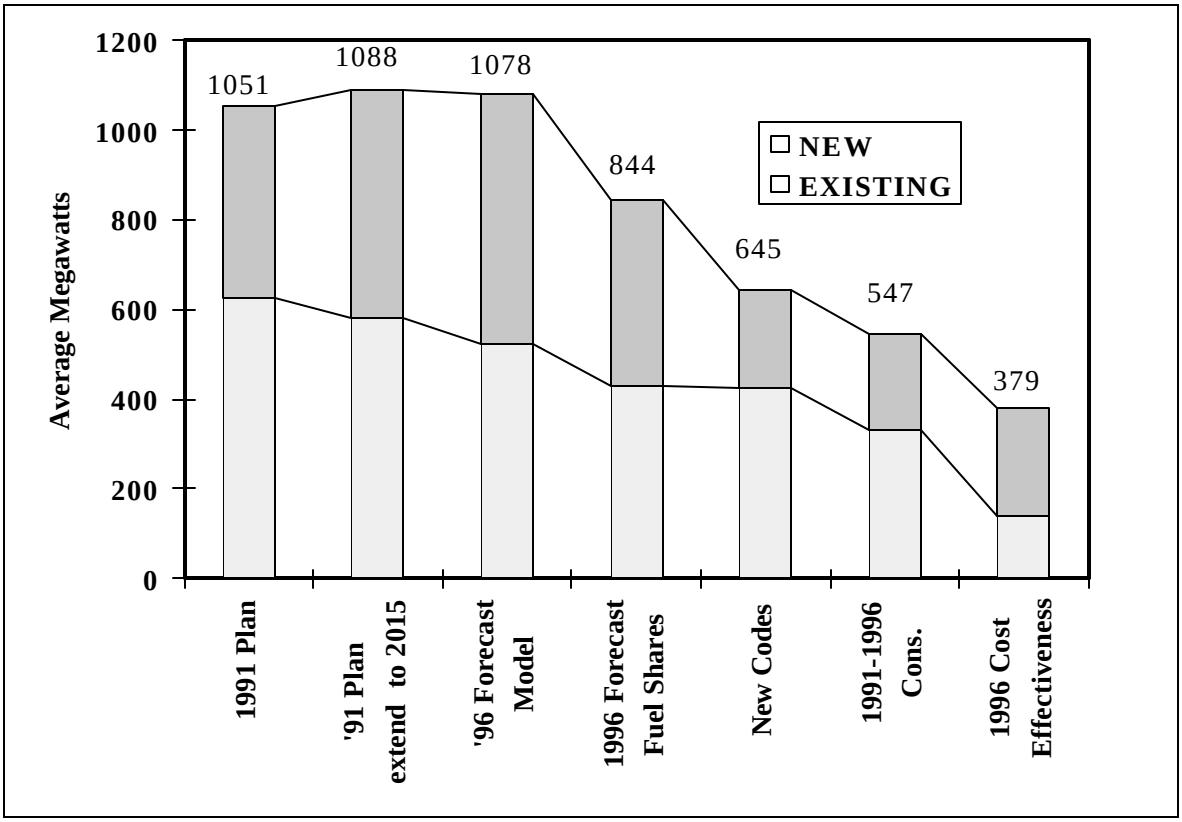
A number of changes have occurred to the commercial building sector as well as to the electric industry over the last five years. While some of the changes simply reflect the changing demographic picture of the Northwest economy, others are specifically related to energy use and distribution. The most significant of changes include:

- Shifting from 1991-2010 to 1996-2015 time frame
- Actual floor space growth patterns and new forecast models that include 1991-1995 actual usage patterns
- Changes in the retail price of energy, both natural gas and electricity
- New federal standards for lighting and HVAC equipment and improvements in building codes in Washington and Oregon
- Conservation acquired through utility and other actions since 1991
- Changes in marginal resource costs and new efficiency measure costs and savings.

Figure G-25 shows the change in resource potential from the 1991 Plan to the new draft plan estimates by accommodating the effects listed above in a cumulative chain of load forecast runs assuming medium load growth[54].

[54] For simplification purposes, this analysis examines the impacts on new and existing buildings only and does not include renovation/remodel effects.

Figure G-25
Disposition of Commercial Resource Changes from 1991 Plan to New Draft Plan



The first bar shows the combined total of roughly 1,050[55] Average megawatts of new and existing conservation indicated in the 1991 Plan. The second bar shows that had the 1991 Plan been run over the years 1996 to 2015, the total available conservation would have gone up to near 1090 average megawatts. The third bar shows the change in potential when the latest forecast of economic activity and energy use in existing buildings is used. The new model reflects a higher floor space growth rate for new buildings as well as a reduction in existing building use due to a number of factors including less remaining floor space resulting from five additional years of demolition and improvements in stock efficiency over the last five years. In the fourth bar, moving from the 1991 to 1995 forecast of fuel prices decreases the saturation of electric heat and thereby drops the savings potential by about 235 average megawatts. In the fifth bar, new state codes adopted in Oregon and Washington and federal standards further drop the new resource potential by around 165 average megawatts. Conservation acquisitions by utilities during the last five years drop the potential in the existing sector by approximately 100 average megawatts. Last but not least, inserting the new cost-effectiveness levels in the draft plan reduces the potential by another 200 average megawatts.

In summary, the resource potential went from 1,090 average megawatts, using 1991 Plan assumptions, to 380 average megawatts using the draft plan. It is interesting to note that of this 710 average-megawatts reduction, only 29 percent is due to revised cost-effectiveness analysis for the efficiency measures. Figure G-26 details these results further.

[55] The 1991 Plan included 627 average megawatts for existing and 443 average megawatts for new in the medium case totaling 1,070 Average megawatts. During this analysis an error in the original load forecast input file was found and corrected, reducing the amount to 1,051 average megawatts.

Figure G-26
Shares of Commercial Sector Resource Potential Reduction from the 1991 Plan by Factor.

ESTIMATING THE REGIONAL RESOURCE POTENTIAL

The analysis procedure used to estimate the commercial sector resource was very similar in structure to that used in the 1991 Plan. The procedure involves four steps. The first step is to establish current levels of energy use and baseline building characteristics. The second step uses engineering models informed by the first step and a levelized costing tool to determine cost-effective levels of efficiency across the various sub-sectors. The third step uses the relative efficiency changes in the prototypes as inputs to the regional load forecast model to estimate the technical resource potential resulting from efficiency-driven changes in forecasted loads. Lastly, these changes are shaped into programs that are chosen for acquisition to meet load growth by the ISAAC model.

The procedure is described in detail in the 1991 Power Plan, which serves as the primary reference for this part of the Appendix. Rather than repeating the description in the 1991 Plan, the following sections will focus on pertinent changes from the 1991 Plan and new information that has been developed in the last five years.

STEP 1. ESTIMATING CURRENT EFFICIENCY LEVELS

Prototype Development

The analysis of savings estimates begins with the development of engineering models to derive the relative impact of specific efficiency measures on various categories of commercial sector building types. While there has been criticism of using engineering models to predict energy savings, several studies have shown that when fed correct inputs, these engineering models can predict building energy use with considerable accuracy. The obvious key to insuring credible results is to assemble inputs that are representative of real world conditions. The engineering models used in this analysis have been extensively

compared to a number of studies that range from detailed instrumentation studies of specific measures in single buildings to large scale utility program evaluations with whole building energy use data. The result of these comparisons is a set of inputs for these models that represents the best approximation of the real world.

This analysis uses the same 10 prototypes that were used in the 1991 Plan. These prototypes were developed through an extensive process documented in detail in a series of reports by SBW Consulting, Incorporated. A full reference for these reports is included in the 1991 Plan.

In order to ensure that the prototypes are representative of the broader population, they were modified to include characteristics data from the Pacific Northwest Non-Residential Energy Survey (PNonRES) for existing buildings and from the Energy Code Compliance in Commercial Buildings in Oregon and Washington Study (Code Compliance Study). These sources provide key information in statistically significant samples about market shares of specific equipment types, insulation levels, and physical geometry such as number of floors and total square footage. Table G-51 summarizes key statistics about the prototypes.

Table G-51

Commercial Building Characteristics - 1996 Base Year

Prototype	Floor area in square feet	Effective lighting operating hours per year	Regional weight in percent	Whole building electric use in in kWh/square feet	Effective lighting power density w/square feet
New Buildings					
Large Office	408000	4250	12.8	17.1	1.3
Small Office	4880	2600	12.0	14.8	1.4
Fast Food Restaurant	2624	6237	8.2	96.2	1.6
Large Retail	120000	5100	6.5	17.6	2.2
Small Retail	13124	4000	9.7	11.2	1.4
Grocery	26052	7150	2.9	66.7	1.5
Warehouse	18025	3120	6.7	7.7	0.9
School	67784	2534	16.0	15.9	1.4
Hospital	272000	4505	16.0	40.9	1.5
Hotel	277200	3021	9.1	17.3	1.5
Existing Buildings					
Large Office	408000	4250	28.3	34.1	2.4
Small Office	4880	2600	27.2	22.7	2.2
Large Retail	120000	5100	17.8	22.2	2.7
Small Retail	13124	4000	26.7	16.5	1.9

Energy Use Modeling

The prototypes were modeled using the public domain software DOE 2.1d developed by the Lawrence Berkeley Laboratories and the U.S. Department of Energy.[56] The prototypes' energy use patterns were

[56] Although revisions to DOE 2.1 (version 2.1e in various releases) were available in the fall of 1994, due to time constraints and debugging (release 56 of 2.1e was released in the fall of 1995) this analysis relied upon DOE 2.1d numbers.

compared to actual building use, and the inputs have been adjusted to produce realistic estimates of energy use. The primary sources of data used to develop and calibrate the prototypes are the End-Use Load and Consumer Assessment Program (ELCAP) and Commercial Hourly End-Use Study (CHEUS). Additional calibration data was derived from the Energy Edge program.

Since the 1991 Plan, significant changes have been made to the energy codes for commercial buildings in Oregon and Washington. In addition, the federal Energy Policy Act of 1992 (EPAct 92) created minimum standards for some classes of commercial equipment and outlawed production of certain types of lighting equipment. The new building prototypes were modified to incorporate these standards by referencing the relative improvements in each end-use efficiency predicted by a series of studies conducted to specifically address the energy impacts of these codes and standards[57, 58, 59].

STEP 2. MODELING EFFICIENCY OPPORTUNITIES

General

The starting point for modeling efficiency improvements was the set of measures included in the 1991 Plan. These measures were first screened for those items that are now covered under the new codes passed in Oregon and Washington or by the federal standards in EPAct. The remaining measures were then reviewed by the commercial subcommittee of the Conservation Resources Advisory Committee (CRAC). The CRAC reviewed the efficiency measures for applicability given current practice and suggested revisions, or in some cases new measures as appropriate. These new measures were then modeled and applied to the prototypes, which provided relative energy use impacts by end-use and forwarded to the regional forecast model.

1991 Plan Measure Updates

The measures in the 1991 Plan that were derived from the original UIC/SBW Studies, were screened for those measures that were no longer viable under the new codes in Oregon and Washington or EPAct. For new construction, all of the measures included in the bundle titled "MCS Package" were deleted and replaced by the Oregon and Washington Code baseline. Although each of the codes contains requirements that are different from each other and from the MCS, in almost all cases, the new code requirements together met or exceeded the performance of the MCS. Because the new codes were designed to provide equivalency with EPAct, the effects are subsumed in the new code baseline.

For existing buildings, the analysis of EPAct measures required an examination of individual efficiency measures to see whether or not the EPAct requirements would apply. The primary places where this effect is in place are seen in the following:

Lighting

The EPAct effectively outlaws sales of 40-watt T-12 Cool white phosphor lamps and 150-watt PAR incandescent lamps. The lighting savings for retrofits were adjusted to assume 34-watt, T-12, energy-saving lamps with magnetic ballasts as baseline for fluorescent lamps and 90-watt halogen PAR incandescents for incandescent lamps.

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[57] Kennedy and Baylon 1992, *Energy Savings in Commercial Buildings: Impact of the 1993 Washington Energy Code - Draft*, Ecotope, Inc. Seattle, WA.

[58] Byers, D., Memo to Andrea Kelly WA UTC, Washignton State Energy Office, 1994

[59] Harris, J. and Boner, A., "Cost-Effectiveness Analysis of the Proposed Non-Residential Energy Code", report to the Oregon Building Codes Structures Board, Oregon Department of Energy and Northwest Power Planning Council, September 1994

Heating Ventilation and Air Conditioning

The EPAct sets minimum requirements for smaller HVAC equipment to be the same as ASHRAE 90.1-1989. These standards were incorporated as the baseline for equipment replacements in the existing stock and for any retrofit measures.

Motors

The EPAct directs DOE to develop electric motor efficiency standards to be in effect at the earliest in 1998. There were no motor efficiency measures in the analysis so they were not impacted directly. For replacements, both Oregon and Washington codes have motor efficiency requirements in place that are equivalent to the EPAct standards.

After screening for measures that were no longer applicable, the remaining measures were reviewed for accuracy given current market conditions. To start with, the costs of all measures were escalated using a gross domestic product deflator of 1.15 to account for the impacts of inflation from 1989 dollars to 1995 dollars. The remaining changes necessary were measure-specific and are treated below.

New Information Developments Since the 1991 Plan

Since the 1991 Plan, a number of new information sources have appeared on the cost and performance of efficiency measures in this sector. For purposes of this analysis they fall into four different categories based on the type of information they provide.

Utility Evaluations

Since the 1991 Plan was published, several evaluations of major utility programs have been completed. The most significant of these is the collaborative effort that covered programs by Bonneville Power, Puget Power, Seattle City Light, Tacoma Public Utilities, and Idaho Power[60]. Additional information was provided from evaluations of programs by Portland General Electric,[61] Pacific Power and Light[62] and the Northwest Power Planning Council's publication 94-17.[63] In general, these evaluations yield important information on their specific programs and their operation but were not focused specifically on technology assessments, thus often making it difficult to translate the results into measure characterizations. However, some general trends were apparent:

Lighting measures generally provided solid savings performance as long as the base case was appropriately defined. In particular, many retrofit programs incorrectly assumed poor performance in the existing system and thus overpredicted savings. Evaluated savings were also reduced in many cases because owners often took the opportunity of the retrofit to increase their amenity levels (increased illumination levels) while improving their efficiency. In fact, if the owner desired that level of illumination, then the efficiency measures actually delivered higher savings than predicted.

Heating, Ventilation, and Cooling system (HVAC) measures were a mixed bag. Chiller upgrades generally met the efficiency performance specified. Savings were acquired as expected ,providing the base case was appropriately specified. Many codes do not require efficiency levels near the current practice for large chillers and thus savings determined using code as baseline are overstated. Adjustable speed drives appeared to be the most unpredictable in their performance. Most of the performance problems could be traced to incorrect application e.g., incorrectly assuming a variable-speed operation for constant-speed

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[60] Xenergy, Regional Economic Resources, Architectural Energy Corporation, 1995. *Northwest Commercial Evaluation Project - Draft Report.* Palo Alto, CA: Electric Power Research Institute

[61] ADM Associates, Inc., 1995. *Energy Smart Design Program Impact Evaluation.* Portland, OR: Portland General Electric

[62] PacificCorp, 1995. *The 1994 Evaluation of PacifiCorp's Energy FinAnswer Custom Program.* Portland, OR: PacifiCorp

[63] Northwest Power Planning Council document 94-17, December 1994. *Making Conservation Work: Practical Answers for Commercial and Industrial Program Managers.* Prepared by SBW Consulting and Dethman & Associates.

equipment, or not properly commissioning of the adjustable-speed drive controls within the overall HVAC systems.

Envelope systems appear to provide the appropriate savings, although the evaluation techniques are often not sensitive enough to accurately sort out the savings from these measures due to the size of the envelope loads in comparison to the internal loads of the buildings. In at least one study, it was discovered that assuming that the energy code was an appropriate baseline turned out to be quite inadequate in the wrong direction. Local building practices and market forces apparently had more impact on baseline insulation levels than did the state codes.

Programs that included building commissioning as part of the program fared better than others. PacifiCorp's FinAnswer program was the only one of the group that required commissioning as a part of program participation. The FinAnswer program also acquired the highest level of achieved savings per unit of any of the programs. Evaluating the program was also much less contentious since each measure had already been well-documented and tested.

Building Commissioning

At the time the 1991 Plan was being developed, information was being developed that indicated that energy efficiency measures may not be performing in the field because they were not being correctly tested as part of the greater building comfort systems. This led to the realization that not just energy efficiency measures but entire building systems were not installed and tested to ensure performance. Following this, a series of national conferences were held on what eventually came to be known as building commissioning. The proceedings of these conferences[64] were extremely useful in setting the context for commissioning as a resource, but there was not a good summary of the current state of the information base surrounding this resource. The Council sponsored PECI to summarize this understanding to use specifically for the purpose of analyzing the resource potential of commissioning in new[65] and existing[66]. These reports formed the basis for the estimates of savings potential for this plan. The primary source for cost data for this analysis came from a study jointly funded by Bonneville and PacifiCorp that examined the costs and savings of commissioning within PacifiCorp's FinAnswer program.[67]

Measure Life

As utility programs began to reach significant portions of the commercial sector, it became apparent that certain types of commercial buildings are undergoing cosmetic and physical changes at a fairly high rate of frequency. This rate of change raised questions about the longevity of the efficiency measures installed in these buildings. In order to more fully explore this issue, Bonneville commissioned a study[68] that surveyed industry professionals regarding the number of changes annually to energy consuming equipment and the potential impacts on to efficiency measures. This first study raised a number of issues that were explored more fully in a second, field-oriented study[69] that attempted to determine the effective vintage of actual equipment in a statistical sample of buildings. This second study was used to revise the measure lifetimes for this analysis. It is important to note that the perspective taken in this analysis looks at measures from the perspective of the longest component of the measure (e.g., lighting fixtures) and then computes replacement

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[64] Portland Energy Conservation Inc., 1993, 1994, 1995. *Proceedings of the National Conference on Building Commissioning.* Portland, OR: PECI

[65] Portland Energy Conservation, Inc., 1995. *Reliability and Persistence of Savings in the 1996 Power Plan.* Portland, OR: Northwest Power Planning Council.

[66] Portland Energy Conservation, Inc., 1995. *Addressing Operations and Maintenance in the 1996 Power Plan.* Portland, OR: Northwest Power Planning Council.

[67] M.A. Piette, B. Nordman, S. Greenberg, 1995. *Commissioning of Energy Efficiency Measures: Costs and Benefits for 16 Buildings.* Portland, OR: Bonneville Power Administration

[68] Synergic Resources Corporation, December 1991. *Bonneville Measure Life Study: Effect of Commercial Building Changes on Energy Using Equipment.* Portland, OR: Bonneville Power Administration

[69] SRC, 1994. *Measure Life Study II.* Portland, OR: Bonneville Power Administration

costs for shorter-lived components (e.g., lamps and ballasts) of the measure. This is consistent with the methodology used in the second measure study.

Other Sources

A variety of other data sources were reviewed and used in evaluation of individual measure performance. These include the reference series from E-Source[70] and the Demand-Side Energy Evaluation Resource from the California Energy Commission.[71]

Efficiency Measure Descriptions

The efficiency measures analyzed for inclusion in this plan should be grouped into general categories as listed below. However, it is important to note that generally these measures are intended to represent a broader class of efficiency improvements, which cannot be modeled in the same level of detail as they will need to be in actual application.

Lighting Measures

The lighting measures included in this analysis tended to fall into two categories, the first being what would be considered traditional utility-type rebate programs. These measures include:

- High-Efficiency Overhead Lighting - modeled by replacing 34-watt, T-12 ES lamps and magnetic ballasts with 32-watt, T-8 tri-phosphor lamps and electronic ballasts in new or existing fixtures. Includes some high-efficiency fixture replacements in retrofit applications to use open parabolic reflective fixtures.
- High-Efficiency Secondary Lighting - modeled by replacing 100-watt incandescent fixtures in wall sconces with 27- or 34-watt compact fluorescent hard-wired fixtures.
- High-Efficiency Display Lighting - modeled by replacing 90-watt halogen PAR lamps with 60-watt halogen, infrared-reflecting lamps.
- High-Efficiency Exit Signs - modeled by replacing 20- to 40-watt incandescent signs with LED or electroluminescent technology using between 1 and 4 watts.

The other group of measures can be considered as much design solution as hardware replacements and therefore involve changing the infrastructure of the lighting industry, not just the equipment. These measures include:

- Ambient/Task Lighting Design - this measure represents the design practice of providing differentiated light levels depending on the task required; typically resulting in a lower level of ambient lighting and a higher level of lighting on task surfaces. This measure is modeled by lowering the overall lighting provided by the ceiling-mounted fixtures to around 30 foot candles and then providing a fluorescent task lamp on each worker's desk. There are in fact many ways to achieve comparable lighting designs, including concentrating the overhead lighting over the task areas and using spillover to light the traffic areas, etc.
- Daylighting Design - this measure represents the potential of using daylighting extensively to supplant artificial lighting. The actual practice of this measure includes everything from simple daylight control of perimeter fixtures to full integration of light shelves and other features to ensure daylight penetration to every work area in the building. This measure is modeled using dimming electronic ballasts and light-sensing controls on the perimeter of the work areas of the building to proportionately vary the artificial light to balance the natural daylight.
- Occupancy Sensor Controls - this measure might be considered to be a traditional utility rebate measure but in practice has been found to provide less than satisfactory results when applied without appropriate design considerations. In addition, there are more and better control technologies that

[70] E-Source, 1994 and 1995. Space Cooling Technology Atlas and Lighting Technology Atlas. Boulder, CO: E-Source
[71] CEC, 1992. *DEER*. Sacramento, CA: California Energy Commission

allow broader application of this technology than just the replacement of wall switches. This measure is modeled assuming occupancy sensing and control of normally unoccupied areas such as filing, storage, and conference rooms, and the potential is proportionate to the share of floorspace consisting of such uses.

Heating Ventilation and Air Conditioning Measures

In keeping with the discussion under lighting, there are mechanical system measures that have been traditionally delivered through utility programs and are best described as hardware upgrades. These include:

- Heat Pump Conversions - modeled as the substitution of a heat pump in place of a standard air-conditioning system with electric resistance heat. This primarily applies to small packaged rooftop systems on small buildings where electric baseboard heat is possible. This does not include heat pump conversions of gas-fired equipment.
- Variable-Speed Drives - modeled as an add-on device to fans and pumping systems with significant varying flow.
- Economizer/Outside Air controls - modeled as add-on controls primarily for retrofit to manage reset of outdoor air during cold conditions and increase outdoor air to provide natural cooling when appropriate.

The group of measures that requires design and infrastructure changes includes:

- Constant Volume System Retrofit - modeled as a full replacement of the terminal units and central fan system in an existing large building.
- Evaporative Cooling - modeled as a central chilled water system replacement.
- Radiant Heating - modeled as replacement for forced air delivery in storage zones or shipping areas.
- Heat Recovery Exhaust/Supply Air Tempering - modeled as a redesign and retrofit of existing buildings where variable air volume is not possible.

Envelope Measures

All of the measures in this category could be considered to be traditional utility program-delivered measures. They include:

- Wall insulation - modeled as an add-on increment to the existing required level from code (e.g. R-5 exterior foam) or as a retrofit of small wood-framed structures.
- Roof Insulation - modeled as increments above R-19 to either R-25 or R-30
- Window Upgrades - modeled as an incremental level of efficiency to include low-emissivity coatings and a thermally broken frame typically resulting in a change in window U-value from 0.60 to 0.45.

Other Measures

The remaining measures modeled include a variety of both traditional utility program delivered measures and others delivered through unconventional means. They include:

- Building Commissioning/ Re-Commissioning - this measure is designed to represent the potential from full commissioning services from pre-design through start-up in new buildings and for full evaluation and overhaul of existing buildings. This measure was modeled in both new and existing buildings as saving 10 percent of the energy used for heating, ventilating and air-conditioning. This results in a typical savings on the whole building use of around 5 percent or toward the low end of the 5- to 40-percent range documented in the PECI report. This measure was deliberately forced in as the first measure in the stack in order to ensure that the full performance from the other measures was achieved in practice.

- Refrigeration System Improvements - this includes a variety of measures aimed at improving the efficiency of process refrigeration systems at new installation or complete replacement for applications in groceries, warehouses and other refrigerated building applications. The measures in this group include floating head pressure, hot gas defrost, anti-sweat timers and covers on refrigerated cases, mechanical subcooling and liquid amplification.
- Domestic Hot Water - there were measures affecting domestic hot water modeled as insulation and time control retrofits.

Measure Interaction

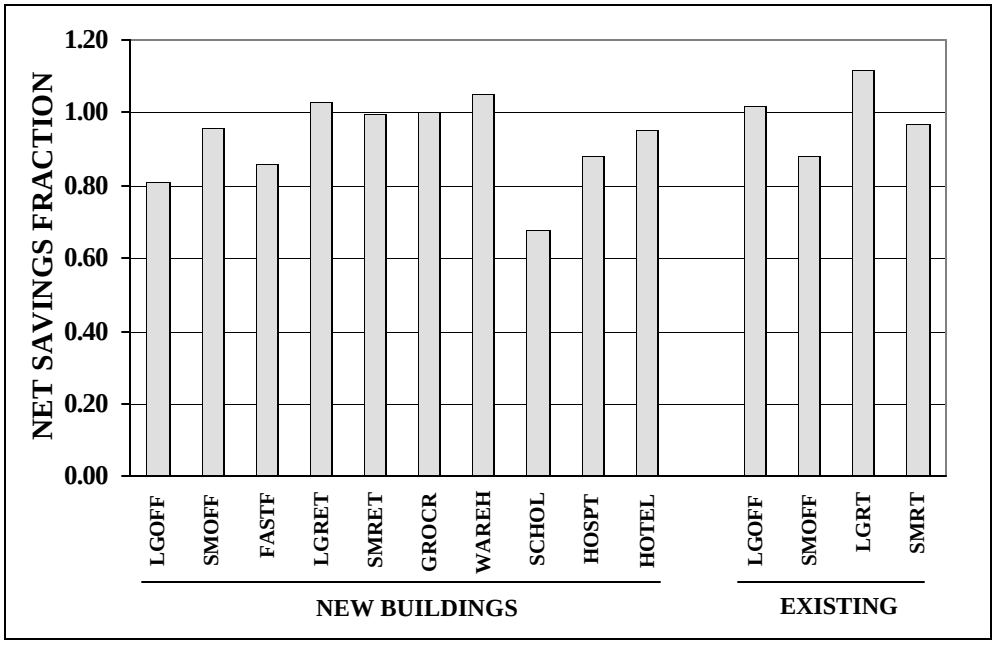
Analysis of efficiency measures in the commercial sector is complicated by the fact that a change in the efficiency of one end-use can indirectly impact other end-uses. For example, reducing the energy use of lighting reduces the amount of internal heat gain and requires more heat to be supplied from the auxiliary heating system during the winter. On the other hand, that same reduction in internal heat gain reduces the cooling load in the summer and the consequent need for energy for the cooling system. An improvement in the heating system efficiency, say by installation of a heat pump, reduces the winter-time heating penalty from lowered lighting power.

Further complicating the issue is the fact that interactions for space heating and cooling are fuel-dependent; i.e., interactions that affect space heating only count for purposes of this analysis if they affect an electrically driven system.

The sum of these factors are applied to each measure and are cumulative as each measure is added. This process may cause a measure that would have been cost-effective had it been applied first to be non-cost-effective after a prior measure is installed; or just the opposite may occur. This requires the analysis to be an iterative process, installing the measures sequentially, sorting according to cost-effectiveness, taking the most cost-effective measure as given and then reapplying the other measures and re-running the analysis.

In order to facilitate this iterative process, these interaction factors are developed using the DOE 2.1 engineering model for each prototype with the base level of efficiency and then applied off-line in a spreadsheet tool that applies the appropriate factors for each of three space conditioning systems: electric resistance, heat pump, and gas-fired. Figure G-27 shows the net fraction of savings resulting from the application of lighting measures after the heating and cooling interactions are applied.

Figure G-27
Net HVAC Interaction Fractions for New and Existing Commercial Buildings



Additional interactions occur when an improvement in heating or cooling system efficiency is put in place. For example, when an electric resistance heating system is replaced by a heat pump measure, the savings resulting from envelope measures applied thereafter is discounted by the net efficiency of the heat pump over the electric resistance system. This requires that the cost-effectiveness analysis be iterative in nature; re-ordering the application of measures in order to appropriately account for these interactive effects.

Cost-Effectiveness Analysis

The measures were applied to the appropriate prototypes using a modeling tool developed for this analysis by the Council. This tool, entitled "ProCost," is explained in more detail in Appendix B-7. In brief, it computes the present value of all of the pertinent cash flows for both the costs and benefits of each measure. A variety of indices are computed from these present values including a benefit-to-cost ratio, a levelized cost equivalent and a simple payback value. For the commercial sector, there were specific modifications to the basic ProCost module in order to handle the complex set of interactions between measures.

Calculation of Benefits

In ProCost, power system benefits are computed using a set of marginal system costs for four load segments (peak, shoulder, off-peak, and weekend) for each month of the period from 1996 to 2015. For the life of the building remaining beyond 2015, the marginal system costs are accumulated assuming escalation at the rate of inflation; i.e. zero real price escalation. This marginal cost structure is described in more detail in Appendix B-6. For the commercial sector, rather than shaping the energy *savings* to the appropriate load segments, individual load shapes were developed to distribute the annual *energy* consumption for a specific end-use for both a baseline condition and an efficient condition for each of five end-uses (heat, ventilation, cooling, lighting, other), three separate base fuel conditions (electric resistance, heat pump, gas fired), and two different types of efficiency measures (lighting or comprehensive) for each prototype. Energy consumption for each load segment for the two cases, baseline and efficient, are subtracted to compute the actual energy in each load segment to multiply by the corresponding marginal cost value. The various fuel cases are weighted proportionately to their fuel share, and then all the end uses are summed across each load segment to derive the overall load shape for that measure in that prototype.

Calculation of Costs

Because many of the measures in the commercial sector have significant operations and maintenance cost differences between measures and baseline, a fairly detailed model of the various fixed and variable cost streams was necessary. The ProCost model was modified to provide for an initial purchase cost, an annual operation and maintenance expense, and up to three separate equipment replacement costs to be repeated within the life of the measure. The measure costs themselves are repeated as appropriate for the life of the building.

For example, consider a high-efficiency lighting measure in the new grocery sector. As a new building, the store structure is expected to last a mean lifetime of 45 years based on the life of the *building.* The lighting measure to replace standard fluorescent overhead fixtures with energy efficient T-8 lamps and electronic ballasts is given a lifetime of 21 years based on the life of the *fixture*. There is an incremental cost incurred to buy the more expensive lamps and ballasts initially at the time of construction. Over the life of the fixture, the lamps will be replaced every three years incurring an incremental cost with each replacement In addition, the ballasts will be replaced every 15 years with a corresponding incremental cost. These replacement costs are repeated for the life of the fixture, six times for the lamps and once for the ballasts. These costs are brought back to present value and added to the initial incremental cost. When the fixture's life is over at 21 years, the life-cycle costing model buys the entire measure over again and repeats the stream of replacement costs until the building is assumed to be taken out of service at 45 years. This provides a consistent stream of both costs and benefits over the life of the building.

Table G-52 lists the output of the cost-effectiveness analysis for all the measures ranked by benefit cost ratio for new buildings. Table G-53 lists the output of the cost-effectiveness analysis for all measures ranked by benefit cost ratio for existing buildings. It is important to note that the annual savings given in these tables is from the prototypes and does not necessarily represent the actual savings predicted by the load forecasting model for the same level of improvement. The annual savings, first cost and PV columns are all normalized per square foot of floor area of the building. The PV Cost column represents the present value of all of the costs including financing costs. The levelized cost column shows the present value costs levelized over the life of the building using a 4.5 percent real discount rate divided by the annual savings. The B/C Ratio lists the ratio of the present value of benefits calculated as previously described divided by the present value of costs. The simple payback column lists the simple payback of the measure in years defined as the measure's first cost divided by the first year savings computed at a nominal rate of 2.5 cents per kWh[72]. The cumulative weighted savings column is the cumulative sum of the annual savings weighted by the amount of the total commercial floor space represented by that prototype.

Measure Ranking

The measures are then sorted according to benefit/cost ratio. Because of the interactive effects of the measures, this process is iterated until a stable rank-ordering from best to worst benefit/cost ratio is achieved. The measures are then bundled for all measures with a benefit cost ratio of 1.0 or greater. This group of measures forms the basis for the characteristics of the resource used by the integrated systems acquisition analysis model (ISAAC).

[72] The rate of 2.5 cents per kWh was used to represent a likely marginal rate assuming that current rate structures are changed to reflect actual wholesale rates.

Table G-52
Cost-Effectiveness Summary Output for New Commercial Buildings

PROTO-TYPE	END-USE	MEASURE DESCRIPTION	ANNUAL SAVINGS kWh/ft2	FIRST COST $/ft2	PV COST $/ft2	LEVEL-IZED COST mills /kWh	B/C RATIO	SIMPLE PAYBACK years	CUMUL. WEIGHTED SAVINGS kWh /ft2
FASTF	LGT	Efficient Exit Signs	0.19	0.05	0.00	2	-114.3	9.6	0.02
SMOFF	LGT	Efficient Exit Signs	0.17	0.04	0.00	2	-40.9	8.7	0.04
WAREH	LGT	Efficient Exit Signs	0.09	0.02	0.00	2	-39.1	8.8	0.04
GROCR	LGT	Efficient Exit Signs	0.09	0.02	0.00	2	-31.7	9.0	0.05
SMRET	LGT	Efficient Exit Signs	0.07	0.02	0.00	2	-30.1	10.1	0.05
LGRET	LGT	Efficient Exit Signs	0.09	0.02	0.00	1	-25.7	8.5	0.06
LGOFF	LGT	Efficient Exit Signs	0.13	0.04	0.00	2	-23.0	12.0	0.08
SCHOL	LGT	Efficient Exit Signs	0.12	0.04	0.00	2	-19.6	13.4	0.09
HOTEL	LGT	Compact Fluorescents	0.92	0.07	-0.07	-3	-6.8	3.2	0.18
GROCR	REF	Floating Head Press	3.06	-0.30	-0.82	-16	-1.9	-3.9	0.27
HOTEL	LGT	Efficient Exit Signs	0.15	0.04	0.00	3	211.8	11.0	0.28
SMOFF	HVC	Heat Pump	0.53	0.05	0.04	5	20.8	3.7	0.34
FASTF	HVC	Heat Pump	1.50	0.13	0.12	5	18.7	3.4	0.47
GROCR	REF	Anti-Sweat Timer	4.73	0.10	0.15	2	16.1	0.8	0.60
WAREH	HVC	Heat Pump	0.85	0.04	0.03	2	15.5	1.8	0.66
HOSPT	ALL	Building Commissioning	3.18	0.29	0.13	3	12.2	3.6	1.17
GROCR	REF	Hot Gas defrost	2.59	0.07	0.12	3	11.2	1.1	1.24
HOSPT	LGT	Efficient Exit Signs	0.07	0.04	0.01	10	5.6	22.0	1.25
FASTF	ALL	Building Commissioning	2.60	0.29	0.33	8	5.3	4.4	1.47
SMRET	LGT	Daylight Dimming	0.76	0.08	0.09	8	4.2	4.1	1.54
HOTEL	ENV	R-11 Wall Insul.	0.23	0.05	0.04	11	3.3	8.5	1.56
WAREH	LGT	Occupancy Sensors	0.61	0.05	0.10	10	3.1	3.2	1.60
SMOFF	ALL	Building Commissioning	0.71	0.29	0.25	23	2.2	16.2	1.69
LGRET	ALL	Building Commissioning	2.73	0.29	0.27	7	2.1	4.2	1.86
HOTEL	ALL	Building Commissioning	1.04	0.29	0.25	16	2.1	11.1	1.96
SCHOL	ALL	Building Commissioning	1.05	0.29	0.27	17	2.0	10.9	2.13
HOTEL	HVC	Variable Speed Drives	0.17	0.03	0.04	16	2.0	6.9	2.14
GROCR	REF	Effic. Evap Fans	2.08	0.27	0.54	15	1.9	5.1	2.20
LGOFF	ALL	Building Commissioning	1.10	0.29	0.29	17	1.9	10.5	2.34
HOSPT	ENV	Add R-5 Wall Insul.	0.31	0.11	0.10	21	1.6	14.5	2.39
HOSPT	ENV	Windows U-0.60 to U-0.45	0.67	0.24	0.22	22	1.6	14.7	2.50
LGOFF	LGT	Occupancy Sensors	1.20	0.26	0.39	20	1.5	8.6	2.65
GROCR	REF	Mech. Subcooling	0.74	0.12	0.24	20	1.5	6.4	2.67
GROCR	REF	Ref. Case Covers	1.58	0.28	0.53	20	1.5	7.1	2.72
GROCR	ALL	Building Commissioning	0.89	0.29	0.30	22	1.5	12.9	2.74
SMRET	ALL	Building Commissioning	0.69	0.29	0.27	25	1.3	16.6	2.81
LGRET	LGT	T12EEM to T8Elect.	1.58	0.23	0.60	22	1.3	5.8	2.91
WAREH	LGT	Daylight Dimming	0.20	0.06	0.08	24	1.3	12.1	2.93
SMRET	LGT	90W Halogen to 60WHIR	0.85	0.01	0.34	22	1.3	0.5	3.01
SMRET	HVC	Heat Pump	0.56	0.12	0.23	25	1.2	8.6	3.06
LGOFF	LGT	Ambient/Task Design	1.41	0.38	0.58	25	1.2	10.7	3.25

Table G-52: Continued

Cost-Effectiveness Summary Output for New Commercial Buildings

PROTO-TYPE	END-USE	MEASURE DESCRIPTION	ANNUAL SAVINGS kWh/ft2	FIRST COST $/ft2	PV COST $/ft2	LEVEL-IZED COST mills /kWh	B/C RATIO	SIMPLE PAYBACK years	CUMUL. WEIGHTED SAVINGS kWh /ft2
SMOFF	LGT	Ambient/Task Design	1.41	0.41	0.54	24	1.2	11.7	3.42
WAREH	LGT	Ambient/Task Design	0.19	0.08	0.08	28	1.2	16.2	3.43
SMRET	LGT	T12EEM to T8Elect.	1.85	0.49	1.06	34	0.9	10.6	3.61
SCHOL	ENV	R-19 to R-25 Roof/Ceil.	0.20	0.12	0.12	39	0.9	24.1	3.64
SMOFF	LGT	Daylight Dimming	1.17	0.52	0.65	35	0.8	17.8	3.79
SCHOL	ENV	Windows U-0.60 to U-0.45	0.24	0.15	0.15	43	0.8	26.1	3.83
SCHOL	ENV	R-19 Wall Insul.	0.40	0.28	0.29	47	0.7	28.7	3.89
WAREH	ENV	Add R-5 Wall Insul.	0.34	0.26	0.25	49	0.7	30.6	3.91
HOSPT	LGT	Ambient/Task Design	0.14	0.06	0.09	40	0.7	17.5	3.93
LGOFF	ENV	Windows U-0.60 to U-0.45	0.74	0.54	0.55	48	0.7	29.3	4.03
WAREH	ALL	Building Commissioning	0.35	0.29	0.27	51	0.7	32.8	4.05
SCHOL	ENV	Add R-5 Wall Insul.	0.30	0.23	0.23	50	0.7	30.5	4.10
GROCR	LGT	T12EEM to T8Elect.	2.04	0.62	1.54	44	0.7	12.2	4.16
LGRET	LGT	90W Halogen to 60WHIR	1.95	0.05	1.55	43	0.6	1.0	4.28
SCHOL	HVC	Variable Speed Drives	0.20	0.11	0.16	50	0.6	21.3	4.32
SCHOL	ENV	R-25 to R-30 Roof/Ceil.	0.12	0.10	0.10	55	0.6	33.4	4.33
HOTEL	ENV	Windows U-0.60 to U-0.45	0.56	0.37	0.49	54	0.6	26.7	4.39
LGOFF	HVC	Variable Speed Drives	0.10	0.05	0.08	51	0.6	21.8	4.40
SMOFF	ENV	Add R-5 Wall Insul.	0.26	0.44	0.44	112	0.6	68.6	4.43
FASTF	LGT	T12EEM to T8Elect.	1.54	0.45	1.15	44	0.6	11.8	4.56
GROCR	LGT	90W Halogen to 60WHIR	0.45	0.01	0.46	56	0.5	0.8	4.57
HOSPT	LGT	90W Halogen to 60WHIR	0.06	0.00	0.06	56	0.4	2.2	4.58
WAREH	ENV	R-19 to R-25 Roof/Ceil.	0.08	0.10	0.10	82	0.4	50.4	4.58
SCHOL	ENV	R-30 to R-38 Roof/Ceil.	0.13	0.16	0.16	83	0.4	49.7	4.60
HOSPT	LGT	Daylight Dimming	0.10	0.09	0.11	71	0.4	36.5	4.62
SMOFF	ENV	R-19 to R-25 Roof/Ceil.	0.03	0.07	0.07	171	0.4	103.6	4.62
SMOFF	HVC	Economizer	0.60	0.49	0.96	97	0.3	33.0	4.70
HOSPT	LGT	T12EEM to T8Elect.	0.31	0.23	0.48	92	0.3	29.3	4.75
SMOFF	ENV	R-25 to R-30 Roof/Ceil.	0.01	0.06	0.06	270	0.2	162.0	4.75
SMOFF	ENV	Windows U-0.60 to U-0.45	0.16	0.80	0.83	331	0.2	197.8	4.77
SMOFF	ENV	R-30 to R-38 Roof/Ceil.	0.02	0.09	0.09	359	0.2	214.7	4.77
HOSPT	LGT	Occupancy Sensors	0.09	0.13	0.28	192	0.1	59.4	4.78
LGOFF	LGT	Daylight Dimming	0.11	0.32	0.40	224	0.1	112.8	4.80
GROCR	REF	Liq. Press. Amp.	0.64	1.09	2.31	216	0.1	68.6	4.82
LGOFF	HVC	Evaporative Cooling	0.17	0.65	1.02	360	0.1	150.1	4.84
LGRET	HVC	Evaporative Cooling	0.20	0.80	1.25	391	0.1	163.0	4.85

Table G-53:
Cost-Effectiveness Summary Output for Existing Commercial Buildings

PROTO-TYPE	END-USE	MEASURE DESCRIPTION	ANNUAL SAVINGS kWh/ft2	FIRST COST $/ft2	PV COST $/ft2	LEVEL-IZED COST mills /kWh	B/C RATIO	SIMPLE PAYBACK years	CUMUL. WEIGHTED SAVINGS kWh /ft2
SMOFF	HVC	Reduce Min. Outside Air	1.53	0.02	0.00	0	-151.2	0.6	0.42
LGOFF	LGT	100W Incand. to 34W Fluor.	0.50	0.24	-0.12	-9	-1.7	19.0	0.56
LGOFF	HVC	Temp Reset, Multi Zone	1.46	0.02	0.00	0	1524.3	0.5	0.56
SMOFF	LGT	Incand. to 34W Fluor.	0.39	0.35	0.02	14	8.7	35.8	0.66
LGOFF	HVC	Roof Insulation R-6 to R-19	0.23	0.03	0.02	9	4.0	5.7	0.80
LGRT	HVC	Reduce Min. Out. Air	1.21	0.08	0.14	8	3.7	2.8	0.80
LGRT	LGT	Efficient Incand.	3.88	0.33	0.25	5	3.4	3.4	0.90
LGRT	ENV	Roof Insulation	1.88	0.36	0.27	12	3.0	7.5	1.11
SMOFF	ALL	Re-Commissioning	1.53	0.23	0.27	13	2.4	6.0	1.18
SMRT	ENV	Roof Insul. (Sales)	3.41	0.66	0.50	12	2.2	7.8	1.86
SMOFF	ENV	Roof Insulation	1.13	0.39	0.32	22	1.5	13.8	2.11
LGRT	DHW	Tank Insulation	0.02	0.00	0.00	20	1.5	6.4	2.32
LGRT	ALL	Re-Commissioning	0.96	0.23	0.28	21	1.5	9.6	2.35
SMRT	DHW	Tank Insulation	0.03	0.01	0.01	20	1.5	6.6	2.86
SMOFF	DHW	DHW Tank Insulation	0.09	0.02	0.03	21	1.4	6.8	3.21
SMRT	ALL	Re-Commissioning	0.86	0.23	0.28	24	1.3	10.7	3.30
SMRT	LGT	Efficient Incand.	0.82	0.26	0.29	26	1.2	12.9	3.30
LGOFF	LGT	T-8 EEM Bal & Parab. Fixt	3.95	1.61	1.42	28	1.2	16.3	3.51
SMRT	LGT	T-8 Elect. (Sales)	1.94	0.68	0.92	35	0.9	14.0	5.86
LGRT	LGT	T-8 Elect. (Storage)	0.43	0.15	0.22	36	0.8	13.9	6.14
SMRT	LGT	2T T-8 Elect.(Stor)	0.15	0.04	0.07	35	0.8	10.2	7.26
LGRT	LGT	T-8 Elec. (Sales)	6.26	2.40	3.20	37	0.8	15.3	7.30
SMRT	HVC	Heat Pump (Repl)	1.05	0.48	0.60	42w	0.8	18.2	7.37
LGOFF	HVC	Variable Air Volume	8.32	2.99	4.86	41	0.7	14.4	7.89
LGOFF	LGT	T-8 Add Electronic Ballasts	0.74	0.34	0.45	44	0.7	18.4	9.01
LGRT	ENV	Caulking & Weather.	0.01	0.00	0.01	50	0.6	16.3	9.22
LGOFF	LGT	Daylight Dimming	0.32	0.17	0.22	51	0.6	20.9	9.45
SMOFF	LGT	T-8 & Elect. Ballast	1.28	0.87	0.89	53	0.6	27.3	9.48
SMOFF	ENV	Low-e Glass	1.87	1.71	1.49	62	1	36.6	9.49
SMRT	ENV	Roof Insul.(Storage)	0.12	0.12	0.10	64	0.5	38.2	9.66
SMOFF	HVC	Optimum Start timer	0.75	0.49	0.65	63	0	26.3	9.66
SMOFF	HVC	Economizer	0.95	0.73	0.98	75	0.4	30.8	9.97
SMOFF	HVC	Heat Pump @ AC repl.	2.50	2.05	2.70	79	0.4	32.8	10.88
SMOFF	LGT	Daylight Dimming	0.26	0.24	0.32	91	0.3	37.0	11.29
LGRT	ENV	Wall Insulation	1.14	1.81	1.60	109	0.3	63.8	11.63
SMRT	ENV	Low-E Wind. (Sales)	0.38	0.68	0.59	122	0.3	71.6	12.32
SMOFF	DHW	DHW Cock Timer	0.01	0.02	0.02	114	0.3	46.8	12.53
SMOFF	LGT	3 Tube Parabolic Fixtures	0.49	1.20	1.01	160	0.2	97.0	12.60
SMRT	HVC	Heat Recov. Exhaust	0.38	0.76	1.06	202	0.2	80.0	12.71
LGRT	HVC	Radiant Heaters	0.03	0.04	0.08	209	0.1	66.0	13.12

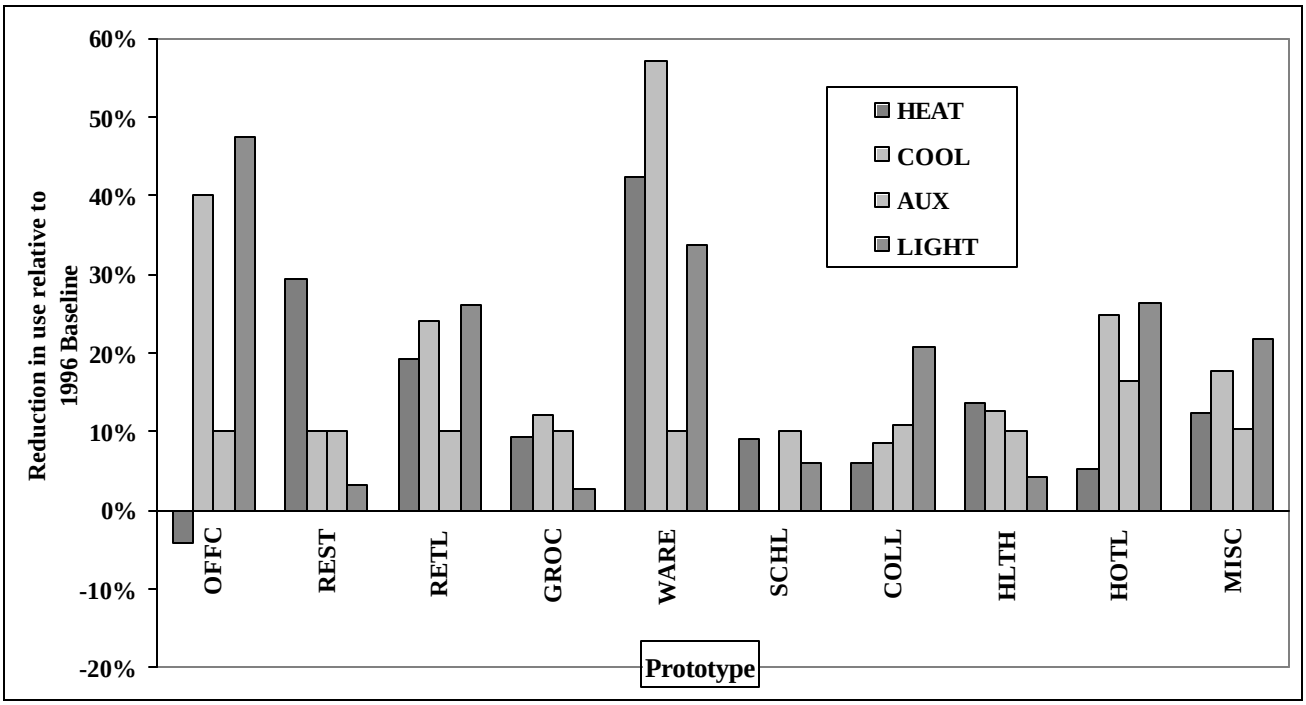
STEP 3. REGIONAL LOAD FORECAST IMPACTS

In order to determine the regional resource technical potential, it is necessary to take the efficiency changes in the prototypes and apply them to the various sectors in the regional load forecast. The first step in this process is to develop a table of energy use for each end-use in each prototype that contains the use with all cost-effective efficiency measures applied as a fraction of 1979 stock use. These relative efficiencies are applied in the load forecast for each of the five load growth cases. For comparison purposes, an identical set of load growth scenarios is run assuming that efficiency is frozen at 1996 levels. In the case of new buildings, these relative efficiencies are applied after the latest building codes and standards are put in place; i.e., included in the frozen efficiency baseline. Both new codes in Oregon and Washington and the EPAct standards are included in this baseline.

Figure G-28 shows the relative changes in energy use for selected end uses relative to the 1996 baseline. Because these are relative values, some of these changes that appear large are in fact quite small in absolute terms. For example, the largest of these, a 57-percent reduction in cooling use in warehouses, is actually only a change from 0.2 kWh per square foot to 0.1 kWh per square foot. It is also important to note that these factors are post application of interaction between measures and therefore do not represent specific change in efficiency alone for a given end-use. For example, although there is no relaxation of efficiency in space heat in offices, space heat actually increases because the decrease in lighting power increases the need for additional space heat.

Figure G-28

Efficiency Change Inputs to the Load Forecast For New Buildings for Selected End-Uses



Figures G-29 and G-30 show the resulting load changes in the medium forecast in the year 2015 by sectors after the relative efficiency changes are applied to the appropriate end-uses. Figures G-31 and G-32 show the resulting distribution of savings by end-use from the medium forecast in the year 2015.

Figure G-29
New Commercial Building Loads by Sector in 2015

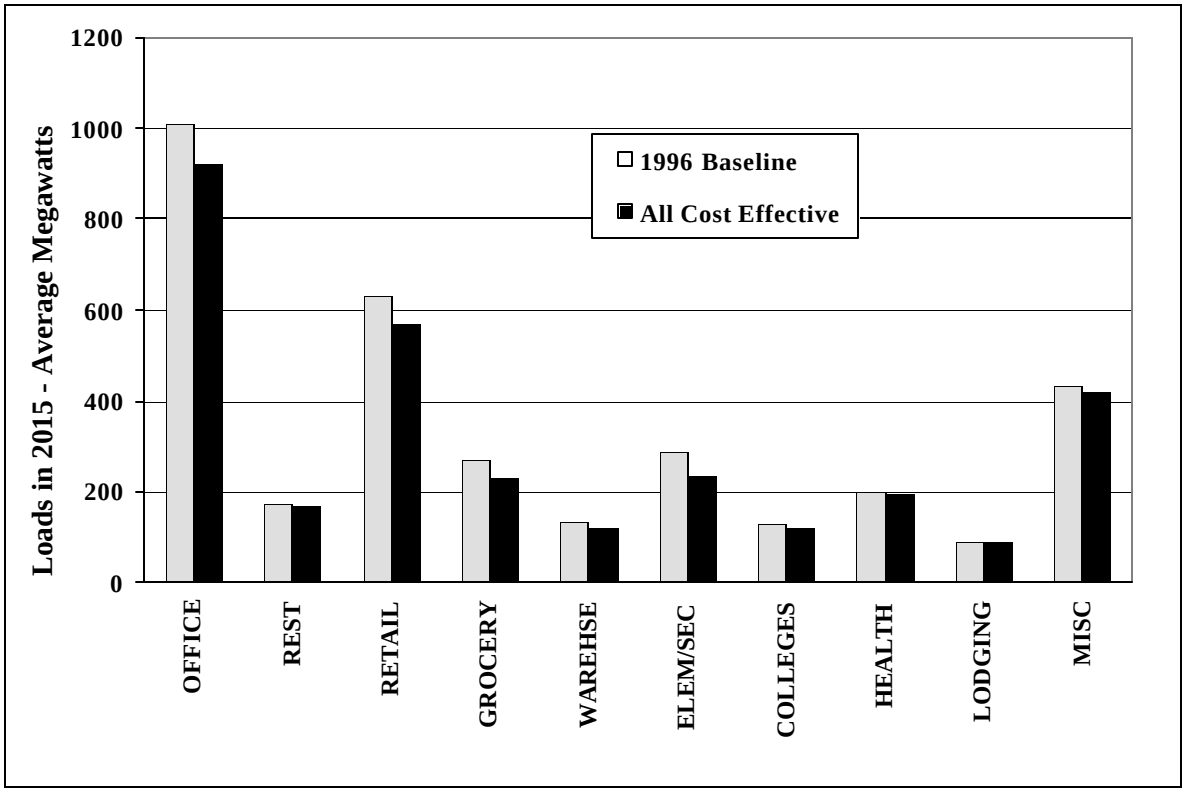


Figure G-30
Existing Commercial Building Loads by Sector in 2015

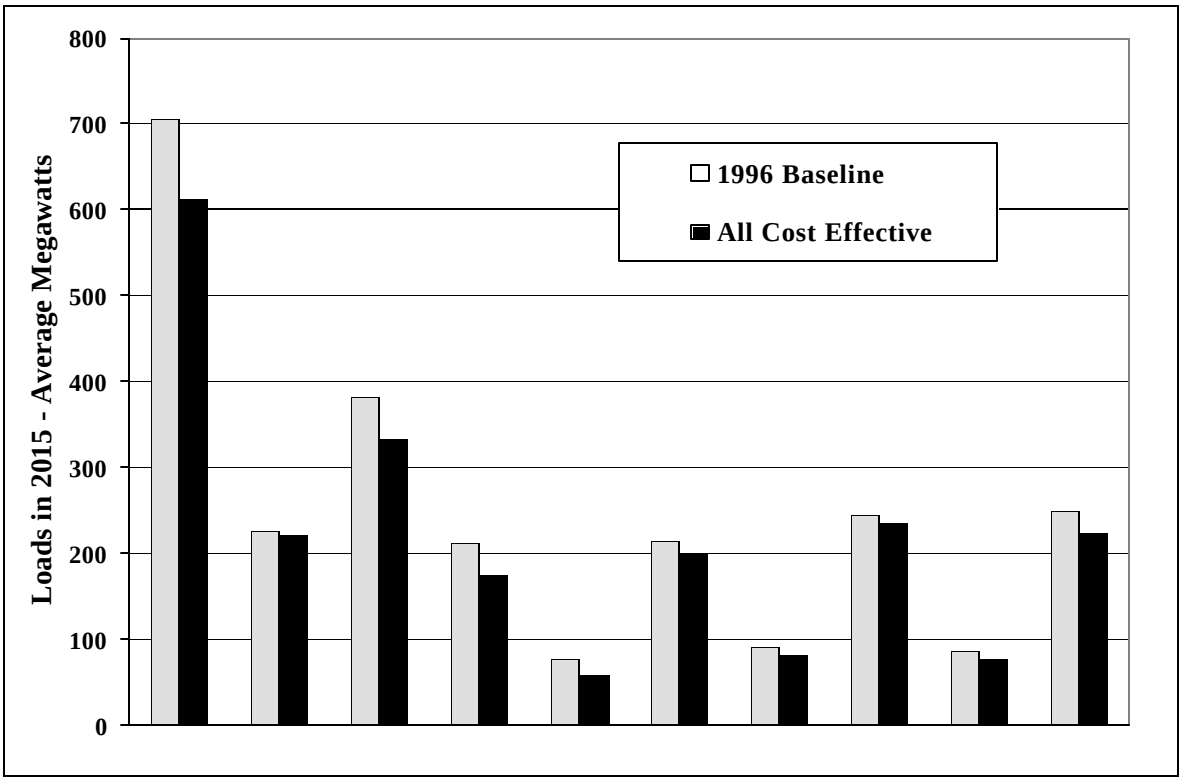


Figure G-31
Distribution of Load Savings By End-Use in New Buildings in 2015 - Medium Forecast

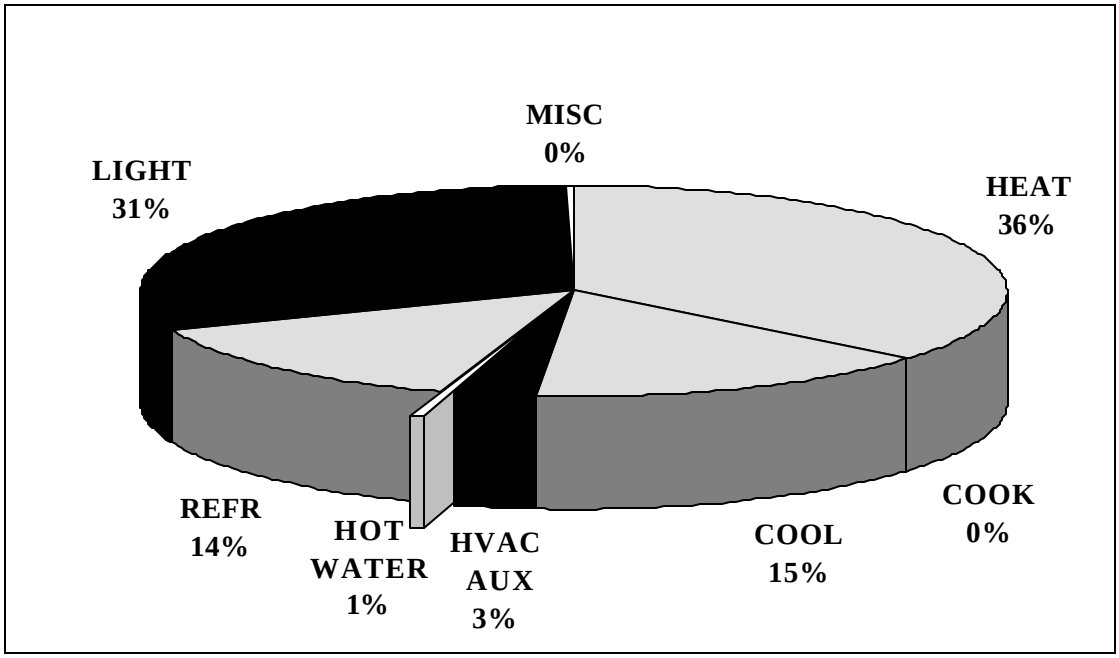
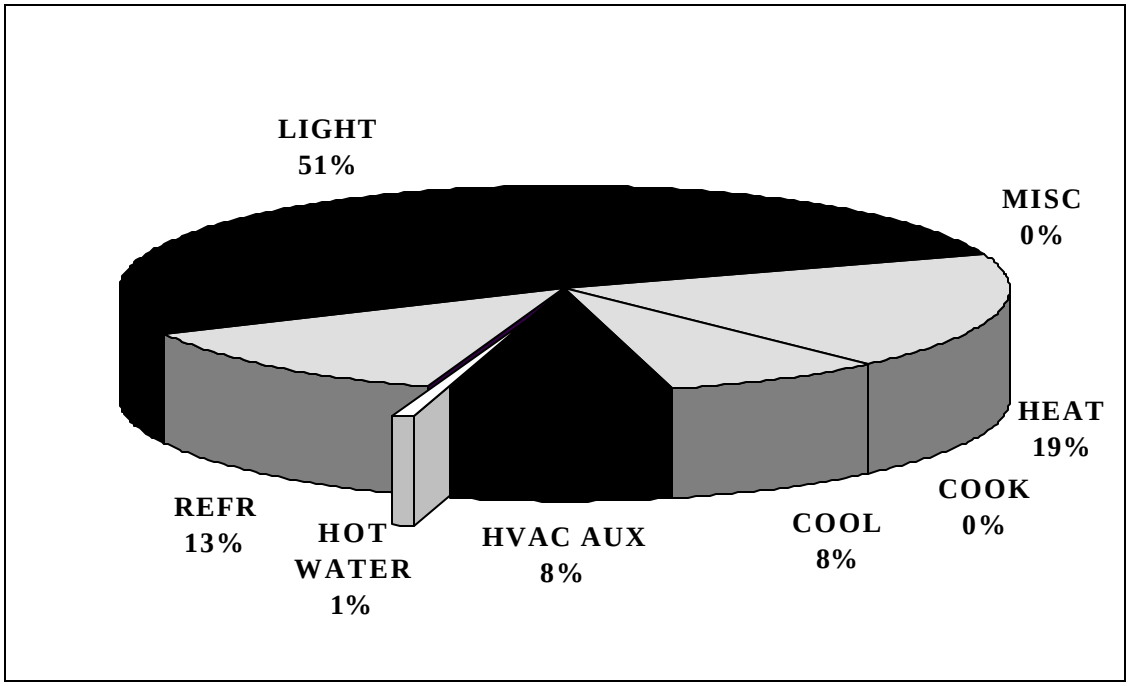


Figure G-32
Distribution of Load Savings By End-Use in Existing Buildings in 2015 - Medium Forecast



The resource available from major renovations is computed separately from new or existing buildings by running the load forecast assuming that all existing buildings are retrofitted to the same level of efficiency as new buildings. The difference between this forecast and the normal retrofit case represents the potential available if all of the existing buildings underwent this level of renovation. This is not the case, however,

since the average building lasts 45 years in the forecast. In order to compensate for this fact, the renovation resource is adjusted by the ratio of the years of program operation (20) to the average building lifetime (45).

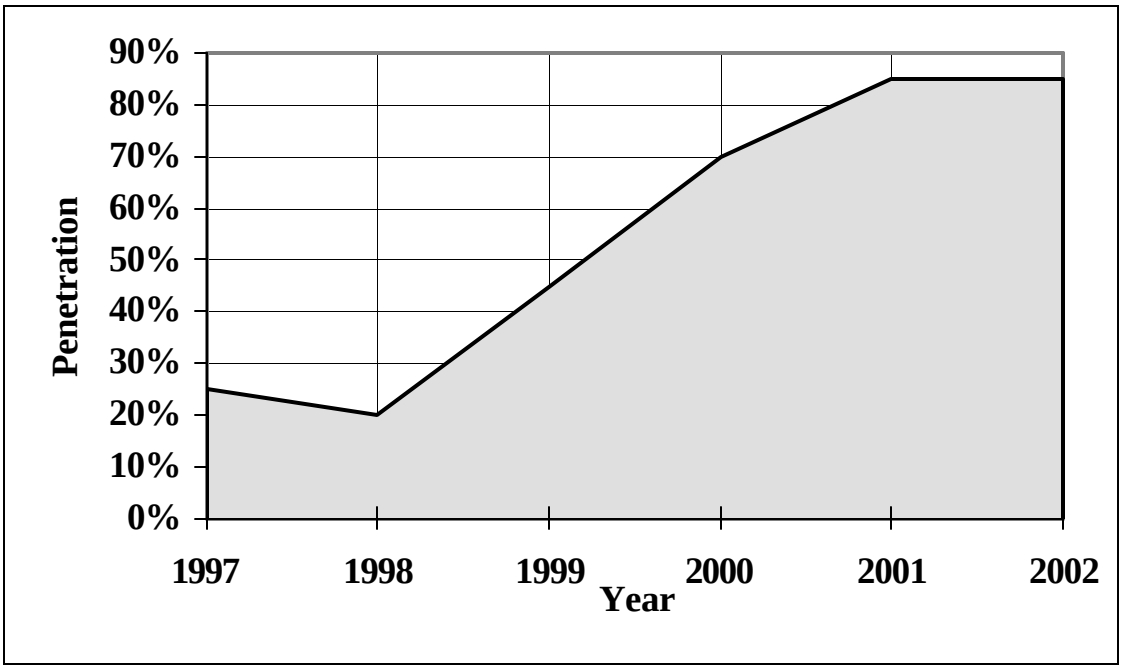
STEP 4. MODELING EFFICIENCY PROGRAMS

The *technical* resource potential from each of the load forecast cases must be translated into *achievable* resource potential for use by the system acquisition model. This requires shaping the savings into a real-world efficiency measure program. There are many different ways to approach this problem. In this analysis, several different ways of approaching this problem are used. The first of these is the traditional approach of taking all the measures that are cost-effective to the region and modeling a program that would assume full regional support and financing to acquire these measures. The second approach attempts to estimate what fraction of each of the measures will be developed by existing or future utility programs without regional intervention and what individual consumers will do on their own without intervention from either the utilities or any other regional effort.

All Cost-Effective Measures Program

There are two primary adjustments to the results from the load forecast to simulate this program. The first reduces the potential to account for the real-world limitations of physical constraints not modeled by the prototypes or load forecast. For example, it is not realistic to assume 100 percent compliance with a building code, even though a building code is probably the most comprehensive delivery mechanism for the resource. Traditionally, the Council has held the view that 85 percent of the technical potential is achievable given all of the resources available under the Northwest Power Act to acquire the efficiency measures. This view is still supported in this plan, and is reinforced by analyzing the measures with building commissioning forced to be the first measure in the stack of cost-effective measures. For new buildings, this is further reduced by an estimate of how long it will take the effort to acquire new measures to "ramp up" assuming a unified regional effort to acquire all cost-effective measures. Figure G-33 shows the ramp assumed in this analysis. The slight dip in the penetration ramp is intended to reflect an expected near-term ramp-down in program activity.

Figure G-33
New Building Measure Penetration Ramps



Existing building potential is reduced by the 85-percent achievable factor and then further reduced by subtracting the estimated conservation acquired over the last five years. Using data from NUTrak, this amount was estimated at 98 average megawatts for the period 1991 through 1995.

The second major adjustment to the technical potential is shaping the energy represented by the measure bundle appropriately into each of the load segments for each month. This is accomplished by summing the energy savings in each load segment across all measures and then normalizing by dividing the total energy across all segments into each segment. The resulting normalized set of load segments is used by ISAAC to shape the resource. Unlike the other conservation resources, which are shaped by a fixed savings shape, the commercial sector load will vary depending on which measures are determined to be cost-effective.

Figures G-34 and G-35 show the percent of annual savings mapped to each load segment for new and existing buildings, respectively. Figures G-34 and G-35 indicate that both new and existing commercial buildings represent winter peaking resources with the existing sector accumulating slightly more in the winter than new buildings. And in both sectors, the majority of the savings come from the peak and secondary load segments.

Figure G-34

Distribution of Annual Energy Savings for New Commercial Buildings by Load Segment

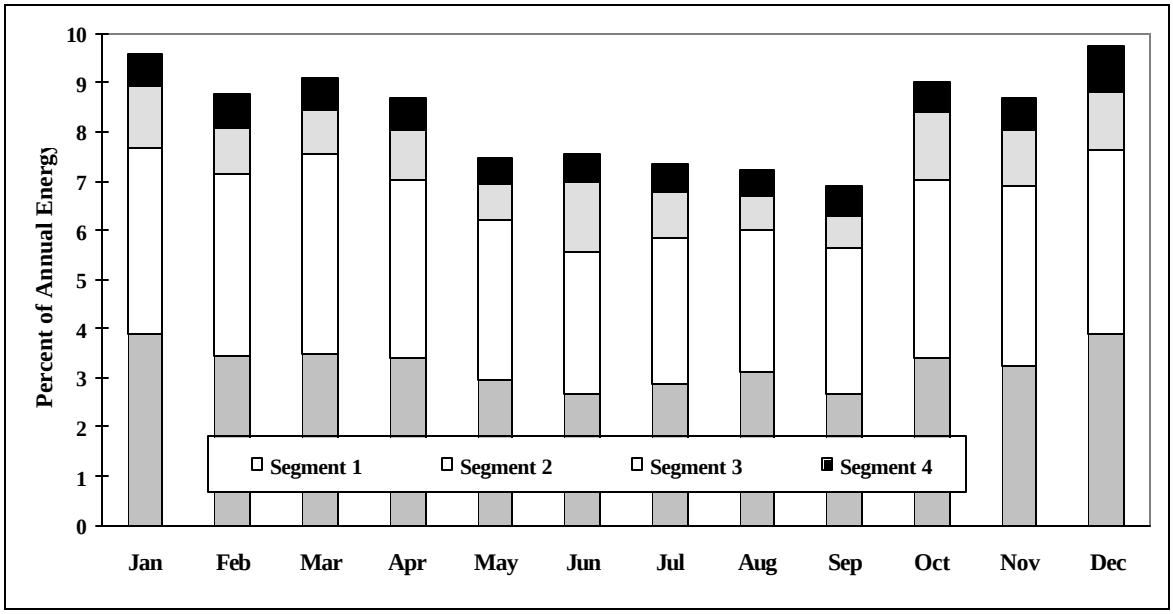
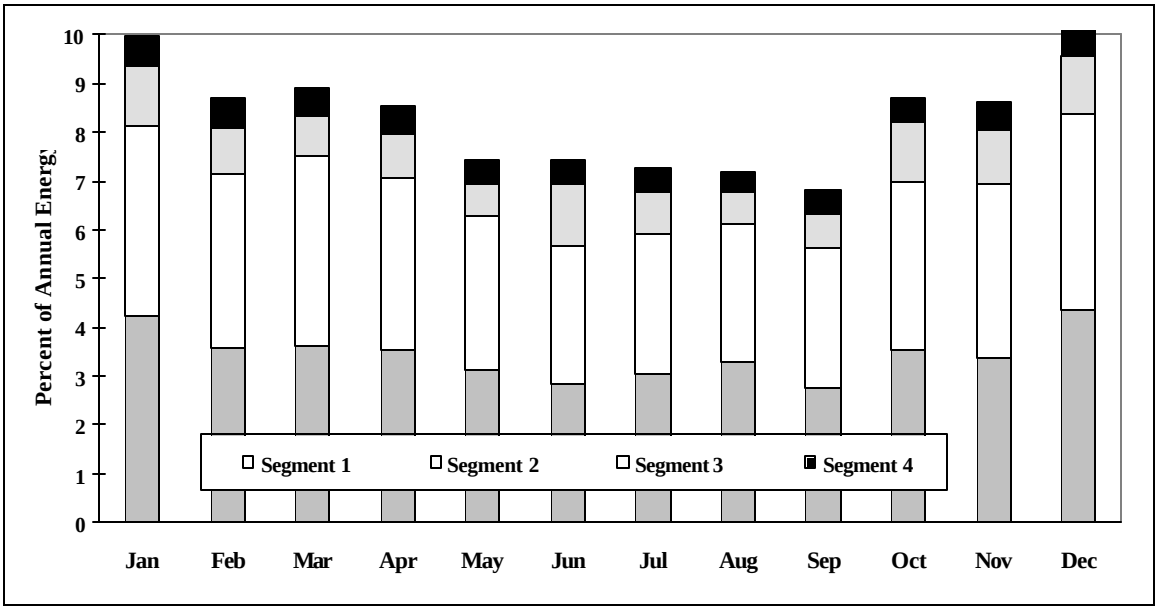


Figure G-35

Distribution of Annual Energy Savings for New Commercial Buildings by Load Segment



INDUSTRIAL SECTOR

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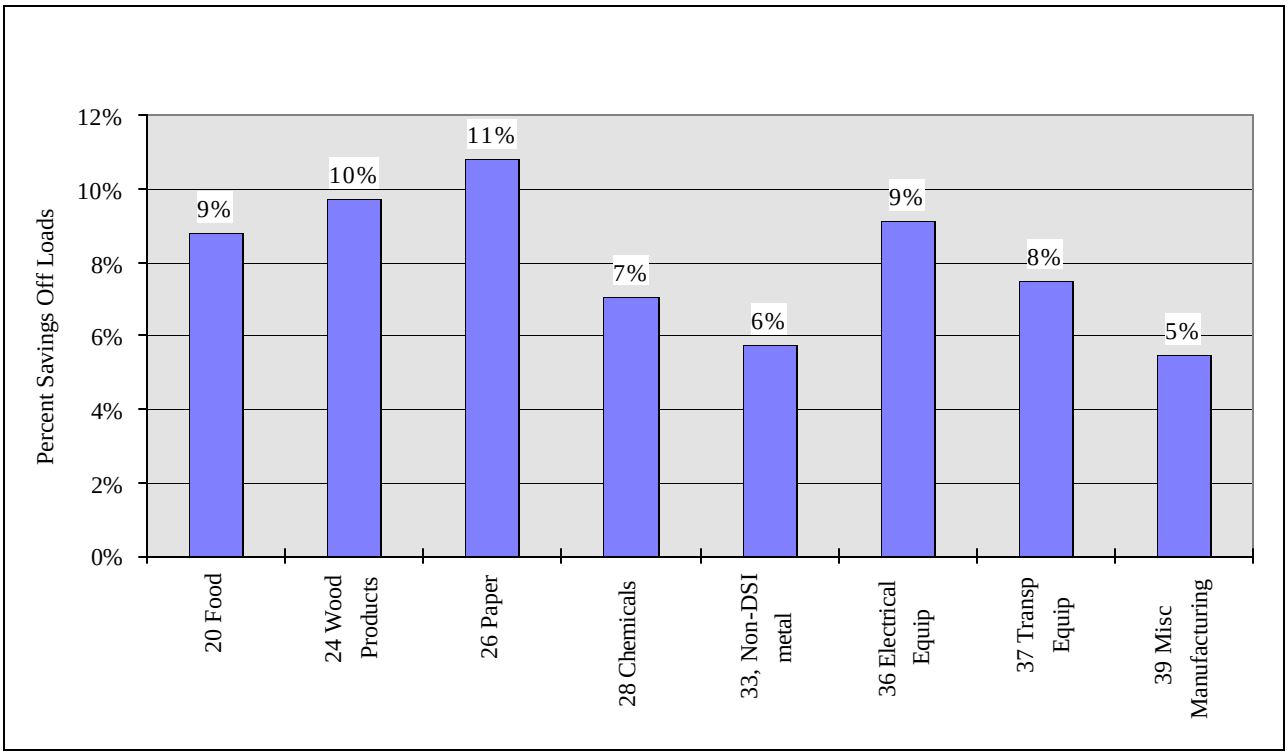
INDUSTRIAL SECTOR

SUMMARY

This chapter finds that approximately 8 percent of electric industrial loads[73] could be saved cost-effectively by the year 2015 if sufficient financial and human resources are provided. Assessing the potential savings and costs from the industrial sector presents a more difficult problem than in any other sector. Not only are many of the industrial uses of electricity more diverse than in other sectors, but the conservation potential is also more site or process specific. Savings could range from a low of 4 percent to a high of 18 percent, based on the information reviewed in this chapter. In terms of the current forecast of electricity loads, this translates to 565 average megawatts in the medium forecast, with a range of 280 to 1,270 average megawatts. These savings are available at a levelized cost of approximately 1.4 cents per kilowatt-hour.

The savings estimates presented here are a composite of work already done in the region, including estimates from in-field audits and program experience. Work is drawn from: the Oregon Department of Energy, Bonneville Power Administration, the Energy Analysis and Diagnostic Center, Portland General Electric, Puget Power, Seattle City Light, B.C. Hydro, and the American Council for an Energy Efficient Economy. These sources used multiple methods to derive their savings, using program experience, audits, evaluations, and judgment from in-field staff combined with various modeling approaches. The average savings percentage across these estimates by major industrial category appears in Figure G-36. They range from 6 percent in the non-direct-service-industry metals to 11 percent in the paper industries. The regionally weighted average across all types is 8 percent after historic savings have been removed.

Figure G-36
Average Achievable Savings For Major Industrial Type



ESTIMATING LONG-RUN COSTS AND SAVINGS

[73] This does not include savings from the direct-service industries, served by Bonneville.

The Northwest Power Planning Council's estimates of conservation are based on all the cost-effective conservation that all parties could accomplish over a 20-year horizon, including actions by government, consumers, manufacturers, trade allies and utilities. Cost-effectiveness is determined by accounting for all the costs and savings of potential resources, including sales from the West Coast market, and then selecting all conservation measures that are less expensive. If the conservation is actually developed, it will require significant resources, including money, developing a favorable environment, ensuring customer satisfaction, and potentially marketing many of the non-energy benefits of conservation actions.

Cost-effective conservation was targeted in prior plans to be acquired through various mechanisms, but primary responsibility fell to utilities during periods when they were acquiring resources to meet load growth. It was argued that utilities could pay up to the avoided cost to secure conservation, and it would still be cost-effective. However, the historic role played by the utility is changing. (See Volume 1 of this plan "The Changing Role of Utilities in Conservation Development.") Consumers have more options than ever to secure electricity resources, and many of these operations are available at lower costs than current retail rates. In this world, utilities will have limited ability to raise one customer's rates to secure conservation in another customer's house or business. How to secure all or part of the cost-effective conservation will still need to be determined. This section simply tries to estimate the overall size of the resource potential.

The 8-percent savings were derived by averaging estimates made by regional parties for each industrial category, and then removing historic savings. These achievable savings are based on values derived by Bonneville, Oregon Department of Energy, Puget Power Sound and Light, Portland General Electric, and Pacific Power and Light. Although other estimates of technical potential were also consulted, the achievable estimates were some of the highest-quality and regionally oriented estimates. Further description of the method to derive savings can be found in the "Summary and Use of Current Data" section below.

ESTIMATES OF SAVINGS AND COST FROM PRIOR POWER PLANS

The Council has estimated savings from the industrial sector four times in the past. As shown in Figure G-37, these estimates have been in the range of 6- to 10-percent savings off industrial loads. Savings are normalized as a percentage of kilowatt-hour consumption because some earlier estimates covered existing industries only, and others covered new and existing industrial loads combined. Table G-55 lists key features of prior estimates of conservation from the industrial sector. The avoided costs in all prior estimates were fairly constant if brought to the same year's dollars. The avoided cost used in the this plan are much lower, but the effect of this is relatively minor, given current data.

Figure G-37

Comparison of Achievable Industrial Sector Estimates in Prior Plans

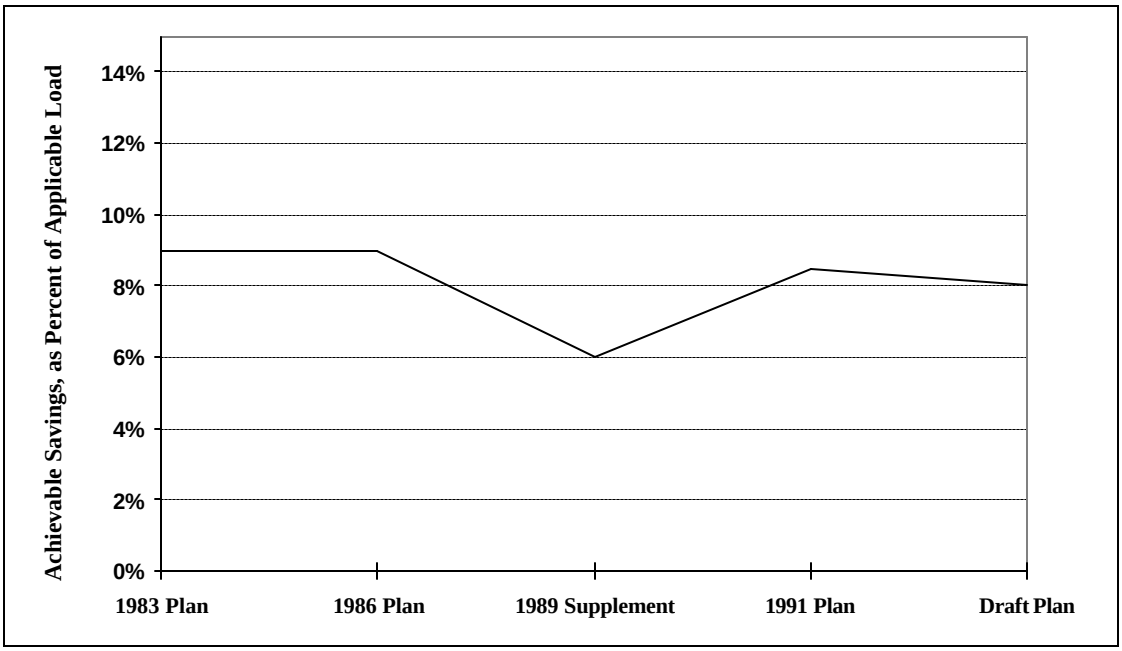


Table G-55

Comparison of Achievable Industrial Sector Estimates in Prior Plans

1983 Plan	1986 Plan	1989 Supplement	1991 Plan	1996 Draft Plan
550 average megawatts	500 average megawatts	260 average megawatts	740 aMW in high[74]; 490 in medium forecast	895 aMW in high, 565 in medium forecast
Savings = 9% of existing loads	Savings = 9% of existing loads	Savings = 6% of existing loads	Savings = 9% of total loads	Savings = 8% of total loads
Existing Industries Only	Existing Industries Only	Existing Industries Only	New and Existing	New and Existing
Includes DSIs	Includes DSIs	Excludes DSIs[75]	Excludes DSIs	Excludes DSIs
Based on Self-Assessment	Survey	Survey	End-Use plus Audit Information	Analysis of Other's Estimates

The 1983 and 1986 Plans, and the 1989 Supplement all used estimates of savings that were based on industrial customers responding to a survey about how much efficiency was available in their plants. The surveys were coordinated by industry trade associations, such as the Northwest Pulp and Paper Association and the Industrial Customers of Northwest Utilities. Data from specific firms were masked by the associations to protect proprietary data. Savings were estimated at about 500-550 average megawatts from existing industries only, or 9 percent off existing industrial loads in the 1983 and 1986 plans, including

[74] In prior estimates, savings were estimated from existing stock only, and so they were independent from assumptions about load growth. In 1991 Plan, part of the savings were a function of load growth, and the medium-forecast and high-forecast savings are given here.

[75] The overall savings estimate in the 1989 Supplement was the same as prior power plans, except that the conservation modernization (con/mod) program for the direct-service industries was accomplished between the 1986 Plan and the 1989 Supplement. As a result, the 220 average megawatts of savings expected from con/mod was subtracted from the prior estimate of potential savings.

savings from the direct-service industries (primarily the aluminum companies). This dropped to 320 average megawatts, or about 6 percent off existing industrial loads, in the 1989 Supplement because savings in aluminum company loads had already been accomplished through the Con-mod program. None of these estimates included savings from new industrial loads, whether these were new plants built on new site or simply increased production at an existing plant. All of these estimates were considered "achievable" because they were what plant managers identified as doable up to a certain cost.

The 1991 Plan changed the basis on which overall industrial sector savings were estimated. At that time, Bonneville had spent significant effort developing an end-use model that would estimate savings and costs for generic measures applied to various end-uses, such as motors and lights. This model indicated savings of about 265 average megawatts for existing loads, and an additional 275 average megawatts for new and expanding loads. These savings were technical potential, and represented about 6 percent savings off non-aluminum industrial use in the year 2010. In contrast to prior estimates, this was for existing and new industrial loads. Similar to the 1989 estimate, it did not include the aluminum industries.

The advisory committee reviewing the model proposed for the 1991 Plan criticized it because it did not cover all end-uses and industries, and it missed recent information available from audits on the variety of applicable conservation measures. For example, the 1991 model did not include savings from adjustable-speed drives. As a result of this, the committee compared the results of the model to results from simple industrial conservation audits. The audits showed savings on the order of 10 percent, which was higher than the model predicted. In the 1991 Plan, the Council used 6 percent savings based on the model as the amount of savings from its "first block" of conservation.[76] It then adopted an additional 4 percent savings, based on the audit results in its "second block" of conservation. This second block of savings was assigned a cost that was twice as high as the first block. However, because savings are so inexpensive from the industrial sector, this still resulted in cost-effective savings. The first and second blocks of conservation, summing to a total of 10 percent technical conservation potential, were used as the conservation estimate from the plan. This was reduced by 15 percent to estimate achievable potential.

The savings for the Draft Fourth Northwest Power Plan are based on the average of the achievable estimates presented below in the "Summary and Use of Current Data" section. While the percentage savings are lower than in the 1991 Plan, the absolute average megawatt savings are larger because the forecasts of electricity use have increased significantly between the 1991 and 1996 Plans.

NEW INFORMATION FROM LAST FIVE YEARS OF PROGRAMS

Since the development of the last power plan, utilities have more aggressively pursued industrial conservation than ever before. The 1991 Plan described a region in deficit and called for significant acquisition of conservation resources. Utilities took the initiative and started developing both conservation and generating resources. Industrial sector conservation programs became much more common, well-managed and funded. As a result of this action, we have better information on conservation programs in the industrial sector than in any prior plan. The program that has acquired the most savings and developed the most experience is Bonneville's Energy $avings Plan (E$P). Another important program has been the Business Energy Tax Credit program, administered by the Oregon Department of Energy. These are described next.

Energy Savings Plan

The Energy $avings Plan (E$P) is a program offered by Bonneville to public utilities and industries, which can be used to acquire savings in industrial loads (except aluminum smelter load). The Energy $avings

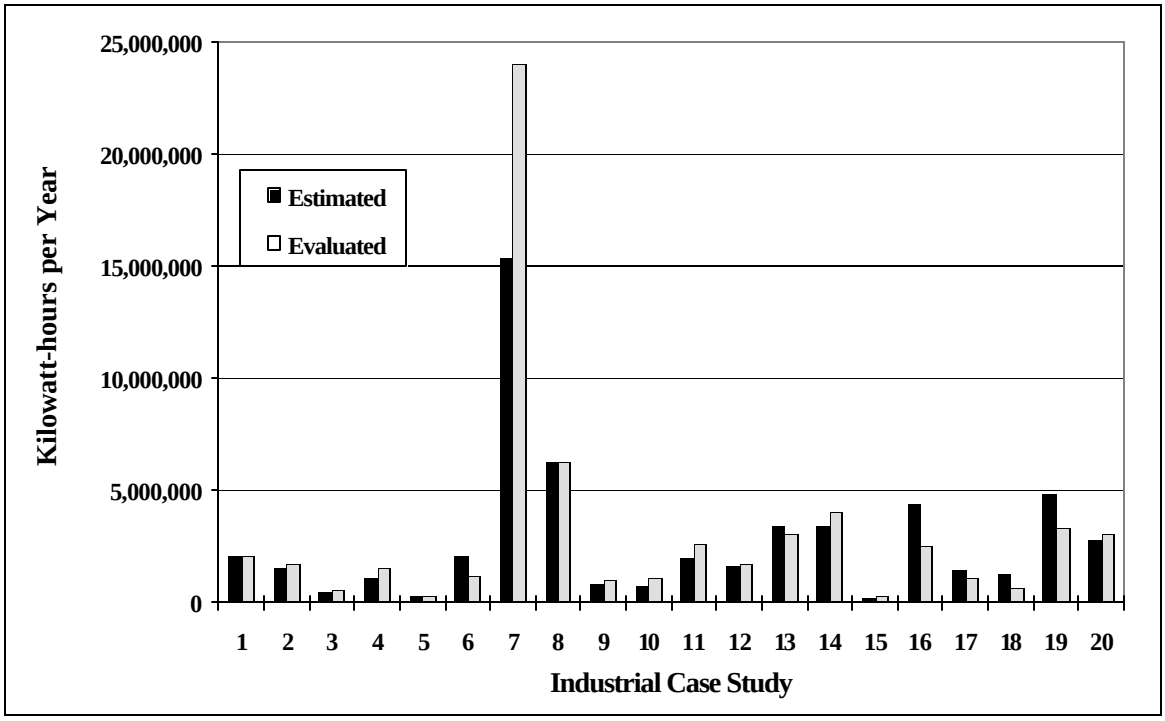
[76]The 1991 Plan had two blocks of conservation. The first block was the amount of conservation measures that cost up to the avoided cost (11 cents per kilowatt hour in nominal dollars, 5.5 cents per kilowatt hour in real or constant dollars). The second block included those resources that were either more expensive, or more uncertain (between 11 and 13 cents per kilowatt hour nominal, 5.5 and 6.5 cents per kilowatt hour real).

Plan program data covers the period between October 1988 and January, 1995. This includes data from 370 projects that saved just over 50 average megawatts. Although the program was offered as early as 1988, in its early development it went through significant changes, and didn't stabilize as a working program until about 1992. Most of the projects in the data described here were post-1992.

Bonneville conducted evaluations on about 30 of the 370 projects. About 20 of these evaluations were conducted after the 1992 stabilization of the program. As shown in Figure G-38, the verified savings for the evaluated projects differs from the post-installation report on a case-by-case basis, but on average, the verified savings are very similar to the savings expected before the measures were installed. This is similar to the results from the pre-1992 data.

Figure G-38

Audit vs. Evaluated Savings Estimates from the Energy Savings Plan Program



The cost of savings from the E$P program were about 0.8 cents per kilowatt-hour to Bonneville, and about 1.4 cents per kilowatt-hour to the region if Bonneville, utility and customer costs are included. [77] These are very inexpensive savings compared to the 5.5 cents per kilowatt-hour avoided cost at the time of program operation, and remain inexpensive compared to the 2.6[78] cents per kilowatt-hour avoided cost today. Figure G-39 shows that if all 370 E$P projects are graphed according to their levelized cost, most of the savings are less than the 2.6 cents per kilowatt-hour avoided cost for the industrial sector. If all projects with more than a 2.6 cent per kilowatt-hour avoided cost are excluded, the total savings drop from 50 average megawatts to 44 average megawatts. Eliminating measures that cost more than 2.6 cents per kilowatt-hour has very little impact on overall costs or savings amounts.

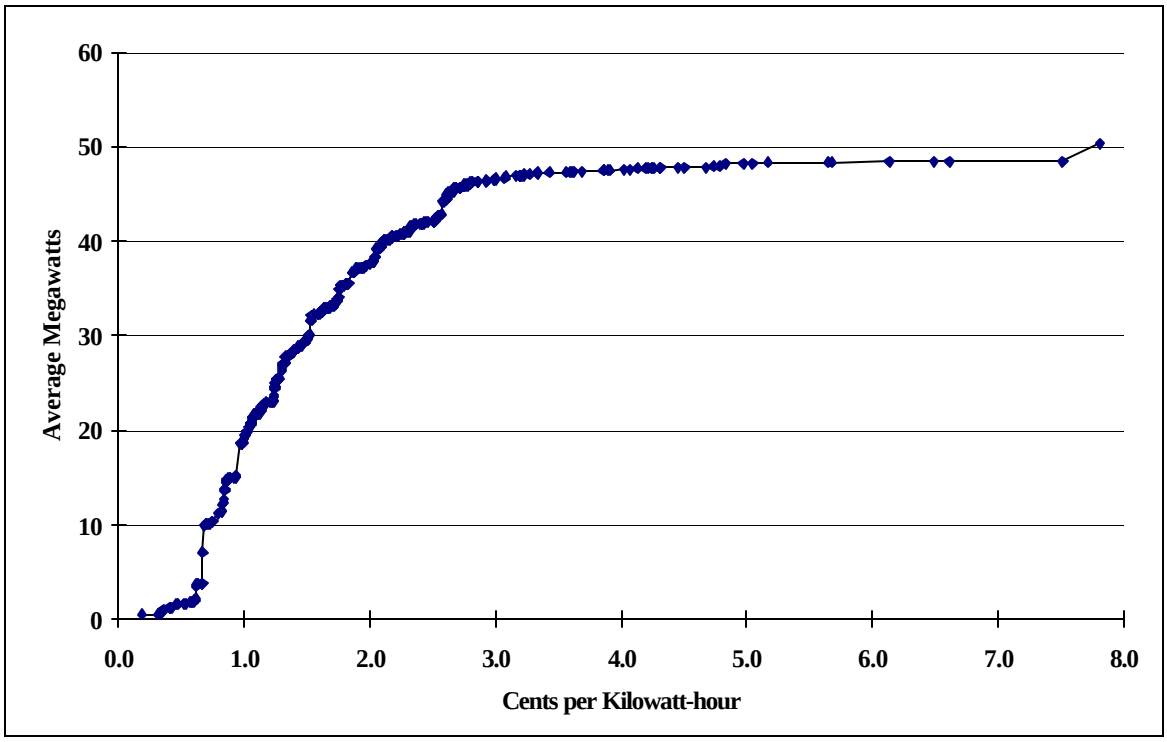
Bonneville used the E$P data as the basis of an estimate of potential savings beyond measures installed in the program, discussed later.

Figure G-39

[77]These costs include administration to both Bonneville and the utilities, and line loss credits. Levelized costs are based on an average 15-year measure life and a 4.75 percent discount rate.

[78]This is the approximate avoided cost for a 15-year resource developed today based on updated gas prices, combustion turbine costs and market prices, including the 10-percent credit from the Act and 7.5-percent line loss credit.

Average Megawatts and Levelized Costs of Savings Secured by the Energy Savings Plan Program



Business Energy Tax Credit in Oregon

The Oregon Department of Energy (ODOE) administers a tax credit to commercial and industrial customers who install efficiency measures in their plants. The Business Energy Tax Credit program (BETC) began in 1980 to encourage commercial and industrial businesses to recycle, use renewable energy, and recover waste heat. Energy conservation was added in 1983. Projects receive a 35-percent tax credit, taken over five years. The Oregon Department of Energy may approve up to $40 million in project costs each year. To qualify for the tax credit, energy projects must save at least 10 percent of the energy used by the systems to which the measure applies.

The program is not specific to electricity savings. Savings of any fuels can qualify for the tax credit. Project paybacks must be greater than one year and less than the life of the equipment. The maximum credit is $2 million per project for industrial measures. To date the program has awarded over $345 million to over 4,100 completed projects. This includes 863 projects for industrial conservation. The 1995 Legislature extended the tax credit through 2001.

Engineering estimates, similar to those used in Bonneville's program, are used to determine if projects meet program standards and if estimated savings are credible. Tax credits are awarded for energy-savings projects that also qualify for utility conservation programs. Until the 1990s, there was little, if any, overlap between the Business Energy Tax Credit and utility industrial conservation programs. Since the 1990s there likely has been more overlap since utility programs began gearing up efforts in this sector in the last few years. Oregon Department of Energy staff estimates that since 1991 about 50-60 percent of the Business Energy Tax Credit projects receiving tax credits also received some form of utility conservation assistance including audits and/or financial incentives.

The data from the business energy tax credit is used to cross-check the levelized cost of savings found in the Energy Savings Plan. If only electricity savings are counted, and some outliers[79] are removed, there were approximately 206 projects totaling about 19 average megawatts. This data represents projects that were installed mostly from 1987 to 1994. The levelized cost of these projects to all parties is about 1.2 cents per kilowatt hour.[80] This low cost is very similar to the results from the Energy Savings Plan.

CURRENT DATA FOR ESTIMATING SAVINGS

A number of organizations, including many in the Northwest, have developed estimates of the amount of technical and/or achievable savings that are available from the industrial sector. The sources referenced for the development of this plan were taken from the following organizations and data sources: Oregon Department of Energy, Energy Analysis and Diagnostic Center, Bonneville Power Administration, Portland General Electric, PacifiCorp, Seattle City Light, Puget Power, B.C. Hydro, and the American Council for an Energy Efficient Economy. Almost all of these estimates encompass a mix of in-field work, program experience and informed judgment, and each has significant strengths and weaknesses. These estimates are described next.

Some of these estimates reflect only technical[81] savings potential, others only achievable[82] savings potential, and some estimate both technical and achievable savings. In addition, some of the estimates cover virtually all industrial plant types (such as wood products or primary metal plants), and others only cover selected plant types.

Oregon Department of Energy's Estimates

Oregon's energy department estimated conservation potential in that state's major industries: paper, wood products, food processing, primary metals, chemicals and electronics. These industries are also key to the region's industrial loads. The estimates were made from a series of studies from 1983 to 1989, and were last updated in 1991.

The studies done in Oregon are a combination of plant energy audits to identify conservation measures, and industry wide surveys to establish baseline conditions, estimate the saturation of measures already in place, and potential penetration for measures that could be adopted. These studies looked at potential savings in electricity, gas, oil, and biomass fuel, although only the electricity savings are reported here.

Much of the work is based on more than 100 site visits by engineers to major industrial plants to estimate the amount and cost of conservation measures that could be installed. During the visits, the engineers asked plant managers if they would consider installing various measures. If the answer was no, then department engineers did not include those measures in the database. The engineers classified the measures into those with less than a two-year payback, and those with between two and eight years payback. A two-year payback is approximately equivalent to a levelized cost of 0.6 cents per kilowatt hour and an eight-year payback is approximately equivalent to 2.2 cents per kilowatt hour.[83] These are below the avoided costs used in this plan. To extrapolate the conservation measures that the engineers found in the field to the savings that could be secured in the future, the results from the audits and surveys were combined with plant-specific and industry-specific forecasts of production. This resulted in the potential energy savings in each industry over time.

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[79] Outliers were defined as projects where the calculated electricity rate is less than 2 cents per kilowatt hour or greater than 7 cents per kilowatt hour, and reported paybacks are greater than 20 years.

[80] This is calculated using a 15-year average lifetime and a 4.75 percent real discount rate.

[81] Technical savings are the amount available if all electricity uses that could be made efficient were made efficient.

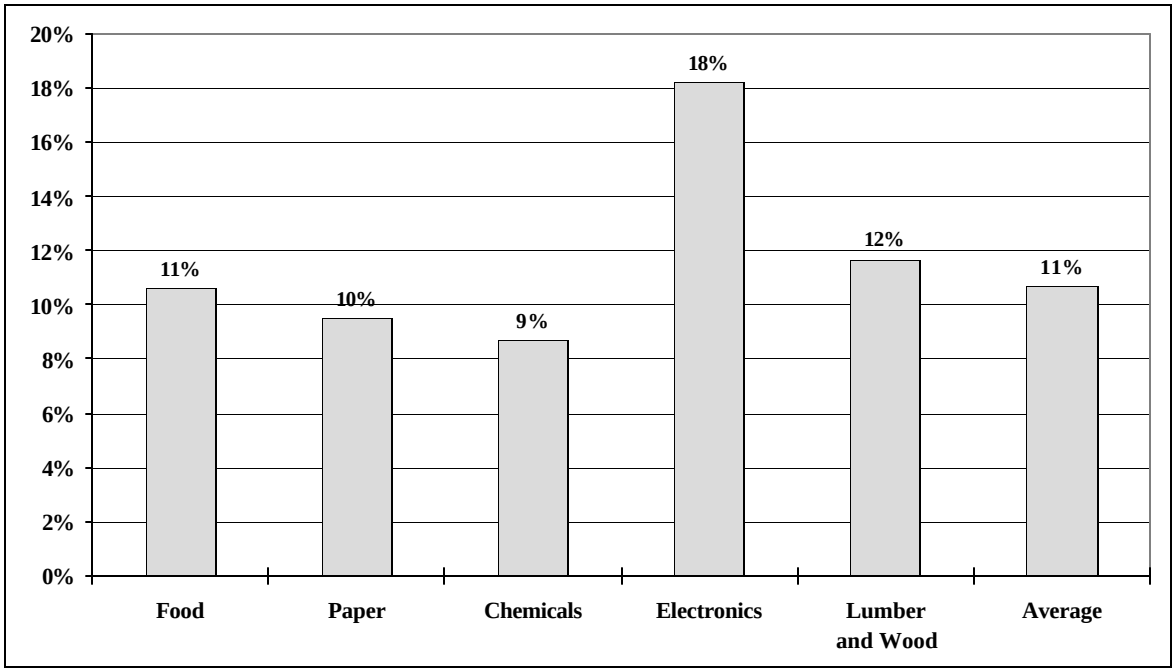
[82] Achievable savings are the amount available if cost-effective technical potential savings are reduced to reflect the amount of savings that are possible to be accomplished over the 20-year planning horizon.

[83] This calculation uses a 4.75 percent discount rate, 3 cents per kilowatt hour electricity price, and 15-year measure life.

As shown in Figure G-40, Oregon estimated achievable industrial sector savings from measures under a 2.2 cents per kilowatt hour threshold by the year 2010 to be between 9 to 18 percent, depending on industry type. If these savings are weighted by the percent of load each industry represents to the total region, average savings is 11 percent.

Figure G-40

Achievable Savings by Industrial Type Estimated by Oregon Department of Energy



Comments on ODOE estimate

This estimate is likely to overstate savings because some industrial conservation has occurred since about 1990. No adjustment was made for this since the estimate likely understates available savings because it does not include the technological improvements and conservation measure price reductions that have occurred in the last five years, such as advancements in adjustable-speed drives.

Two key strengths of this estimate are: 1) that it is based on a large sample of in-field industrial plants and 2) that managers of the industrial facilities were consulted during the estimation process and only measures they considered feasible were included.

Bonneville Power Administration's Estimate

In helping guide the development of the industrial estimates for the power plan, Bonneville used a mix of the results from its industrial program (Energy $avings Plan, or E$P), described above, with expertise from its field staff to estimate further potential savings. Some of the descriptive text that follows is taken from Bonneville's description of their project.[84]

Bonneville staff initially collected savings data for 370 projects from its E$P program database. Bonneville staff were able to obtain load data for 83 industrial sites which had at least one E$P project. These 83 plants had a total of 182 projects installed though the E$P program. About one-third of the projects were in lighting, one-third in compressors, and one-third distributed across motors, electro-chemistry, energy management systems, variable-speed drives, pumps, and other.

[84] Bonneville Power Administration, "An Empirically Based Analysis of Industrial Conservation Potential in BPA's Service Territory", November 22, 1995.

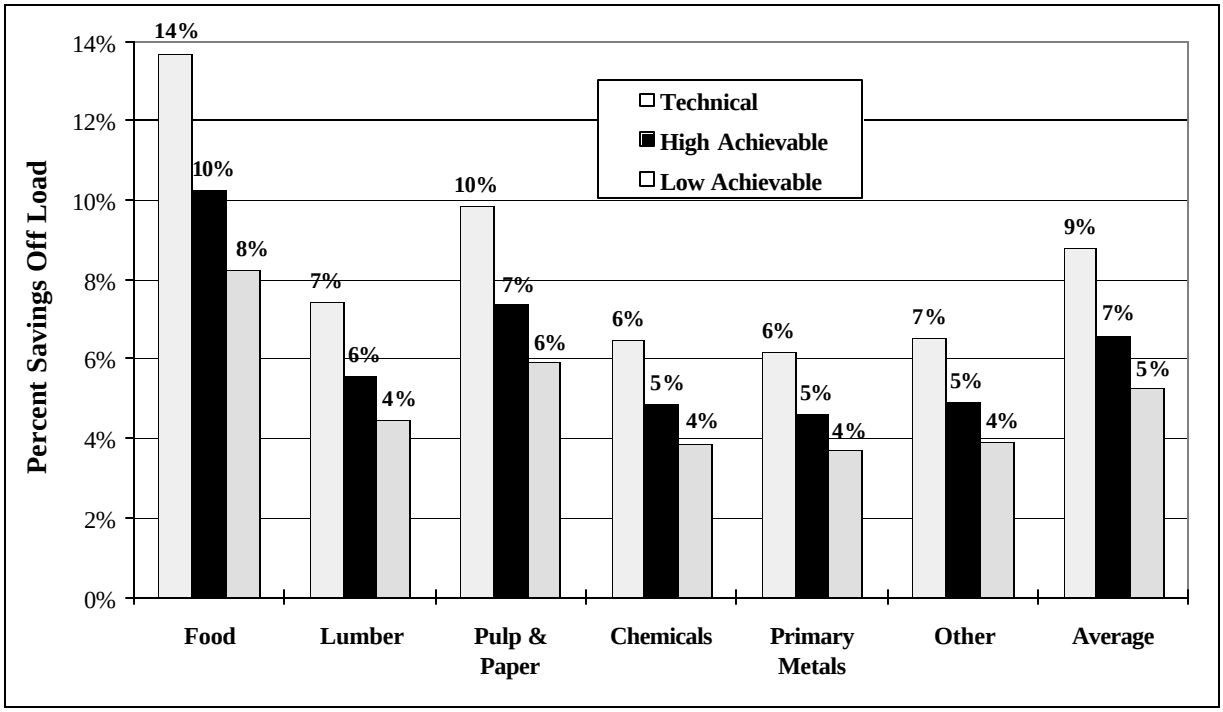
The load and savings data for these 83 plants were segmented into seven major industrial categories consistent with Bonneville's load forecast. Historical savings as a percentage of load were computed within major categories and then applied to the usage from Bonneville's industrial load forecast for the year 2010 for each industrial category. This yielded an estimate of almost 2-percent savings off forecasted loads, or approximately 49 average megawatts, after subtracting program savings to date. These results did not represent technical potential because it was possible that more measures could be accomplished in this subset of E$P plants. For example, about two-thirds of the plants had only one project installed and about 80 percent of the plants had savings from only one end-use addressed.

Bonneville field staff assigned to E$P were asked to review the E$P data and make an estimate of additional savings that could be achieved. Some of the field staff looked at individual plants, and others gave an estimate across the board. Additional savings were added to 29 of the 83 plants. Savings were then calculated again by 1) calculating savings as a percent of load within major industrial category, 2) applying these percentages to forecast industrial load, and 3) subtracting savings already achieved by E$P. The result was 7 percent savings off forecast loads, equating to 179 average megawatts. Before historical savings are removed, the result is 9 percent savings off load. This value is used below to be comparable to other estimates described here and so as not to remove historical savings twice.[85]

Bonneville then estimated achievable potential by assigning a range of penetration rates, from 60 percent to 75 percent. Technical savings, and the low and high achievable savings for each industrial category are depicted in Figure G-41, before historical savings are removed. The weighted average savings for technical potential and low and high achievable potential are 9, 7 and 5 percent, respectively.

[85] The analysis in this chapter averages the savings estimate for each industrial category and then subtracts historical achievements. If historical achievements were already removed from the Bonneville estimates, they would end-up being removed twice.

Figure G-41
Estimated Savings by Industrial Category from Bonneville Power Administration Estimates



Comments on Bonneville's Estimate

Bonneville's paper indicates that their estimate overstates savings. However, there appear to be factors on both sides, under and over estimating savings, as described next.

Savings from Bonneville's method might be overstated because the full-percent savings that was estimated from existing industries was applied to new industrial loads as well, and the new facilities are likely to be more efficient to start with. On the other hand, new facilities offer the potential for the more thorough application of efficient technologies throughout the whole process, not a retrofit situation that is more constrained by current plant configuration and operations.

Savings might also be overstated because there was no downward adjustment to reflect the potential for self-selection bias. To the extent the industries in the sample, which are the first ones in the program, represented the industries with the biggest potential, there would be an upward bias in using these to represent the remaining industries.

On the other hand, Bonneville's estimate may understate savings because the E$P program largely tried to eliminate savings that were very economical to the industrial plant, even without a utility incentive. This means that savings from projects that would be installed by industries on their own were not accounted for in Bonneville's analysis and, therefore, would be in addition to their estimate.

Savings might also be understated because the field staff did not take a comprehensive look at all measures that could be installed for some plants. For example, field staff estimated additional savings beyond those already secured in E$P for only 35 percent of the plants in the sample, even though 80 percent of the plants had only one end-use (such as lights) addressed.

Finally, technical and achievable savings potential were not defined in the same way as the terms are used here. For example, some of the field staff tried to estimate savings without constraints that would correspond to an estimate of technical potential. However, other field staff considered limitations in making

their estimate of savings, such as what level of funding might be available from utilities. In these cases, applying a reduction factor to reflect achievable is somewhat redundant.

Nevertheless, Bonneville's effort is noteworthy, and has been incorporated in the overall estimate made here.

Energy Analysis and Diagnostic Center Data

This section describes two estimates of savings that are based on the Energy Analysis and Diagnostic Center audits of small- and medium-sized firms. The first study, sponsored by Bonneville,[86] looked at the nationwide data collected by the Energy Analysis and Diagnostic Centers for operations and maintenance measures only applied to electrical equipment. Because it covered only other measures, it is not included in the summary of estimates above. The second study was an analysis done by Council staff looking at the data from the Oregon center only for all measures that save electricity, not just operations and maintenance measures. The Energy Analysis and Diagnostic Center data is described first. Much of the general description of EADC that follows is taken from the Bonneville-sponsored study.

EADC Data

The Energy Analysis and Diagnostic Center (EADC) is a program funded by the U.S. Department of Energy. The Energy Analysis and Diagnostic Center uses graduate and undergraduate engineering students under the direction of university faculty members to perform energy surveys of small- to medium-sized manufacturing plants. The program began in 1976 with four universities acting as centers. It has since expanded to 22 universities. One of the early universities in the program was Oregon State University. Greg Wheeler is director of the Oregon Energy Analysis and Diagnostic Center effort.

To be accepted as an Energy Analysis and Diagnostic Center client, manufacturing plants must meet certain criteria, including: 1) annual energy bills less than $1.75 million, 2) annual gross sales less than $75 million at the plant site, 3) between 50 to 500 employees at the plant site, 4) no on-site energy manager, 5) located within 150 miles of an Energy Analysis and Diagnostic Center, and 6) a SIC code between 20 and 39.

The audits generally consist of one- to two-day site visits by an Energy Analysis and Diagnostic Center team. The team consists of a supervising faculty member and two to four engineering students. The report they generate contains a detailed plant or process description, a list identifying the major energy consuming equipment, an historical survey of plant energy consumption, and a detailed analysis of cost-effective energy conservation opportunities.

Primarily inexpensive and simple measures are identified by the student teams. Figure G-42 indicates the percent of Energy Analysis and Diagnostic Center savings that are estimated at each payback level. Almost 50 percent of the savings are less than a one-year payback, and 90 percent of the savings have less than a five-year payback. (A five-year payback measure is equivalent to a levelized cost of 1.2 cents per kilowatt-hour.)[87] Approximately one year after the report is complete, the client is contacted to participate in an implementation survey. All this information is then collected in the Energy Analysis and Diagnostic Center database.

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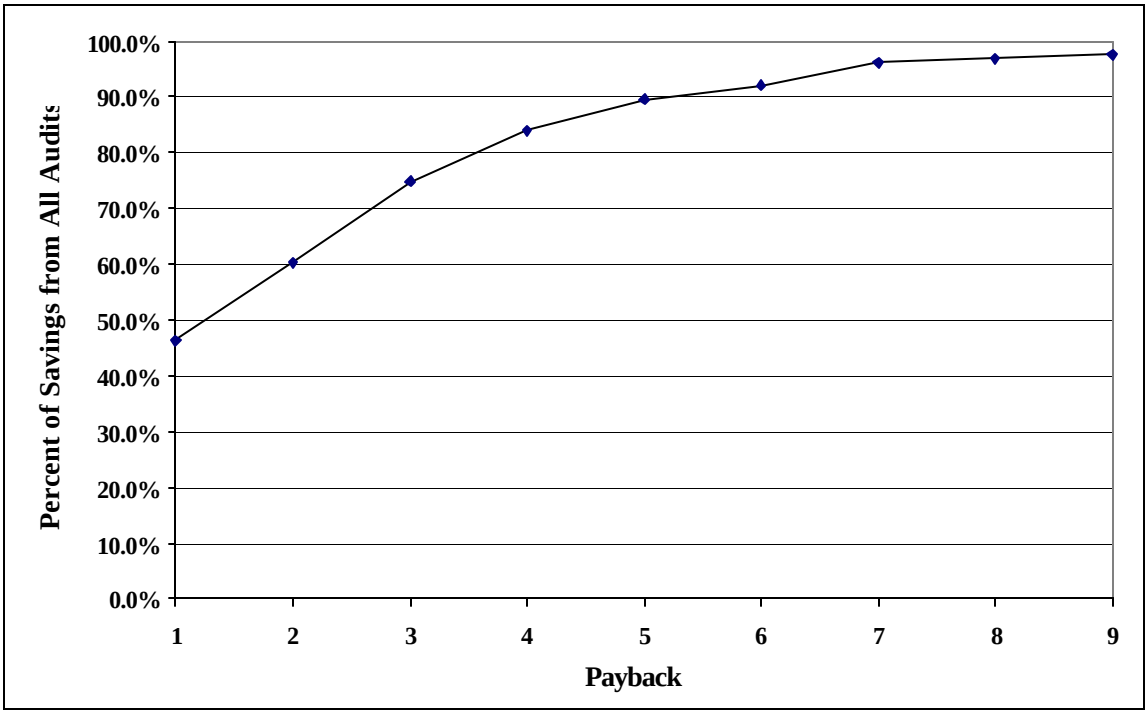
[86] S.A. Parker, K.L. Gaustad, R.f. Szydlowski and D.W. Winiarski, Pacific Northwest Laboratory, "Industrial Operations and maintenance Demand-Side Management Resource Development: Literature and Data Review", January 1994, for Bonneville Power Administration, PNL-9023/UC-350. Much of the text that follows describing the EADC data and Bonneville anaysis is taken from this document.

[87] This calculation assumes a 2.5 cents/kWh electricity rate to the industrial customers.

Figure G-42
Percent of all EADC Savings by Payback Level



The program does not offer incentives, but the reports generated by Oregon State University typically include an incentive analysis to aid the facility in pursuing potential incentives from other parties. To date, the overall program has resulted in more than 4,500 assessments nationwide and over 30,000 conservation recommendations.

The Energy Analysis and Diagnostic Center contacts customers about one year after the audit to see if any measures have been installed or will be installed. About 66 percent of the total Energy Analysis and Diagnostic Center savings have been or will be installed according to the survey, representing about 5-percent savings off these loads. Seventy-five percent of these savings are reported to be installed without incentives or rebates from an additional party.

Pacific Northwest Laboratory (PNL) Analysis of EADC for Operations and Maintenance

The PNL work[88] was done for Bonneville Power Administration in 1993, and at that time the Energy Analysis and Diagnostic Center database contained 2,400 audits. From these audits, Pacific Northwest Laboratory, in consultation with an advisory committee, pulled those measures that qualified as "operation and maintenance."[89] Under their definition, some of the measures they selected might be considered capital

[88].Parker, et al, ibid.

[89] The report used the following criteria to define operation and maintenance actions:

- An activity that is financed as an expense rather than capital
- A low-cost item that can be installed or performed by the O&M staff, although it may be contracted; an activitiy or item that is considered a routine capability
- An item or activity that has a simple payback of less than one year
- Any item or activity that will bring the equipment back to its original design specification; e.g. repair
- A repetitive activity; e.g. preventive and predictable maintenance
- Any activity affecting the operation of the equipment, e.g. control settings, set points, schedules, and procedures.

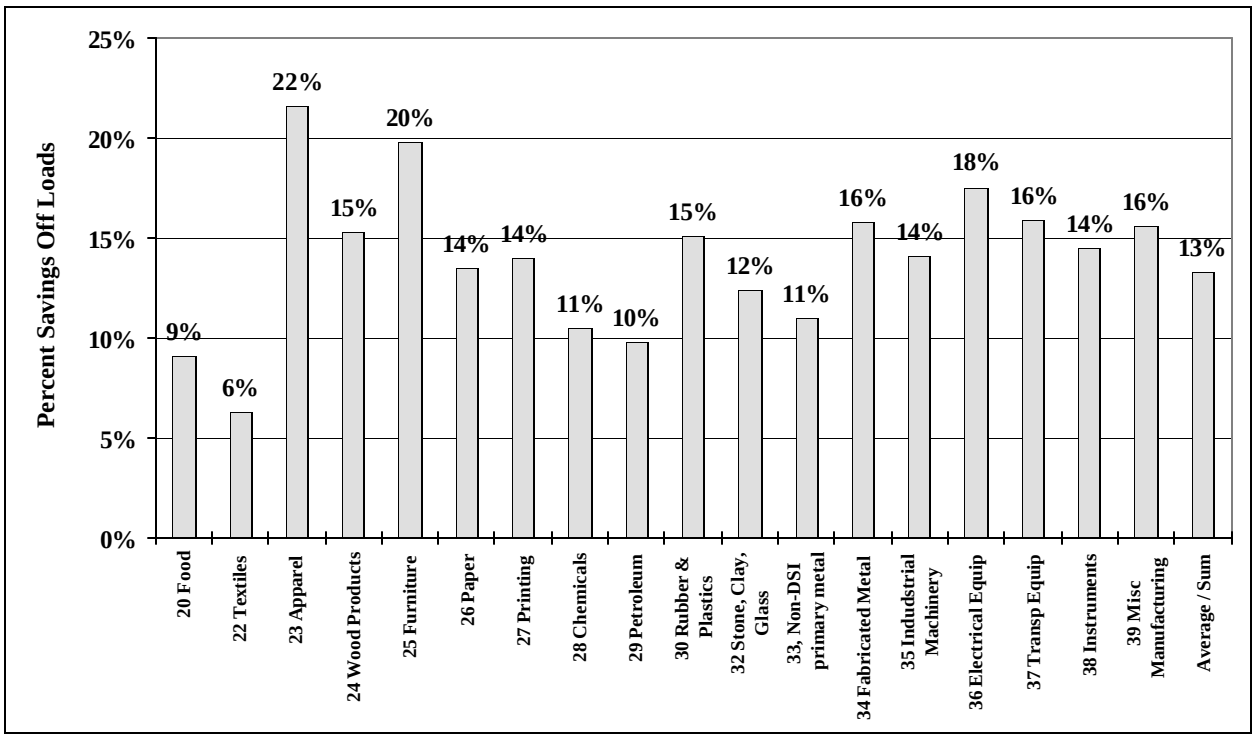
improvement items, which would result in a higher savings than just operation and maintenance measures. The selected measures were then sorted by industry-type (SIC classification).

The contractor then determined how often each measure was recommended (the frequency) in a facility and how much each measure saved (as a percentage of total use). These were multiplied and summed for all measures to get potential savings. The example given in the report is: if a specific energy measure saves an average 8 percent of a plant's energy consumption within a specific industry type, and is only applicable 25 percent of the time (1 in 4 plants within that industry category), then the overall potential savings to that industry category is 2 percent (8 percent x 25 percent = 2 percent).

The results of this analysis by industrial category are shown in Figure G-43. If these savings are weighted together by their representation in the electricity load forecast, the average savings are 13 percent.

Figure G-43

Estimated Savings from Operations and Maintenance Measures in the EADC Database



Comments on PNL EADC Analysis

In addition to the comments below on the general EADC data base, there are some important considerations to think about in looking at the operations and maintenance estimate derived by PNL from the EADC analysis.

Operations and maintenance measures do not reflect all the savings that could be achieved from a comprehensive review of all measures at a given facility. Operations and maintenance measures are likely to reflect the lower end of potential savings that could be attained.

However, these measures are likely to have a much shorter lifetime than savings from capital improvements, and have not been the focus of extensive measurement in an industrial plant.

The data base has some entries that are up to 15 years old. This means that some of the data probably reflect lower efficiency levels than one would find from more recent audits. Unfortunately, the report did not indicate the audit dates, and how many were from earlier times.

Council Staff Analysis of EADC data from Oregon Program

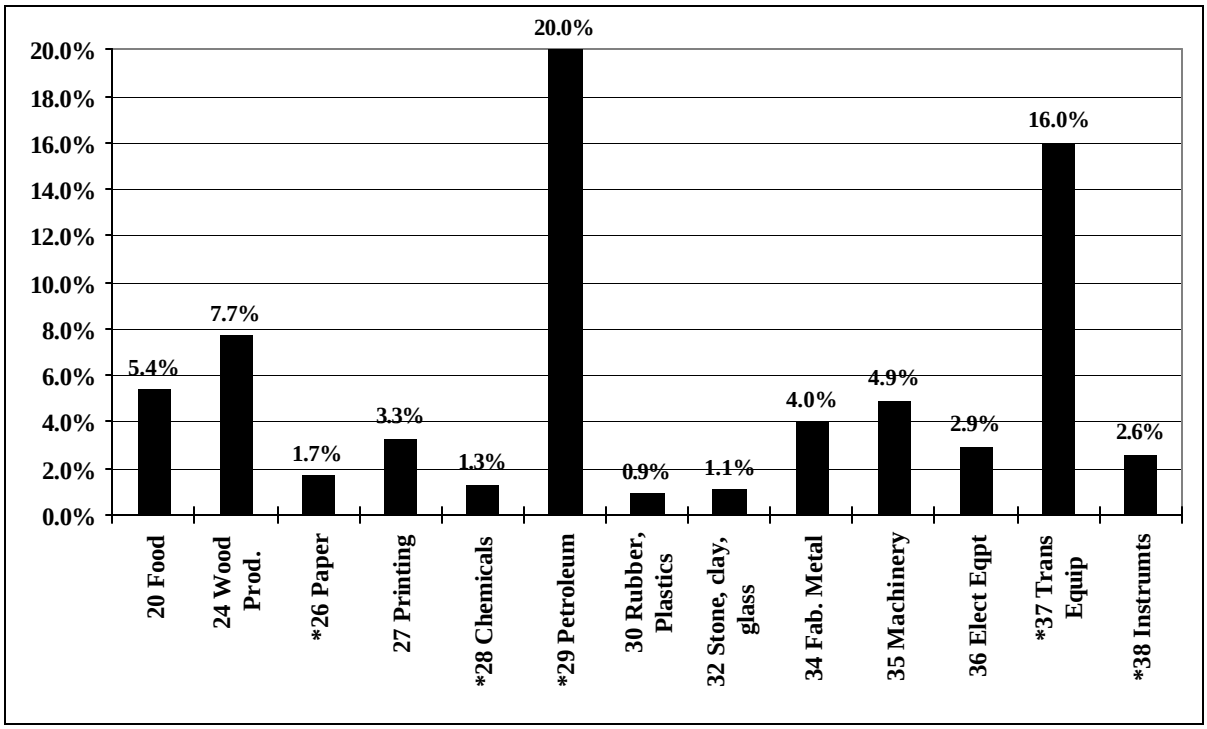
In an effort to estimate all the savings identified by an EADC audit, not just savings from operation and maintenance measures, Council staff analyzed the EADC data base for Oregon.

Staff received the data base of the program, which included 4,500 assessments nationwide. This data base was then winnowed to reflect only those audits that were done in Oregon and only those measures that saved electricity. Any measure that saved electricity by switching fuels, or that was part of cogeneration was excluded. The data were limited to Oregon to ensure that the industries represented plants in the Northwest. (Oregon is the only Northwest state with an Energy Analysis and Diagnostic Center.)

The result of this winnowed-down data base was over 180 audits and 780 recommended measures specific to Northwest industries. The audits started in 1987. The energy savings recommended in the audit were divided by the electricity use of the plants to determine the savings off loads from these audits. Figure G-44 shows the amount of savings by industrial type that were identified by on-site audits by the Energy Analysis and Diagnostic Center team of engineering students. The overall savings are 6 to 7 percent if the plants are simply averaged. However, the overall savings in the Energy Analysis and Diagnostic Center audits were 4 percent off usage, when weighted by forecasted loads for each industrial type. It is important to note that the Energy Analysis and Diagnostic Center does not go into the largest plants, and therefore its audits don't fairly represent the savings potential from these large customers. For example, both of the highest savings and some of the lowest savings come from estimates that have only one or two audits for that industrial type even though these industries represent a significant portion of regional electricity consumption. These industries are marked with an asterisk. However, even if these are removed, savings remain at 4 percent.

Figure G-44

Savings by Industrial Type from the Oregon Energy Analysis and Diagnostic Center Audits



General comments about the EADC Database

The EADC data will introduce some error if its results are applied to the entire industrial sector because the data itself comes from audits on small- to medium-sized firms. Large firms represent a significant share

of electricity use and are hypothesized to be more likely to have their own energy managers, which might leave less conservation still to acquire. On the other hand, some think that there is generically a higher-percent savings available from larger firms than from smaller ones, which would indicate that the Energy Analysis and Diagnostic Center data would have a bias to the low side.[90]

The Energy Analysis and Diagnostic Center data likely understate overall savings even in small- to medium-sized plants because major process improvements are generally outside the program scope; the audit is typically an overview of the most simple measures that can be identified in a short period of time. This is illustrated by the fact that 50 percent of the identified savings fall below a one-year payback.

Finally, a strength of the Energy Analysis and Diagnostic Center data is that it is based on on-site evaluations of industrial plants. In addition, all recommendations are discussed with plant engineers and/or management before leaving the plant to ensure that the recommendations are feasible. On the other hand, the energy savings in the data base are based on engineering estimates, not metered data.

The savings of 13 percent derived from Bonneville's analysis of operations and maintenance measures in Energy Analysis and Diagnostic Center are incongruous with the savings of 4 percent found in the analysis of all measures in the Oregon portion of the Energy Analysis and Diagnostic Center data base. The general hypothesis would be that operation and maintenance savings should be less than savings from all measures. Because the analysis that includes all measures is specific to the Northwest, and is based on a more updated version of the Energy Analysis and Diagnostic Center data base, it is used to represent the size of savings from Energy Analysis and Diagnostic Center audits.

Portland General Electric's Estimate

Recently, Portland General Electric (PGE) developed new estimates of industrial savings potential for its 1995 least cost plan. This estimate incorporated two separate approaches: one that was fairly simple for standard measures – lighting, motors, and variable-speed drives -- in all the industrial categories, and one that took a much deeper look at those industries with the largest loads in their service territories, particularly the paper and wood products industries.

The estimate for lights, motors and adjustable-speed drives was derived by estimating the proportion of forecasted loads that were in these end-use categories, by industrial type. Savings and costs for these end-uses were then estimated by looking at measures that would be applicable to the types of customers in Portland General Electric's service territory. This was done by a consulting company with national experience in the industrial sector. Results were calibrated to Portland General Electric's historical activity, including historic costs, penetration rates and applicability of measures. The contractor relied on national data in the case of motors where Portland General Electric's historic activity was limited.

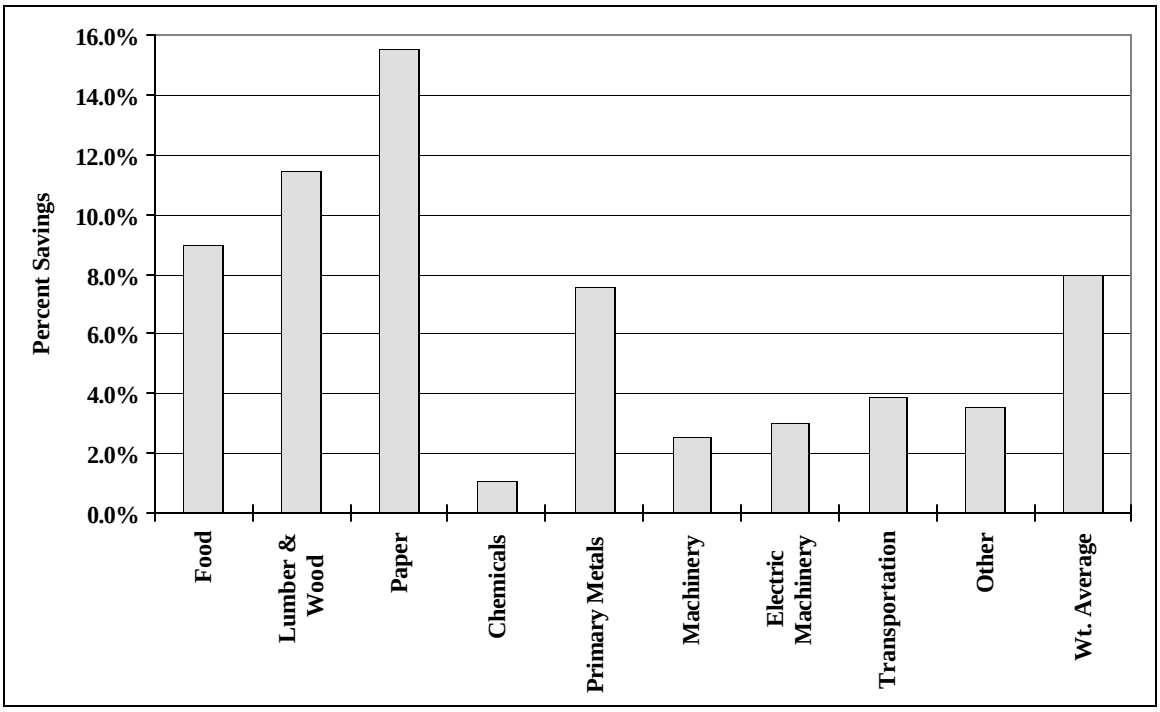
For the larger customers in Portland General Electric's service territory, Portland General Electric investigated the potential for process efficiency improvements, including more extensive motor-system changes, by using information from field staff combined with the expertise of an engineer experienced in these industrial types. The savings estimates were developed through both on-site information and survey work. Categories of potential efficiency gains included: motors, controls, ducting and piping, process/layout, lighting, and liquid heating. The engineer originally was hired to investigate these industries to assess whether there were sufficient efficiency gains possible to justify a process-oriented program in the industrial sector, especially focusing on lumber and wood, paper, and high technology industries. This estimate was the most comprehensive study undertaken by Portland General Electric to date.

Technical savings derived from this two-part process were reduced to reflect only those savings that were "economic" or cost-effective. This was then reduced about 26 percent to further reflect an estimate of the economic savings that were achievable. Historic savings from Portland General Electric's programs were

[90] For example, Bonneville presented information at the Conservation Resources Advisory Committee that indicated a rough estimate of savings would show 10 percent savings in large plants and 7 percent savings in small plants, based on one field staff's judgment.

also taken out of Portland General Electric's estimate.[91] The resulting achievable savings are presented in Figure G-45.

Figure G-45
Achievable Savings Estimates from Portland General Electric



Puget Power's Estimate

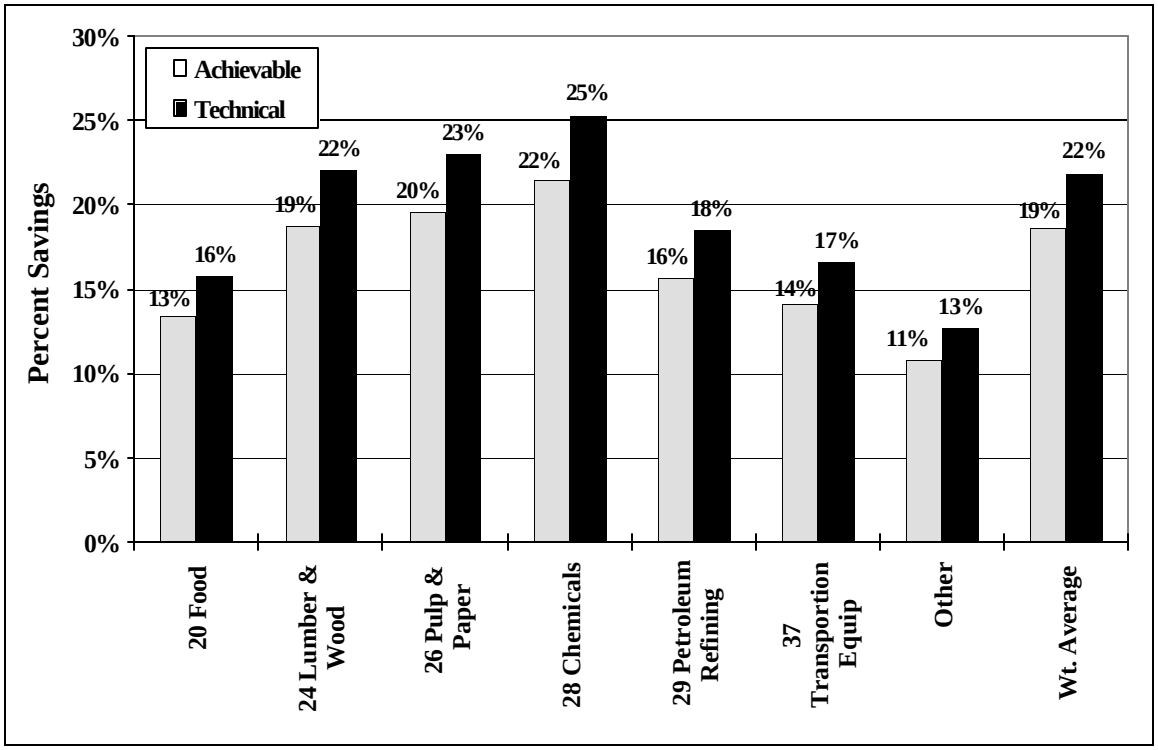
Puget's estimate of industrial conservation potential was developed in 1994 as part of its integrated resource planning process. These estimates were made when long-term avoided costs were based on the cost of a gas-fired combustion turbine and relatively high fuel costs. The methodology and assumptions used to generate these estimates were reviewed on a regular basis by members of the Technical Advisory Committee, including representatives from the Washington State Energy Office, Industrial Customers of Northwest Utilities, and the Power Planning Council.

Puget used a model developed by Bonneville, called Industrial Supply Curve 2 (ISC2) to estimate its industrial conservation potential, which is the updated version of the model used in Puget's 1992-93 Plan. This is a model that was used by Bonneville and the Council in the past. The model divides forecasted loads into end-uses and then applies specific conservation measures to the applicable loads. Some modifications were made by Puget to facilitate integration with its industrial load forecasting model. In addition during the development of the inputs for the model, Puget's industrial energy management engineers spent considerable time reviewing measure cost and savings estimates. As a result of this review and some new work that had been done by Washington State Energy Office and ADM associates, additional changes were made to the model. Upon the recommendation of the technical advisory group, Puget re-estimated the 20-year industrial conservation potential in early 1994 using the updated version of the conservation model.

Technical and achievable savings estimates, which are based on 1994 avoided costs, are shown by industry in Figure G-46. This shows an average 20-year achievable savings potential of about 19 percent off industrial sector load,[92] at an average cost of less than 2 cents per kilowatt-hour.

[91] This was not known in time to adjust the overall savings presented at the end of this section; the end of this section also removes historic savings. As a result, Portland General Electric's historic savings are removed twice.

Figure G-46
Estimated Percent Savings from Puget Power



Comments on Puget Power's Estimate

As this estimate is updated to reflect lower avoided costs, the savings projected by Puget would be reduced. However, given the information from the E$P program and from other programs, lowering the avoided cost within this range has fairly small effects on the size of the resource.

Puget is using a modified version of a model originally developed by Bonneville. Bonneville felt uncomfortable with the model for use in this power plan. Puget used the model after revising it to reflect concerns that its advisory committee raised, including incorporating reviews by Puget engineers, as described above.

If the savings derived by Puget for its service territory were spread evenly over the 20-year forecast period, it would represent 0.8 percent of the total forecasted load in its territory per year. Puget thinks that this is a reasonable size because over the three-year period from 1992 to 1994, when Puget was ramping-up its industrial conservation programs, it acquired an average of 0.6 percent of its total forecasted industrial load per year.

Seattle City Light's Estimate

Seattle City Light (SCL) has spent the last eight years researching industrial electricity savings in its service territory. The first step in the overall research was to develop a comprehensive end-use database for the Seattle service area. This data base covered 83 percent of Seattle's total industrial loads. A key piece of the data base was information collected through a major research project, called the Industrial Research and Demonstration Project (IRD). IRD was implemented to (a) develop overall goals for industrial conservation

[92] If Puget's estimates for each SIC are weighted by the respresentation of those SICs in Puget's forecast, the achievable savings are 15 percent.

(b) construct data bases on end-use loads, energy savings and conservation opportunities (c) estimate conservation potential, and (d) define program targets for industrial conservation.

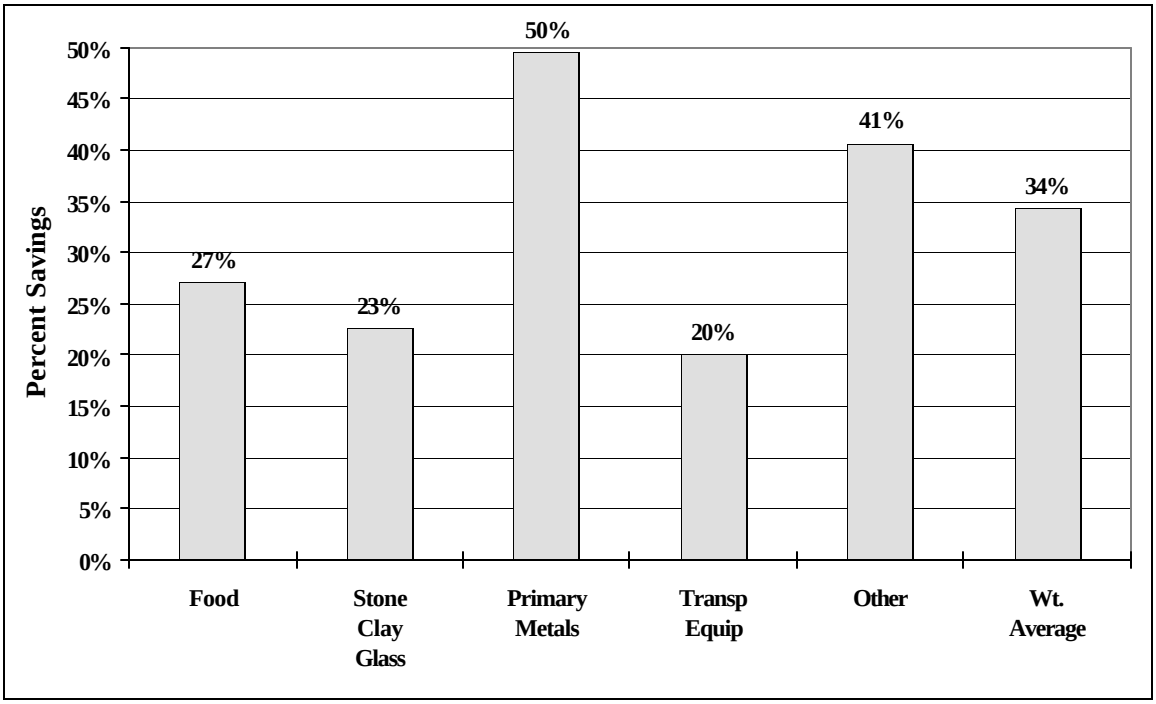
To obtain first-hand data, Seattle City Light recruited industrial customers to install energy improvements and provide detailed information on costs, benefits and energy-use performance of these measures. This information was supplemented with survey and performance data from previous Seattle City Light studies, national data bases such as those available from the Electric Power Research Institute, and technical documents published by industry specialists. This data base was then further supplemented by information from the Energy Analysis and Diagnostic Center (EADC, described above) for industries in Seattle City Light's service territory.

Seattle City Light's goal was to identify all efficiency opportunities that could lead directly or indirectly to energy savings if they were implemented by industrial customers. The IRD Project found that, while industrial customers were interested in energy efficiency, they were often even more interested in efficiencies such as decreasing process time or lowering production costs. Because Seattle was interested in following up on the technical estimate of savings with programs to acquire the savings, they were also interested in identifying the reasons industrial customers might adopt energy saving measures. As a consequence, Seattle looked at the energy saving measures and divided them into key categories: those that simply had energy savings but not other consequential benefits, and those that also caused key benefits such as decreasing process time. These were called direct and indirect efficiency gains. They concluded that very significant electricity savings were available from both the direct and indirect efficiency measures.

The final data base on energy-use efficiencies produced by Seattle City Light is depicted by industry type in Figure G-47. It shows how much electrical energy can be potentially saved if all the improvements identified in Seattle City Light's data base are put in place in each of the industry types listed in the figure. This represents an estimate of technical savings. If these savings are weighted by the representation of each industry in the Northwest, the savings are an average of 34 percent. The estimates of savings presented here from Seattle City Light do not include savings from fuel switching or cogeneration.

Figure G-47

Seattle City Light's Technical Potential Savings Estimate



Comments on Seattle City Light's Estimate

Because Seattle City Light included indirect as well as direct savings in its estimates of conservation potential, its estimates are more comprehensive than many of the others described here. Indirect savings were identified as those measures that would save electricity, but would likely be desired by an industrial customer because they had significant non-energy benefits, not necessarily because they saved electricity. In addition, Seattle City Light based much of the analysis on data collected in industrial plants in its service territory.

On the other hand, the definition of technical potential used by Seattle City Light included more comprehensive change-outs of equipment than envisioned in some other studies. An example is taken from a Seattle letter:[93] Suppose a customer has five identical furnaces, and replaces one of them with an efficient furnace. Suppose the new furnace consumes 20 percent less electricity per pound of production than the furnace it replaced. Seattle would count the savings as 20 percent, because only one-fifth of the total furnace load was targeted. Seattle then used the 20-percent savings and multiplied by all use in the furnace end-use. Most other conventional methods (for example, the general Energy Analysis and Diagnostic Center database) would use the total furnace load as the denominator and report a 5 percent savings for the furnace end-use instead of 20 percent. Seattle's method allows easier comparison with technical specifications, and was recommended to them by their engineers, but it does not account for variation in furnace designs, uses, and physical constraints, which might limit the application of the efficient furnace. This basic difference would mean that Seattle's estimates are higher than most of the estimates presented in this paper. However, because the Council used achievable estimates of savings as the basis for the regional estimate, this did not effect the number adopted in this Plan.

The particular industries in Seattle's service territory do not represent a major portion of regional industrial loads.

B.C. Hydro's Estimate

In 1992 and with further work in 1994, B.C. Hydro published a detailed analysis of the technical and achievable electricity savings that could be developed in their service territory.[94] The technical estimates are based on a model called the Intra-Sectoral Technology Use Model (ISTUM), which is used by B.C. Hydro to do both load forecasting in the industrial sector, and conservation savings estimates. It was developed by Battelle Pacific Northwest Laboratories and Simon Fraser University. The model simulates technological change as a function of changes in physical output, retirement of old equipment, and capital and operating costs of new technologies.

The overall analysis consisted essentially of the following five steps:

1. 1. Construct detailed process models of electricity-intensive industries. A process flow model disaggregates an industry's production process into several key steps. An example of process steps in pulp and paper would be 1) pulp digesting, 2) pulp bleaching, 3) paper forming, and 4) paper drying.
2. 2. Dissagregate electricity demand in each process step by end-use
3. 3. Calibrate the process models to current product mixes and consumption levels.
4. 4. Collect and estimate base stock, efficiency and cost data on key electricity end-use technologies in each industry. This included data collection and consulting with key engineers involved in specific industrial processes.
5. 5. Conduct a number of model runs to estimate the amount of savings that would be possible under different scenarios.

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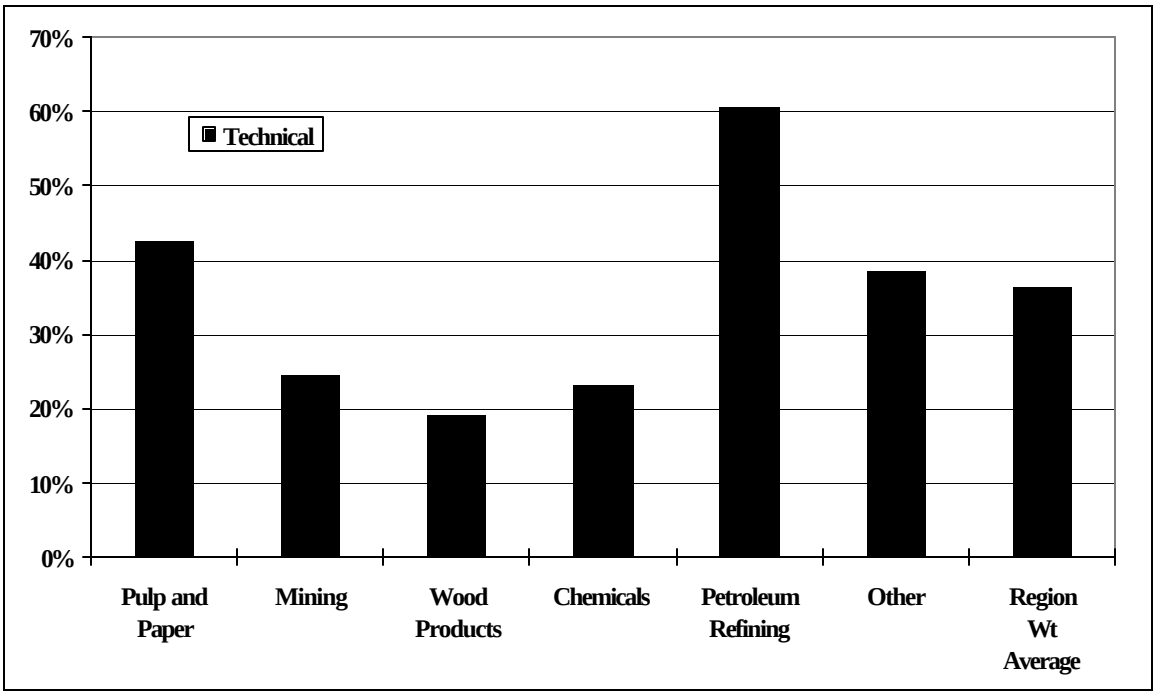
[93] Letter to ZoAnne Arrington, Bonneville Power Administration from Deb K. Das, Seattle City Light, page 3, April 17, 1995.

[94] B.C. Hydro, prepared by M.K. Jaccard and Associates, "1991-1994 Electricity Conservation Potential Review: the British Columbia Industrial Sector", Volumes 1 and 2, February 1992 and
B.C. Hydro, prepared by SRC, "Achievable Conservation Potential in British Columbia through Technological and Operating Change," July 1994.

Technical savings by industrial type are shown in Figure G-48. If these savings are weighted by their representation in the Northwest region, average technical savings at a 6 cents (Canadian) per kilowatt-hour cutoff (B.C. Hydro's avoided cost) are about 36 percent. This estimate however, includes savings from motor efficiencies that are now adopted into federal legislation in this country. A guesstimate of how much the savings would be reduced was taken from the report by subtracting the savings attributed to the Power Smart program, which is primarily operating a motor efficiency program that is capturing a large percentage of the market. This reduced the overall potential to about 30 percent. This reduction was checked with one of the authors of the study, who indicated that it was reasonable to expect that a small portion of the savings they identified came from the motors themselves. The equipment driven by the motor, such as pumps and fans, and process changes were much more important drivers of the savings estimate.

Figure G-48

B.C. Hydro's Technical Savings Estimates by Industrial Category



One of the authors of the analysis was asked how much the technical savings would be reduced if the 6 cents per kilowatt-hour cutoff were reduced to the 3-cent range. The author indicated that while no analysis was done at that cutoff, his opinion was that a very significant portion of their savings were much cheaper than 3 cents per kilowatt-hour.

Comments on B.C. Hydro's estimate

The study is noteworthy because B.C. Hydro worked closely with engineers in the field to develop the process-flow models and searched widely to develop the data set on efficiency and cost of measures. In addition, it is one of the first studies to take a close look at the entire motor system, not just the motor and its controls.

American Council for an Energy Efficient Economy's (ACEEE) Estimate

In 1994 ACEEE published a report on the electric savings potential from the manufacturing sector. [95] This report estimates electric ity end-use in all the manufacturing industry types, with the six most electricity-

[95] American Council for and Energy -Efficient Economy, R. Neal Elliott, "Electricity consumption and the Potential for Eelctric Energy Savings in the Manufacturing Sector, April 1994.

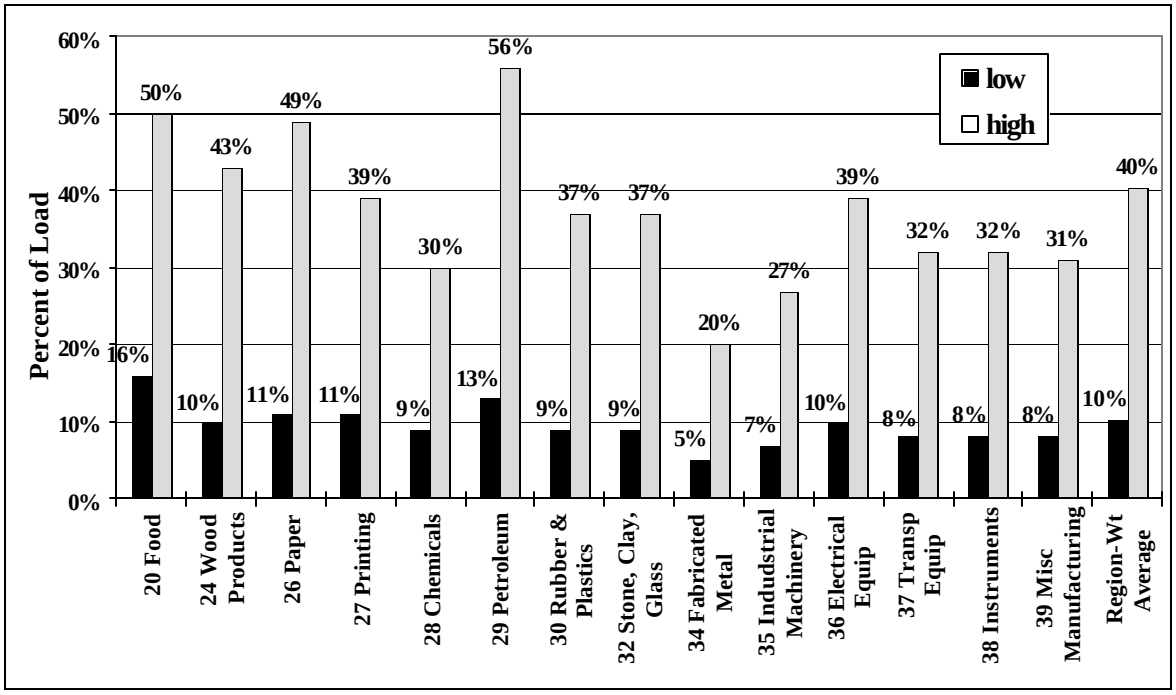
intensive industry types (chemical, pulp and paper, food, metals fabrication, industrial machinery, and transportation equipment) addressed separately and in greater detail.

The report breaks electricity use in each industry type into three broad end-use categories: process, motor, and lighting loads. Motor systems represent about 70 percent of all end-uses, with process and lighting comprising 23 and 7 percent respectively. From these end-uses, a range of conservation estimates is made. If weighted by the representation of industries in the Northwest, the study estimates that 10 to 40 percent of total electricity consumption can be saved through an orderly change-out of equipment at the time of equipment failure, process modernization or new construction. According to ACEEE, this estimate is conservative, since the study does not consider process optimization or redesign that would significantly increase the conservation potential.

Figure G-49 shows the savings by industry type. If they are weighted to reflect the industries' representation to Northwest loads, the overall savings are between 10 and 40 percent.

Figure G-49

High and Low Technical Savings Estimates from ACEEE



The report only considers end-use consumption of electricity. Neither cogeneration or fuel shifting are included.

Comments on ACEEE's Estimate

Its strength lies in the fact that multiple sources of information were consulted and brought to bear on the analysis. Its weakness is that is an overview of others' materials, and it is not necessarily all empirically based. It is also from a national perspective, although the average of industries represented in this document reflects the mix of industries in the Northwest.

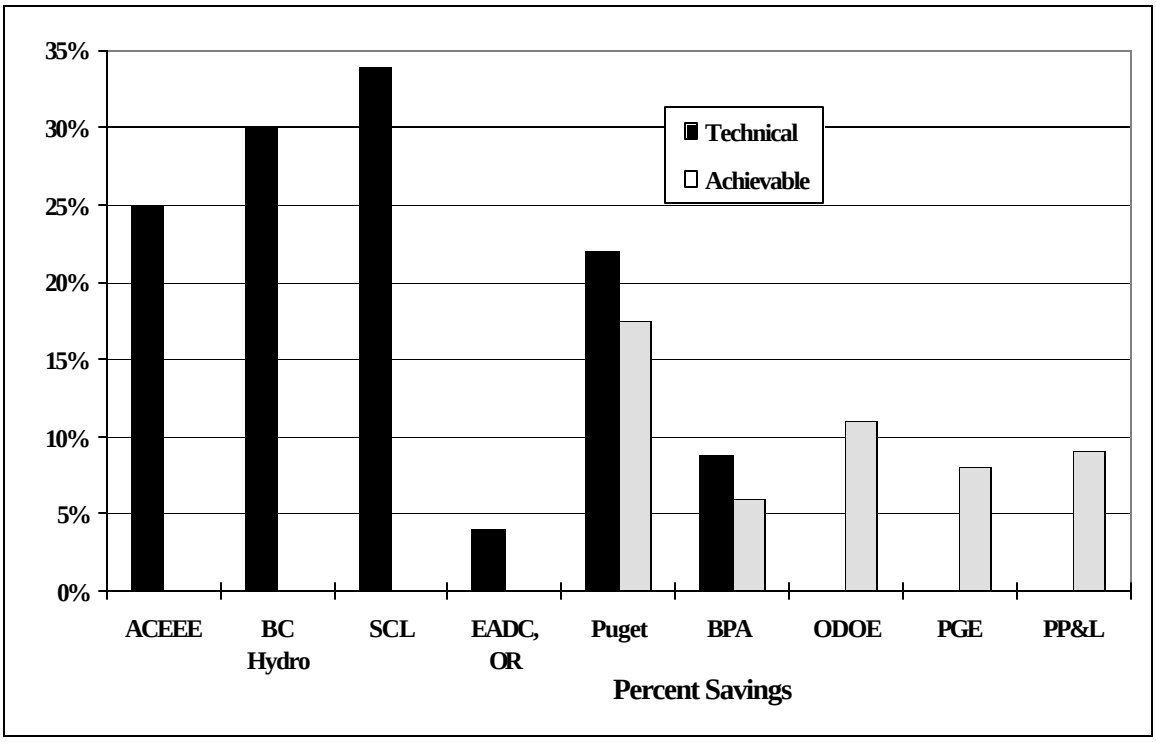
SUMMARY AND USE OF CURRENT DATA

This section summarizes the results of the estimates reviewed in the previous sections. It also discusses how those estimates were used in deriving total costs and savings from the non-direct-service industrial sector for this power plan.

Savings

Figure G-50 shows the average technical and achievable savings estimated by the parties discussed in the previous section. Some parties only estimated achievable potential, and others only estimated technical potential. Technical savings, weighted by the representation of industrial loads in the Northwest, range from 4[96] to 34 percent, and achievable savings range from 6 to 19 percent before historic savings are removed. As described in the prior section, each of these estimates has particular strengths and weaknesses. However, most of them have tried to rely on field data as the key basis for their estimate, and then use informed judgment or end-use models to extend the field data to further applications.

Figure G-50
Average Technical and Achievable Savings Estimates from Various Parties



Most of the sources only looked at selected industries, usually those with the largest loads for a particular service territory. Figure G-51 shows the estimates of technical savings potential made by various parties for each industrial type. Figure G-52 shows the same information for achievable savings.

[96] It should be noted that this estimate comes from the EADC data base, which represents simple measures in small industries.

Figure G-51
Technical Savings Estimated by Various Parties by Industrial Type

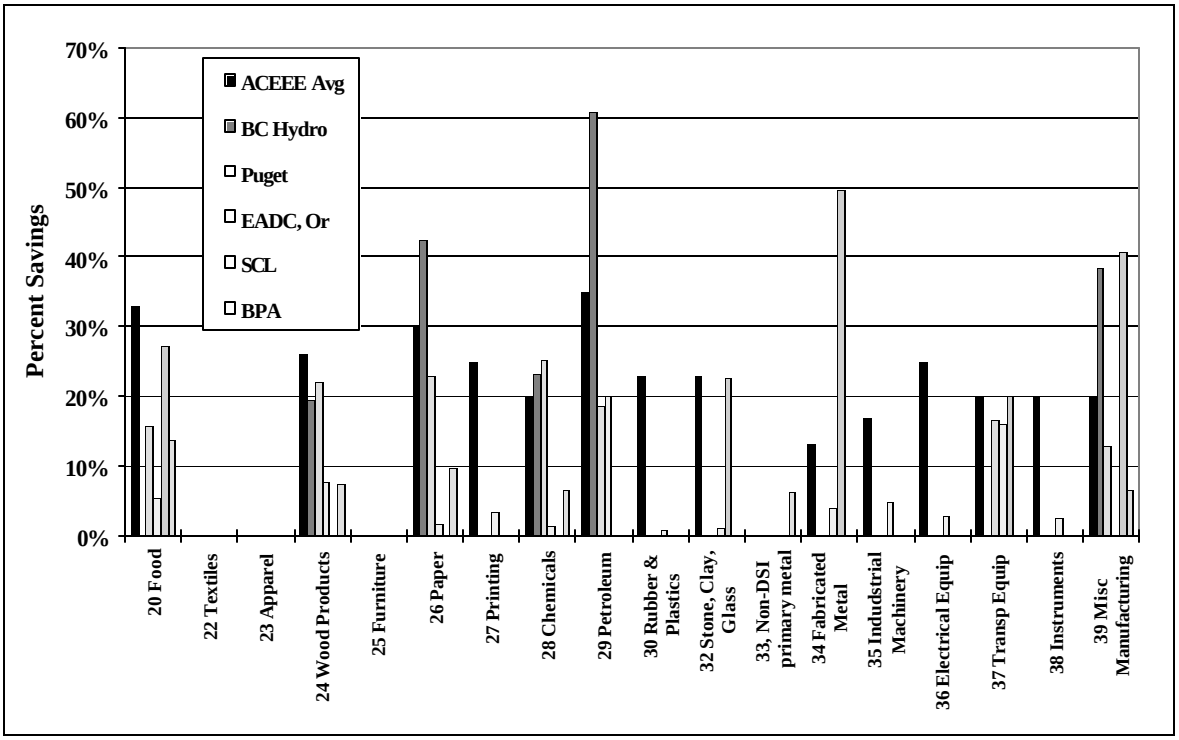
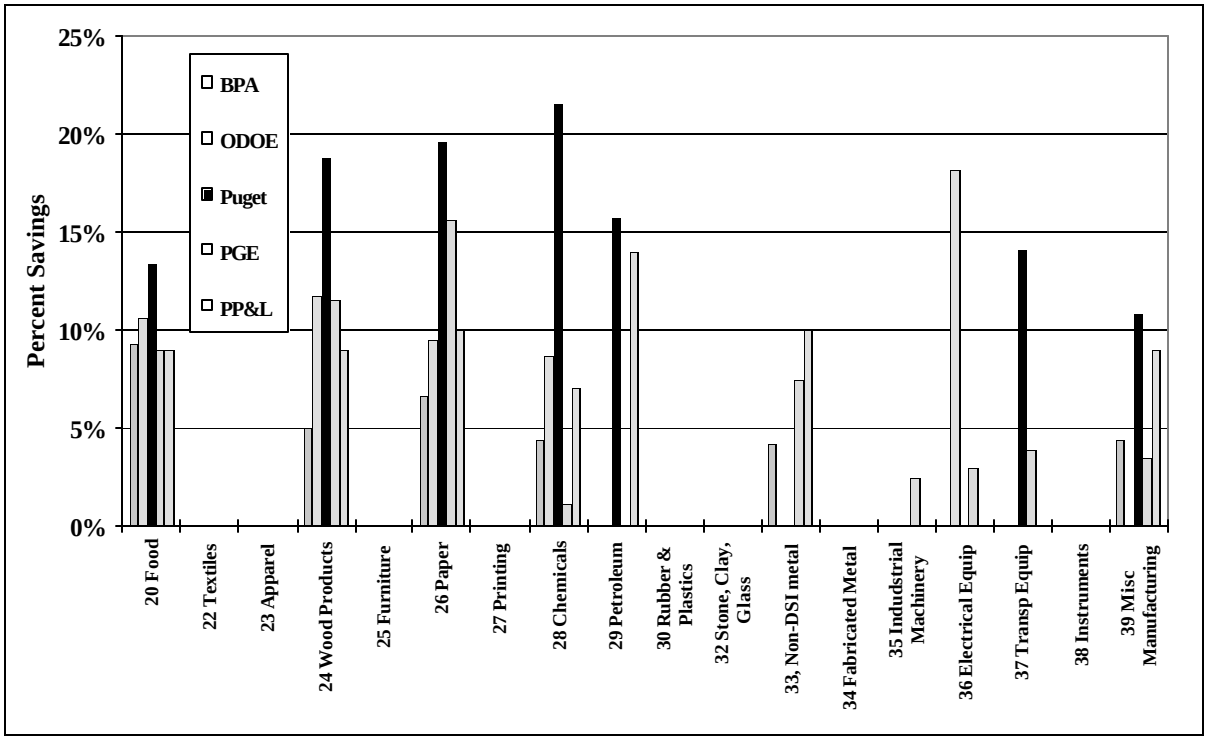


Figure G-52
Achievable Savings Estimated by Various Parties by Industrial Type



The savings used in this draft plan are based on the average of the savings for each industrial type across the multiple estimates. First, the percent savings for each industrial category were averaged for those parties who made an estimate. Second, the average savings for each category were then multiplied by that category's consumption in the load forecast to derive a savings estimate for each category. These were summed to reflect savings from all non-direct service industry loads. The information is presented in Table G-56 for technical estimates and Table G-57 for achievable estimates. This resulted in an average overall savings for the industrial sector of 17 percent for technical potential, and 9 percent for achievable potential. The average achievable savings for the largest industrial categories (accounting for 75 percent of loads), appear in Figure G-53, before historic accomplishments are removed. This figure differs from Figure G-36 because historic loads have been revised from Figure G-36.

Table G-56

Technical Savings by Industrial Category Estimated by Various Parties

								2015 Loads	**Savings**
	ACEEE Avg.	**BC Hydro**	**Puget**	**EADC, Or**	**SCL**	**BPA**	**Avg. Tech**	**aMW**	**aMW**
20 Food	33%		16%	5%	27%	14%	19%	435	83
22 Textiles							24%	13	3
23 Apparel							24%	9	2
24 Wood Products	26%	19%	22%	8%		7%	17%	421	69
25 Furniture							24%	7	2
26 Paper	30%	42%	23%	2%		10%	21%	2040	436
27 Printing	25%			3%			14%	136	19
28 Chemicals	20%	23%	25%	1%		6%	15%	806	123
29 Petroleum	35%	61%	18%	20%			34%	203	68
30 Rubber & Plastics	23%			1%			12%	362	43
32 Stone, Clay, Gla	23%			1%	23%		16%	281	44
33, Non-DSI primary metal						6%	6%	609	37
34 Fabricated Meta	13%			4%	50%		22%	86	19
35 Industrial Machinery	17%			5%			11%	558	61
36 Electrical Equipment	25%			3%			14%	729	102
37 Transportation Equipment	20%		17%	16%	20%		18%	228	41
38 Instruments	20%			3%			11%	61	7
39 Miscellaneous Manufacturing	20%	39%	13%		41%	7%	24%	67	16
Average / Sum	25%	30%	22%	4%	34%	9%	17%	7051	1176

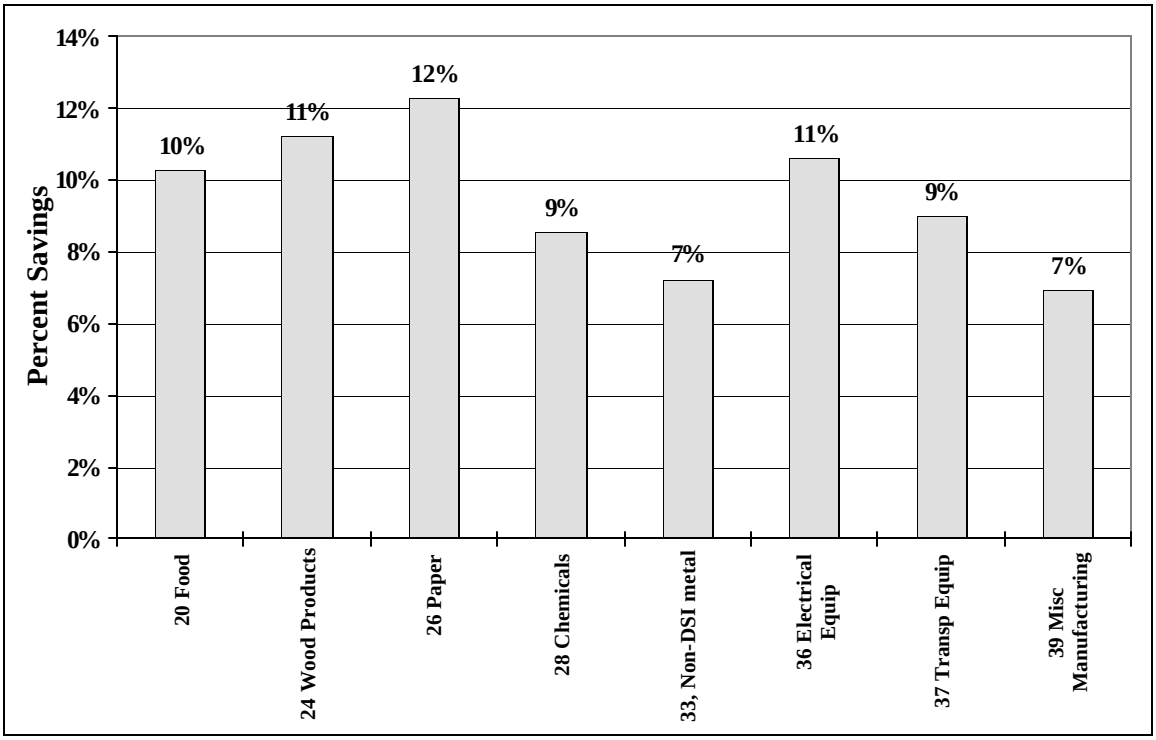
Table G-57
Achievable Savings by Industrial Category Estimated by Various Parties

							2015 Loads	Savings
	BPA	**ODOE**	**Puget**	**PGE**	**PP&L**	**Average**	**aMW**	**aMW**
20 Food	9%	11%	13%	9%	9%	10%	435	45
22 Textiles						7%	13	1
23 Apparel						7%	9	1
24 Wood Products	5%	12%	19%	12%	9%	11%	421	47
25 Furniture						7%	7	1
26 Paper	7%	10%	20%	16%	10%	12%	2040	250
27 Printing						7%	136	9
28 Chemicals	4%	9%	22%	1%	7%	9%	806	69
29 Petroleum			16%		14%	15%	203	30
30 Rubber & Plastics						7%	362	25
32 Stone, Clay, Glass						7%	281	20
33, Non-DSI metal	4%			8%	10%	7%	609	44
34 Fabricated Metal						7%	86	6
35 Industrial Machinery				3%		3%	558	14
36 Electrical Equipment		18%		3%		11%	729	77
37 Transportation Equipment			14%	4%		9%	228	21
38 Instruments						7%	61	4
39 Miscellaneous Manufacturing	4%		11%	4%	9%	7%	67	5
Region-Wt Average	6%	11%	19%	8%	9%	9%	7051	668

Some sources did not show an explicit estimate for various industrial categories because that particular category represented such a small portion of loads or because the sample size for that industrial category was too small. Typically, these industrial categories were grouped into the “miscellaneous manufacturing” category at the time the original estimate was made by the various parties.

Figure G-53

Average Achievable Savings for Largest Industrial Categories before Historic Savings are Removed



Finally, historic savings, as reported in NuTrak, which are about 100 average megawatts, were then subtracted from the achievable potential, resulting in 8 percent[97] for achievable savings. This is lower than the 10 percent discussed in the Conservation Resources Advisory Committee forum. Given the current load forecast of electricity use at 7,051 average megawatts, achievable savings are approximately 565 average megawatts without line losses in the medium forecast.

The Council has historically used an 85 percent penetration rate to translate technical potential into achievable potential. Using 85 percent penetration, applied to the 17 percent technical potential from Table G-56, and removing historic savings, results in an achievable potential of about 13 percent. However, the sources of estimates for achievable potential were judged to be some of the highest quality and regionally oriented estimates. As a result, instead of adjusting the technical estimate and combining it with the achievable estimates, this plan is based only on the 8-percent savings potential derived only from the sources that had already estimated achievable potential.

The average value used here is a composite of the work already done in the region, including many estimates from in-field audits and program experience. It is comparable in size to estimates derived in previous power plans. While the avoided cost is lower in this plan than in previous years, this has not had a large effect on the amount of savings because most of the savings in the industrial sector are quite inexpensive, according to program experience. In addition, technologies that were emerging or in the demonstration stage in prior plans, but which have significant conservation potential, such as adjustable-speed drives, are now becoming much more available and understood, and this increases the potential savings.

[97] There is some double-counting of the removal of historic savings because some of the investor-owned utilities had already subtracted historic savings before they reported their percentage savings estimates. If corrected, this would act to raise the savings reported here.

There is uncertainty in this estimate of potential achievable savings over 20 years. If the lowest value found in the achievable estimates were used instead of the average, the savings would equal 4 percent off loads. If the highest achievable value were used, the savings would be 18 percent. A range of 4 to 18 percent would result in a range of 280 to 1,270 average megawatts, instead of the 565 that is used in this plan.

Levelized Costs

Levelized costs were taken from the Energy $avings Plan and Business Energy Tax Credit Experience discussed above. These were adjusted for the Council's adopted discount rate (4.75 percent real), line losses (7.5 percent), and administrative costs.

Yearly Acquisition Levels

Another key feature of the Council's analysis of conservation resources is how much of the conservation resource can be developed in a particular year. If a particular conservation resource is integrated into the construction of a new building or a new appliance being purchased, then the savings are modeled to track the yearly additions of new buildings and appliance purchases. If a particular conservation resource can be developed from buildings and industries that already exist, then the amount developed in any given year must be paced -- not all of it can be developed at once.

This plan split the savings between new and existing industrial facilities based on the growth in the load forecast. In the medium forecast, 64 percent of loads in the year 2015 come from existing plants, and 36 percent of the loads are from new or expanding facilities. The timing of new loads dictates the timing of savings associated with those loads. However, the timing of savings in existing loads had to be scheduled. This was done based on historic experience.

In the past, the Council looked at those utilities with the most experience in developing the industrial conservation resource, and estimated what percent of their achievable savings they were acquiring per year. This became the maximum amount of yearly conservation that could be acquired from existing facilities. This value was about 30 average megawatts per year in the 1991 Power Plan. Zero was considered the minimum amount of yearly conservation that would be acquired. Zero acquisition levels would occur if the region were in a surplus and the industrial resource was more costly than short-term market prices. It would not be feasible to step in one year from zero to maximum amounts, and so a ramp-up was established that required three years to step from zero to a maximum level. Similar arguments are made for stepping down, because industrial projects have a long lead time and many in process this year might not show up as savings for a year or more.

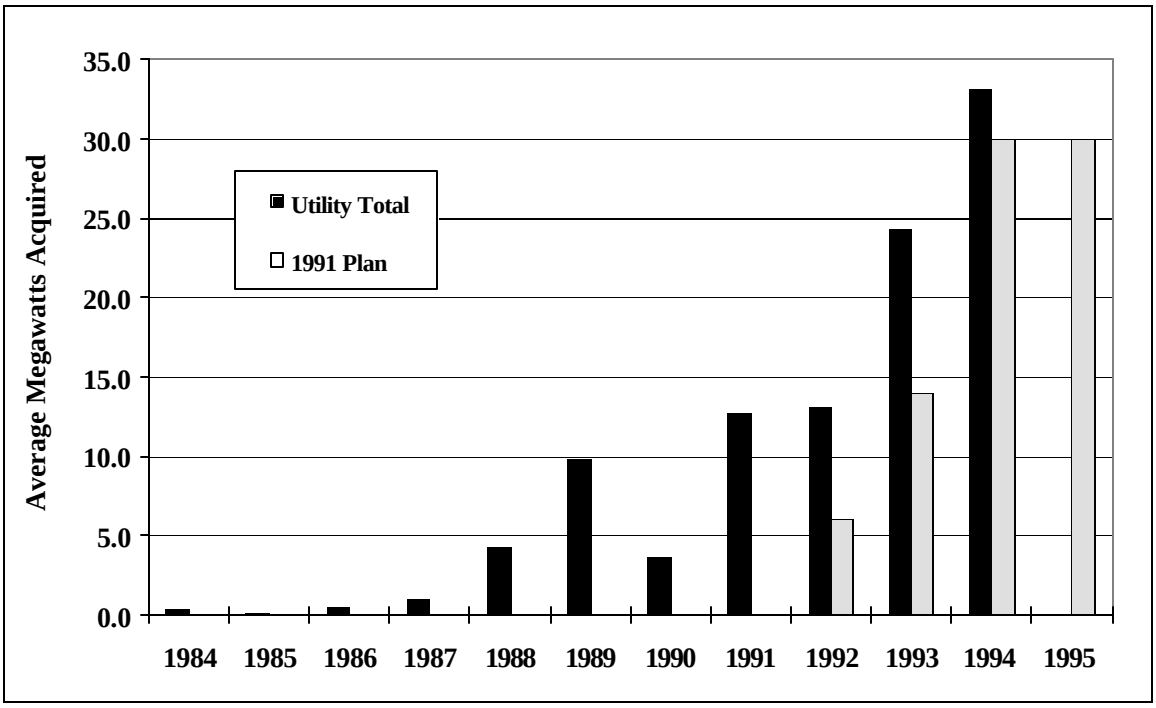
The region has more experience with industrial conservation acquisition today than ever before. Figure G-54 indicates the amount of industrial conservation that was acquired by utilities over the last 11 years from the NuTrak database[98]. Alongside the utility accomplishments are the annual levels of acquisition for the industrial sector that were implied in the 1991 Power Plan if the 1,500 average megawatt target across all conservation resources were to be met by the year 2000. The level in the power plan represented savings from all sources -- by industries on their own, by government actions, and by utilities. For example, the Oregon Department of Energy's Business Energy Tax Credit savings would add to the utility savings to the extent they are not already counted in the utility estimate.[99] Clearly, the region's utilities exceeded the estimate of yearly savings that was anticipated to be developed by all parties in the 1991 Plan. Utility conservation savings from the industrial sector topped 33 average megawatts in 1994.

---

[98] 1994 values are preliminary.

[99] After 1990, as utility programs expanded, an estimated 50-60 percent of BETC projects got both the Energy Tax Credit and a utility incentive. None of the BETC savings is displayed in the table.

Figure G-54
Historic Utility Industrial Savings and 1991 Plan Estimates



Based on this historic information, staff proposes to use 30 average megawatts per year as the maximum amount of conservation that could be acquired in any year. This does not imply that utilities are the delivery mechanism for these savings or that near-term levels might not be much less. It simply means that we think we could duplicate the level of effort that was expended over the last few years to develop industrial conservation if sufficient resources are provided.[100] It is not clear that utilities will be the primary mechanism for this development in the future. This issue is closely tied to the discussion of utility roles for conservation in a restructured industry, which is being developed in a different forum. Clearly rate impacts, stranded investments,[101] and customer service are all issues that will significantly impact the role a utility could potentially play in the development of this resource.

Minimum levels of industrial conservation development are still considered to be zero, and four years was estimated as the time it would take to step up or down between the minimum or maximum level.

ADDITIONAL ISSUES

The above discussion of industrial sector conservation is by necessity simplified. There are extremely complex and interactive issues that play into the discussion of industrial conservation which have not been discussed here. However, in an attempt to at least briefly discuss additional issues, they are raised in the following sections.

[100] It should be noted that the 33 average megawatts was accomplished in the industrial sector in 1994 even when one of the larger utilities in the region was not developing much industrial conservation. With their contribution, the level would be even higher.

[101] The term is used loosely here and could mean that a utility invests money in a facility that then leaves the utility's system, or it could mean that industrial customers are asked to repay conservation investments made on their behalf by utilities as they leave the system.

Electrification and Fuel Choice/Switching

Over the next twenty years, there will likely be an increased competition between electricity and gas providers, and even among electricity providers. Some predict that switching either to gas or to electricity will occur. Certainly, many utilities will engage in load-building and load-retention activities. In addition, some have argued that emerging electric technologies might result in significant electrification. This will result in some cases in increased electricity use. In turn, it has been argued that these types of activities could entirely negate the conservation savings estimated in this sector.

The industrial sector estimate considered here is basically one that looks at total regional loads, regardless of who serves those loads. In that sense, it is independent of competition among electricity providers. This estimate is also based on the Council's forecast of industrial loads. These forecasts cannot consider all possibilities, and the future is uncertain. For these reasons, a high, medium-high, medium, medium-low and low forecast are all developed. While one of these in isolation does not capture the types of electrification and electric fuel retention scenarios that could develop, the aggregate of them probably does encompass the levels of activities that could occur in fuel choice in the industrial sector. Because the conservation estimates track the forecasts, they also encompass a range that allows for the types of activities that might occur among the electricity/gas fuel competition. The conservation estimates here are made independent of the load-retention or fuel-switching changes -- in essence the conservation is estimated after whatever level of load retention or fuel switching activity occurs.

Administrative Costs

Seven of the 19 evaluations done on Bonneville's Energy Savings Plan industrial program recorded administrative costs, including the cost of evaluating the program. These costs ranged from 7 to 20 percent of the full cost (both utility and customer) of the conservation measures. The average administrative cost of the seven case studies was 10 percent. Historically, the Council has used a 20-percent administrative cost adder for conservation. However, given the further information provided by these evaluations, this plan uses 10 percent.

Lifetimes

The value used historically by the Council and Bonneville is an average of 15 years for median lifetimes across all measures. In all sectors, measure lifetime is the point in time when 50 percent of the measures have been removed permanently from use. If there is a second-owner life, then the years of service for the second or subsequent owners are also included in the lifetime. If there are replacement or operation and maintenance costs incurred over the average lifetime, these costs are factored into the levelized costs of the measure.

There is very little empirical data to estimate the lifetime of most of the industrial measures considered in the conservation assessment. Most data has come through engineering and audit estimates of typical equipment lifetimes, combined with some judgment on remodeling and equipment replacement. Some end-use models, such as the Industrial Supply Curve Model 2, use measure-specific lifetimes, and the average lifetime across all the measures would be reflected in the avoided costs. However, this model is not used as the basis for developing the estimates in this plan, and it was decided to continue with the historic use of an average 15-year measure life.

IRRIGATION SECTOR

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IRRIGATION SECTOR

SUMMARY

In 1994, the region's agricultural sector consumed about 661 average megawatts of electricity for irrigation, about 4 percent of the region's total consumption. The technically achievable potential for conservation measures, estimated with a marginal measure not exceeding a cost of about two and a half cents per kilowatt-hour, is about 10 average megawatts. This estimated potential resource comes from making existing loads more efficient, rather than efficiency improvements in new irrigated acres. These savings are available at an average cost of about 1.6 cents per kilowatt-hour, taking into account administrative costs and adjustments for transmission and distribution savings. Figure G-41 depicts estimated irrigation sector conservation available at various costs--the irrigation conservation supply curve.

The conservation resource in public utility service areas is estimated to be about 45 percent of the total potential, with about 55 percent in the private utility service areas, based on the proportion of total irrigation loads in the Council forecast, not including Bureau of Reclamation loads.

OVERVIEW OF IRRIGATION IN THE PACIFIC NORTHWEST

Acres Irrigated

There are an estimated ten million irrigated acres in the four Northwest states of Idaho, Montana, Oregon, and Washington, of which about 56 percent are currently sprinkler irrigation, as Table G-54 and Figure G-36 portray. While the total number of acres under irrigation has remained flat, there has been a gradual shift from surface to sprinkler irrigation. In general, surface irrigation uses gravity rather than pumping to bring the water to the field and to apply it to the crops, while sprinkler irrigation nearly always utilizes electricity in the process.

Table G-54

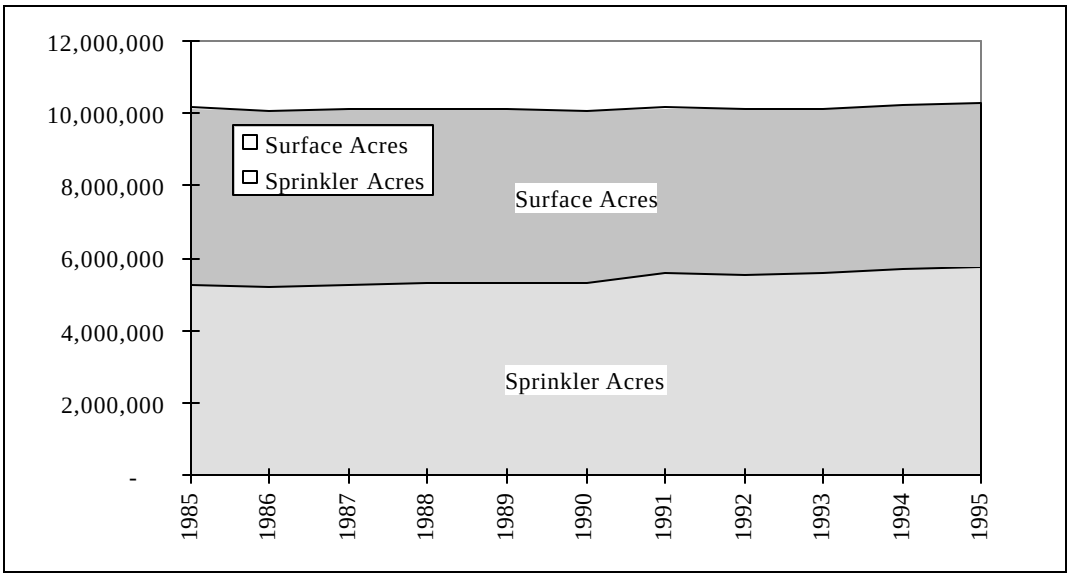
Irrigated Acreage, Four Northwest States, Sprinkler and Surface, 1985 - 1995[102]

	Irrigated Acres	Sprinkler Acres	Sprinkler %	Surface Acres	Surface %
1985	10,140,860	5,274,340	52%	4,866,520	48%
1986	10,074,925	5,225,985	52%	4,848,940	48%
1987	10,098,900	5,254,975	52%	4,843,925	48%
1988	10,120,910	5,306,770	52%	4,814,140	48%
1989	10,111,200	5,292,185	52%	4,819,015	48%
1990	10,034,965	5,292,410	53%	4,742,555	47%
1991	10,134,900	5,594,860	55%	4,540,040	45%
1992	10,081,300	5,549,960	55%	4,531,340	45%
1993	10,111,525	5,591,470	55%	4,520,055	45%
1994	10,246,400	5,690,200	56%	4,556,200	44%
1995	10,280,470	5,743,150	56%	4,537,320	44%
Average	10,130,578	5,437,846	54%	4,692,732	46%

[102] Source: Irrigation Journal, "1995 Irrigation Survey Reflects Steady Growth," January/February 1996.

Figure G-36
Irrigated Acres in the Four Pacific Northwest States,[103]

Sprikler and Surface, 1985-1995

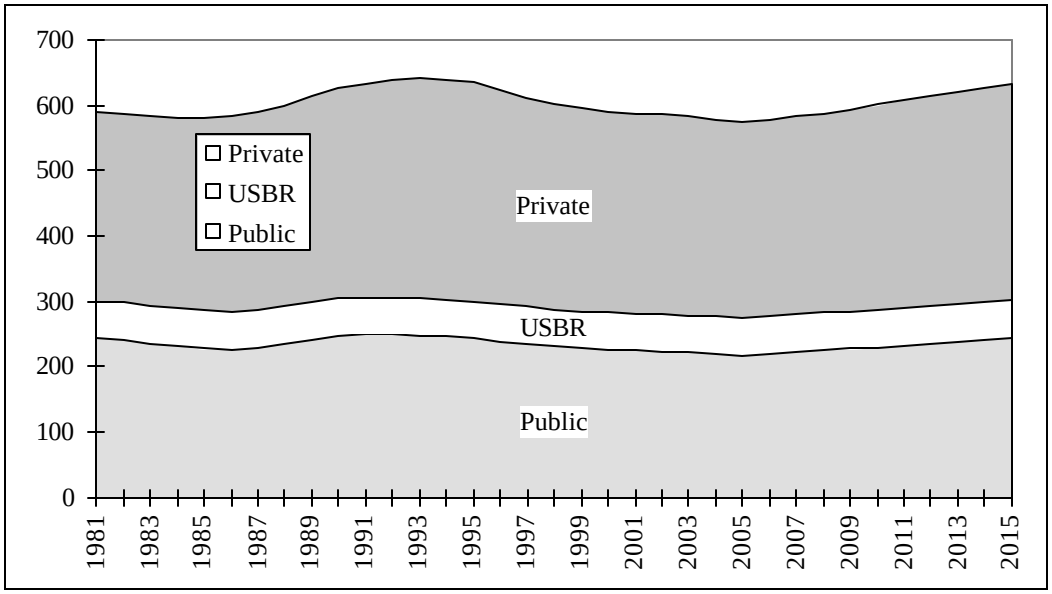


Irrigation Power Sales

Figure G-37, based on the Council's preliminary medium load forecast, charts irrigation power sales by utility type and sales from the U.S. Bureau of Reclamation, from 1981 to 2015.

Figure G-37
Irrigation Power Sales by Utility/Agency Type,

Backcast and Forecast, 1981-2015, Preliminary Medium

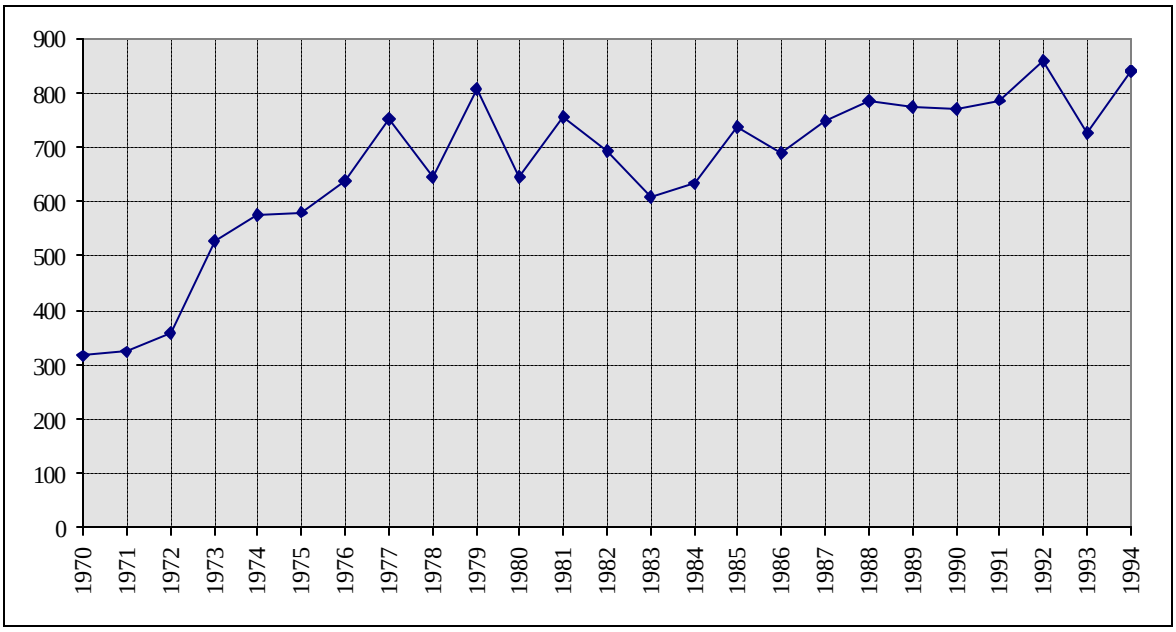


[103] Source: Irrigation Journal, "1995 Irrigation Survey Reflects Steady Growth," January/February 1996.

Figure G-38 charts the actual historical total regional irrigation sales by utilities, from 1970 to 1994. This does not include power use by the U.S. Bureau of Reclamation (which averages about 60 average megawatts per year). Figure G-38 differs from the pre-1994 data in Figure G-37 because it is unadjusted for the volatility of weather and economic conditions from one year to the next.

Figure G-38

Total Regional Irrigation Sales, 1970-1994, in Average Megawatts[104]



As a gross indicator of average consumption per acre, the table below calculates the kilowatt-hour per acre using the values from figures G-36 and G-38. The energy used includes the consumption associated with the U.S. Bureau of Reclamation irrigation project in the mid-Columbia area of Washington State. This is a gross measure, and the average consumption is low because eastern Montana power consumption is not included but its acres are.

Table G-55

Electrical Consumption Per Sprinkler Irrigated Acre, 1985 - 1994

Year	Sprinkler Acres	aMW Used	KWh/Acre
1985	5,274,340	615	1,021
1986	5,225,985	561	940
1987	5,254,975	618	1,030
1988	5,306,770	649	1,071
1989	5,292,185	641	1,061
1990	5,292,410	683	1,131
1991	5,594,860	656	1,027
1992	5,549,960	739	1,166
1993	5,591,470	585	917
1994	5,690,200	722	1,112
Average	5,407,316	647	1,048

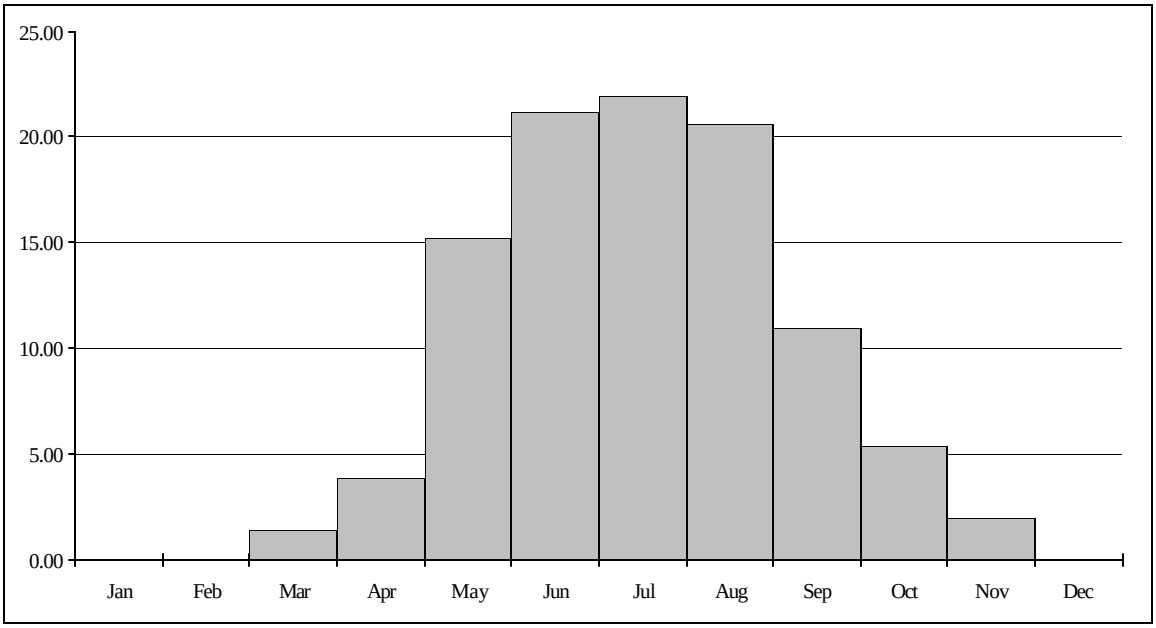
[104] Source: BPA regional sales database, 8/11/95.

Irrigation Load Shape

Energy savings from irrigation efficiency improvements are available when irrigation is happening. Figure G-39 charts the irrigation load shape curve which the Council uses. In the cost-effectiveness analysis of irrigation savings, the avoided cost reflects the value of the savings at the time they are produced. Thus, in a winter-peaking regional system where the system constraints are in the winter, irrigation savings gets valued less than, say, savings from heating, which tend to directly coincide with system peaks. Of course if the local utility distribution system serving the irrigator suffers capacity constraints in the irrigation season, then the actual value to that local system would be greater if the conservation measures helped the utility delay or defer distribution system improvements.

Figure G-39

Irrigation Load Shape, Percentage Annual Load by Month



OVERVIEW OF UTILITY IRRIGATION CONSERVATION PROGRAMS

Through 1994, the region's electric utilities have reported cumulative savings in the irrigation sector of 22.0 average megawatts. As reported to Nutrak (Northwest Utility Conservation Tracking System), these savings came from: Bonneville Power Administration, 17.6 average megawatts (basically savings acquired by BPA customer utilities running BPA programs); Idaho Power Co., 4.3 average megawatts; and Montana Power Co., .03 average megawatts (for entire MPCo system). PacifiCorp had some irrigation conservation activity in 1994 but didn't claim any savings in its Nutrak filing.

Following are brief descriptions of the current or most recent irrigation energy conservation programs operated by these Northwest utilities.

Bonneville Power Administration WaterWise Program

Bonneville has operated conservation programs in the irrigated agriculture sector since 1979. Initial efforts consisted of a pilot program that evolved in 1982 into a regional pump testing and system evaluation program, administered and operated by participating utilities. The program has been expanded to include contracts with certified analysts to test and evaluate irrigation systems. Irrigated agriculture programs provide incentives and rebates to encourage irrigators to adopt cost-effective energy conservation measures.

The WaterWise Program includes System Testing and Design Work (Stage I), Hardware Retrofit (Stage II), and Irrigation Management features. Pump testing and analyses are provided to locate system components that could, through retrofit, produce energy conservation. Irrigation management facilitates the efficient use of energy and water resources by optimizing the operation of the irrigation system.

The WaterWise Program reflects a decade of utility and BPA experience in irrigation-related conservation programs. The program matured because of the contributions of many utilities, analysts, state and Federal agencies, and other interested parties.

The Irrigated Agriculture Hardware Program expired and was rewritten in 1991. The resulting WaterWise Program was an acquisition agreement operated by 39 utilities, all east of the Cascades.

Historically, system testing and retrofit activities were limited to small and medium systems. FY 1992 saw the addition of procedures to analyze large irrigation systems (over 480 acres). Some large irrigation systems' project costs exceed $1 million. The program budget was nearly doubled for FY 1992 to cover these new systems.

BPA has incorporated irrigation management techniques into the WaterWise Program. These techniques, when practiced correctly, have the potential to save energy and water, and improve crop yield. Previous BPA pilot programs, conducted during the last 3 years, have shown good potential for water and energy savings through irrigation management. Beginning in 1994, Bonneville separated out its irrigation management activities into a WaterWise Scheduling Program.

Idaho Power Company Agricultural Choices Program

On April 21, 1993, by order No. 24848 of the Idaho Public Utilities Commission, Idaho Power's Agricultural Choices Program was approved for agricultural customers served by Idaho Power Company. This program promotes hardware modification of customer owned irrigation equipment to permanently reduce pumping horsepower and electric system demand. The new Agricultural Choices Program is designed to meet the efficient redesign/design needs of large, medium, small and new irrigation systems, served under one of Idaho Power's irrigation tariffs in Idaho, Oregon, and Nevada.

The component of the program targeting large customers is applicable to customers with nine or more pumps totaling at least 1000 horsepower (Hp) in a single interconnected irrigation system. Large customers will provide an analysis of their systems (via engineering study). Upon Idaho Power review, the customer may enter into an agreement to receive incentive payments from Idaho Power for retrofitting the system, which will make it more energy efficient, resulting in lower energy demand and usage.

The component of the program targeting medium-sized customers is applicable to customers with connected irrigation loads of at least 40 Hp in a single interconnected irrigation system. Medium customers may have an irrigation system analysis provided by Idaho Power or by a dealer/consultant of their choice. After review of the analysis Idaho Power may enter into an agreement to improve the irrigation system efficiencies and the customer will receive from Idaho Power an incentive payment for making energy efficiency retrofit(s) to their irrigation system.

The component of the program targeting small customers is scheduled for roll out in the spring of 1994 and will be applicable to customers with connected loads less than 40 Hp in a single interconnected irrigation system. Small customers supply an analysis of their system (analysis provided by customer's dealer). Upon Idaho Power review, the customer may enter into an agreement to receive incentive payments from Idaho Power for making energy efficiency retrofit(s) to their irrigation system.

The component of the program tageting new irrigation customers is scheduled for roll out concurrent with the "small" system. It will be applicable to new irrigation accounts installing pressurized irrigation systems on land that has never had a permanent pressurized system installed before. New customers will provide a design proposal of their system to Idaho Power (design provided by customer's dealer). Upon Idaho Power review, the customer may enter into an agreement to receive incentive payments (customer and

dealer) from Idaho Power for adopting new energy efficient design features into the irrigation system installation.

Water quality and environmental issues continue to impact the farming community and will be on the increase in the future. This may cause a larger number of farmers to convert to pressurized irrigation systems, as well designed pressurized systems can result in more efficient use of water, fuel, and chemicals in addition to saving energy.

Montana Power Company Irrigation Pilot Program

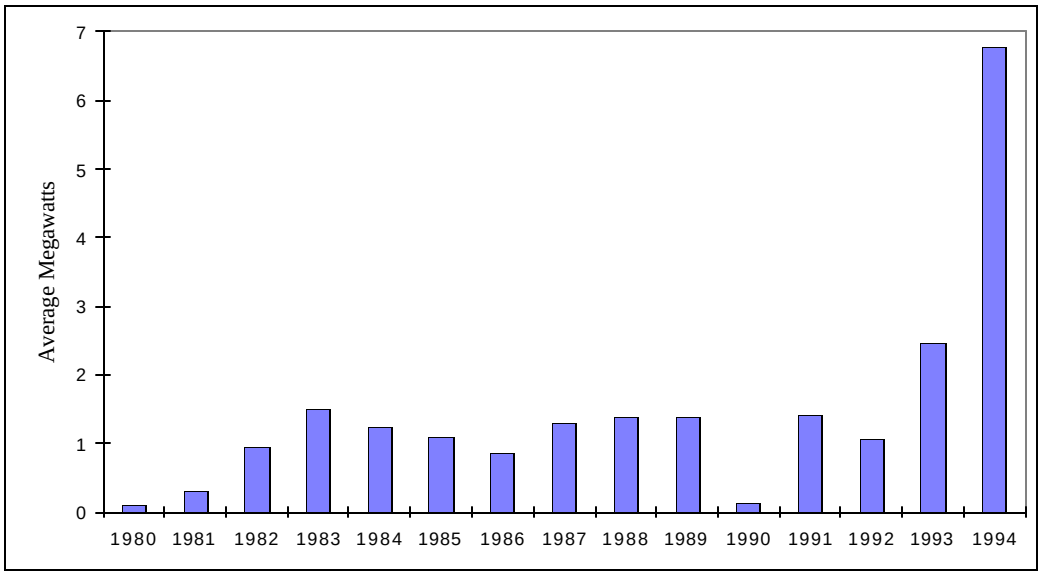
Contracted through the National Center for Appropriate Technology, this program offers free irrigation audits for Montana Power Company customers with irrigation systems of 20hp or greater. Provides interest free loans for improvements in efficiency identified by the audit, to include the pump, motor, sprinkler equipment, nozzles, regulators and drop tubes.

Total Irrigation Savings

Figure G-40 charts the adjusted annual first year savings for irrigation programs sponsored by Northwest electric utilities. These savings basically reflect programs that providing testing or hardware retrofit assistance with one notable exception. In 1994 Bonneville began offering a scheduling program that produced 5 aMW that year. This is an O&M measure, that only provides savings in the year that it is delivered. In other words, it has a measure life of one year.

Figure G-40

Annual First Year Electric Savings in Irrigation, Adjusted, 1978-1994[105]



ESTIMATE OF POTENTIAL FOR FUTURE IRRIGATION EFFICIENCY IMPROVEMENTS

In putting together estimates of future potential irrigation efficiency, the Council staff used an approach where the potential savings could be expressed as bundles of that were similar in the type of savings captured (e.g. end use, subsector), the techniques used to capture them, and so forth. The "market bundle" approach

[105] The savings values in Figure AG-5 are adjusted for uniform treatment of T&D savings.

was used to to identify and explore different real-world paths that might be followed by utilities or others to deliver irrigation energy savings in the future.

Each bundle is more fully described in Appendix G-3. Because of economic and institutional changes, the regional plan does not set conservation acquisition targets for the region's utilities. The irrigation market bundles were defined largely to follow three important threads established through the evolution of irrigation conservation programs over the past decade or more in the region.

For irrigation, three market bundles were identified:

- hardware retrofits
- scheduling
- education

Irrigation Hardware Retrofits

The hardware retrofits market bundle addresses problems and opportunities with the hardware of existing irrigation systems. Hardware retrofits can include an initial system assessment, design, installation of measures, and post-installation testing.

The principal conservation measures installed in irrigation hardware retrofits are:

- low pressure irrigation on center pivot systems;
- fittings redesign;
- main-line modifications; and
- improved pump efficiency.

Low pressure irrigation involves using sprinkler or spray application devices designed to operate at lower pressures than conventional sprinkler devices. These low pressure devices can be divided into three major types: low pressure spray heads, low pressure impact sprinklers and drop tubes.

The fittings of an irrigation system include valves, elbow joints and other components used to connect the irrigation pump to the pipes of the system and to connect the pipes within the system to each other. Fittings redesign involves using larger tapered fittings to replace valves and elbows that are too small or that change abruptly in size and direction.

Main line modification involves increasing the size of the system's main line or relining, resulting in decreased energy losses due to decreased friction. This redesign can sometimes be accomplished most economically by installing a second main line pipe parallel to the existing one.

Field tests show that many irrigation pumps operate at unacceptably low efficiencies and thus consume much more energy than is necessary to deliver the water. According to Pacific Northwest Extension Publication PNW 285, the four primary causes of low overall pumping plant efficiencies are:

- mismatches of pump, irrigation systems, and changed depth to water source;
- improperly designed or sized fittings;
- pump wear due to abrasion or cavitation; and
- poor maintenance practices.

Typically, hardware retrofit programs are considered to have an average measure life of 15 years.

Irrigation Scheduling

Also known as water management, improved scheduling involves management of both timing and amount of water applications throughout the growing season. This reduces water use without reducing crop yields, and energy use is reduced due to a decrease in pumping requirements. Scheduling is the cornerstone of a basic comprehensive management approach to efficient water and energy management, with all other

conservation measures being necessary components. Experience indicates that scheduling is easier to implement on center pivot systems than on hand-move and sideroll systems.

The question has been raised whether scheduling really saves electricity. Savings from scheduling depend upon farmers overwatering in the base case, which is not well documented. In addition, variations in annual rainfall and evapotranspiration mean that scheduling may save energy in normal water years, but not when extreme conditions exist. In very dry years, water is a limited resource, and scheduling may simply improve the crop, since water is applied at appropriate times, but not save energy since overwatering is constrained.

There is a range of sophistication for activities which fall under the heading of scheduling. At the low-tech end, it may involve an irrigator relying on general information on soil moisture content, recent and forecast rainfall, and generalized evapotranspiration data for his crops, combined with visual information-gathering such as driving by a field, walking a field, feeling the soil for moisture, visually inspecting plants, and so forth. This information would be the basis for determining how much and when to apply water, and then operating the system accordingly.

At the sophisticated end of the spectrum, scheduling can involve aerial imagery from aircraft or satellites to ascertain where crops are receiving too much or too little water and/or agrichemicals, precisely located using GPS (global positioning system) devices on the ground. Ground truth information can come from neutron or ultrasound probes that precisely measure the moisture being held within the root zone. Forecast meteorological information allows more precise estimates of expected natural rainfall and evapotranspiration. Skilled agronomists can identify the need for nutrients and pesticides. Computerized control systems then order automated systems to deliver the needed water and agrichemicals precisely as prescribed, to the exact location, exactly when needed.

There is an important educational component built into an irrigation scheduling program, particularly the sophisticated programs, where an irrigator is often visited twice a week by an agronomist to be briefed on the progress and needs of his or her crops.

In programs across the region, there are private specialists who now provide scheduling and water management services to both participants in utility-funded programs as well as non-participants. Because the scheduling services only directly affect water use in the growing season that is scheduled, the average measure life is considered to be only one year.

Irrigation Education

The third irrigation market bundle is education. Historically, utility and other irrigation efficiency programs have incorporated an important education component into both hardware and scheduling programs. The reason for treating education as a separate market bundle is the recognition that in the future, utilities may not be in a position to fund hardware and scheduling programs as they have in the past. By separating out education, the Council recognizes that it would be possible to provide competent and accessible information, training, and technical assistance to irrigators separate from incentives toward hardware and/or scheduling.

Even absent incentives, individual irrigators who are informed with up to date information on best irrigation practices and the relative costs and performance of system configurations, are better equipped to make good decisions--that is, decisions that best contribute to their bottom line as well as most efficiently use the valuable resources of energy, water, and soil.

Irrigation education is currently provided by state agricultural extension services, the U.S. Natural Resources Conservation Service (formerly SCS), and by state energy and water resouces agencies. An excellent example is the program of “Energy Efficient Irrigation Workshops” provided in Idaho every year since 1992. These workshops are jointly sponsored by the Energy Division of the Idaho Department of Water Resources, the University of Idaho Cooperative Extension System, and a host of cooperating utilities and federal agencies.

They publish an excellent "Energy-Efficient Irrigation Practices Handbook" and bring the workshops to the irrigator at numerous locations across the state, in mid-winter, prior to the start of the irrigation season.

For planning purposes, the Council's analysis assumes that educational efforts have a measure life of three years. It is impossible to precisely assign energy savings to an educational program, but virtually everyone who has worked in the area of irrigation efficiency agrees that education delivers results. As one long-time irrigation specialist observed, "Humans aren't born knowing how to irrigate."

IRRIGATION SUPPLY CURVE

The irrigation supply curve is plotted in Figure G-41 and appears in table G-56, which follows the figure.

These values are based on a thorough review of conservation costs and savings reported by utilities operating irrigation efficiency programs, combined with professional judgment and discussions with seasoned experts in the field.

Estimates of irrigation conservation potential are made difficult due to major data limitations, including: data from Bonneville's WaterWise Program (costs, savings, acres,); utility sales for purposes of irrigation; and linkage of irrigated acres to utility service areas and utility irrigation sales. Most of the available information is sufficiently removed from the specifics (county, utility, crop, system type) that detailed analysis is essentially not possible. One bright light on the horizon is the legislatively required program to measure and report groundwater usage in Idaho, now in its infancy. With a little extra effort, this program could pave the way for inexpensive early identification of opportunities to conserve water and energy.

Of particular value was the "Review of Potential Irrigation Energy Conservation Savings in the Pacific Northwest," prepared for Bonneville by Trimmer Engineering, Inc. Although this report is limited in that it looked only at public utilities that were running Bonneville's WaterWise program, it did systematically estimate the physical opportunities for additional energy conservation. It identified what was attainable from an engineering standpoint. It did not examine cost-effectiveness. This study estimated an energy ratio, defined as the ratio of how much energy was required to irrigate by the amount actually sold by the utility. For those utilities with energy ratios less than 0.7, the study estimated that a maximum of 40 average megawatts may be available. There are also many individual opportunities in utilities with higher energy ratios, but they were not estimated in the Trimmer study. Also of particular value in putting the supply curve estimates together was additional personal communication with Walt Trimmer.

Figure G-41 charts the supply curve which combines the estimated savings from each market bundle and arrays them on the basis of the quantity of savings estimated to be available at various costs.

Figure G-41
Irrigation Supply Curve

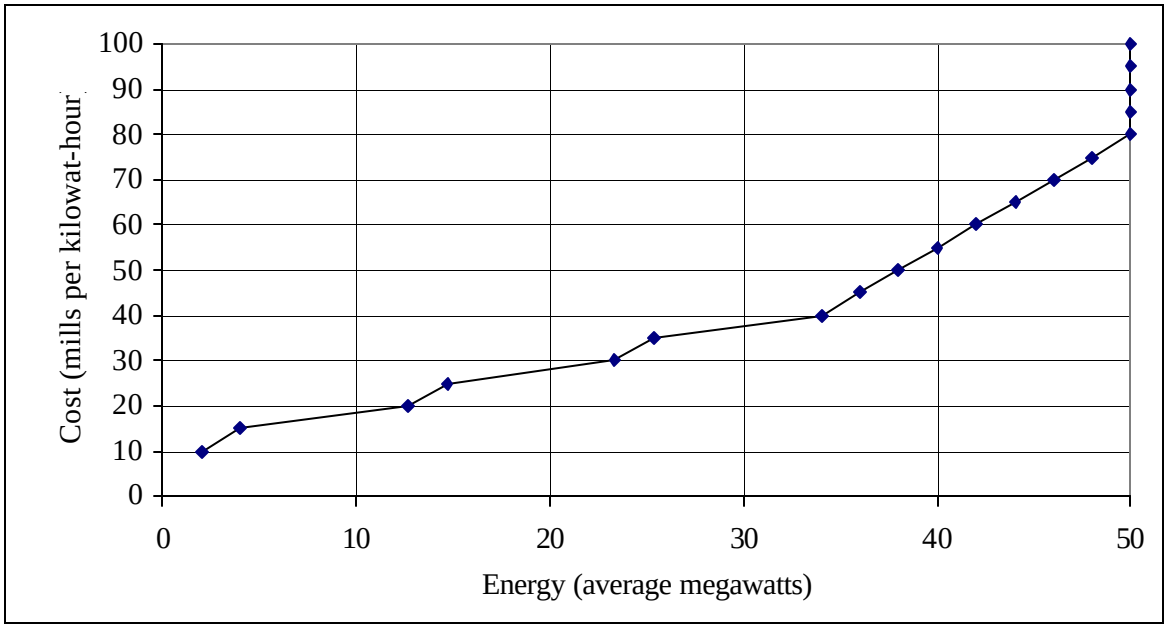


Table G-56, Irrigation Supply Curve Values

achievable regional irrigation savings in aMW adjusted to include 7.5% T&D Loss Savings

life	Mills/kWh	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	total
15	**Hardware**	0	0	0	0	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	1.95	0	0	0	0	21.5
1	**Scheduling**	1.4	1.4	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43	0	0	0	0	21.5
3	**Education**	0.7	0.7	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0	0	0	0	10.8
	SUM	2.2	2.2	2.15	2.15	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1	0	0	0	0	53.8
	cumsum	2.2	4.3	6.45	8.6	12.7	16.8	20.9	25	29.1	33.2	37.3	41.4	45.5	49.6	53.8	53.8	53.8	53.8	53.8	53.8

mill bins	10	20	30	40	50	60	70
aMW	2.2	4.3	6.25	8.21	8.21	8.21	8.21
avg mills	10	17.5	28.3	37.5	47.5	57.5	67.5
avg msr life	1.7	1.67	5.83	8.02	8.02	8.02	8.02

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TRANSMISSION AND DISTRIBUTION SYSTEM EFFICIENCY

SUMMARY

While there are always opportunities to make efficiency improvements in regional transmission and distribution systems, there are attributes of these potential energy savings that make them difficult to quantify. This is because:

1. Line losses (and loss reduction opportunities) are site-specific to each system and load patterns on that system. Systemwide savings cannot be generalized.

2). Economic management of transmission and distribution savings require a balance between the costs of lost power and the costs of increasing the system's capacity.

3) Given the current industry restructuring, the economic signals that drive transmission and distribution system improvements will likely affect system owners and operators and are likely to be internal to the system.

For these reasons, the Council did not quantify an estimate of transmission and distribution savings in the Draft Fourth Northwest Power Plan.

Transmission and distribution systems transport electric power from the generating plant to the retail customer. A simplified transmission and distribution system is illustrated in Figure G-42.

Figure G-42
Simplified Diagram of Transmission and Distribution

Step-up transformers increase voltage from the terminal voltage of the generating equipment (typically 13.8 kilovolts) to transmission voltage. Power is transported over long distances between generating plants and load centers on transmission lines. These operate at voltages of 69 to 500 kilovolts, or higher. Higher transmission voltages can reduce electrical losses and allow use of smaller transmission conductors. Near load centers, substation transformers reduce voltage from transmission levels to the voltage used for local distribution. Power is distributed from the substation to end users on primary distribution feeders. These run along streets and roads, above ground (overhead distribution) or buried (underground distribution), at voltages ranging from 2.4 kilovolts (older feeders) to 34.5 kilovolts. Distribution transformers, located at intervals along the primary distribution feeders, reduce primary distribution voltage to customer service voltages (120 to 600 volts, depending on the user). Power is transferred from the distribution transformer to the end user by secondary feeders.

It is estimated that between 7.5 and 9 percent of the total regional electricity load is lost during transmission and distribution. Site-specific values used by individual utilities in the region range from 5 percent to 15 percent, depending on the distance between source and load and on the overall loading of the system. Bonneville, having no distribution system, experiences lower losses as a percentage (about 2.5 percent) than the system as a whole. Losses as a percentage, during peak loads can be significantly higher, because they are determined by the square of the current and the total impedance of the system. Peak losses become important for capacity-constrained systems or areas with transmission capacity constraints, such as those being experienced in the Puget Sound area.

The following section discusses the regionwide technical potential for reducing energy losses on transmission and distribution systems.

LOSS REDUCTION MEASURES

A number of measures may be used to improve transmission and distribution efficiencies. These measures can be categorized as follows:

- Replacement of transmission and distribution system components, such as transformers and conductors, with components having lower electrical losses.
- Modification of system operating conditions, such as nominal voltage levels, to reduce losses.
- Modification of load characteristics to reduce transmission and distribution system losses. Examples include reducing peak loads and reducing reactive loads.
- Reconfiguration of the transmission and distribution system. An example is reconfiguring distribution feeders to reduce the average distance, and therefore losses between a substation and its loads.

In a study prepared for the Bonneville Power Administration, Westinghouse Electric Corporation assessed 88 measures, including 49 “state-of-the-art” measures and 39 “future” measures, as having potential to improve transmission and distribution system efficiencies (BPA, 1986). In that study, 15 of the 88 measures were identified as having the greatest potential benefit for Bonneville and its customers. Several of these 15 measures, such as revised transmission and distribution system design standards, are not in themselves efficiency measures, but rather means of implementing transmission and distribution loss reduction. Moreover, not all of the “state-of-the-art” measures are commercially proven. The Bonneville study of loss reduction potential on Bonneville customer systems (BPA, 1987) was based on three commercially proven loss reduction measures with widespread application to regional

transmission and distribution systems. These studies, along with discussions with utility transmission and distribution staff, suggest that the loss reduction measures described below hold the greatest promise for application to transmission and distribution systems in the Pacific Northwest.

Reconductoring

Transmission and distribution conductors may be technically adequate to serve their intended load, yet may experience high losses due to conductor resistance. Substitution of larger, lower-resistance conductors may economically reduce system losses.

Increase Primary Distribution Feeder Voltage

Primary distribution feeders operate at voltages ranging from 2.4 to 34.5 kilovolts. Increasing the nominal operating voltage of a feeder will reduce the current carried and hence losses. Increasing primary distribution feeder operating voltage requires complete feeder rebuilding and replacement of most components.

Reactive Power Control

Transmission and distribution systems transport both "real" and "reactive" power. Real power is the portion of the total power that provides useful energy to end users. Reactive power is consumed by certain end uses, particularly motors, but does not produce useful energy. Both reactive and real power transfers contribute to transmission and distribution system loads and losses. Real power must be generated at a generating plant, but reactive power can be supplied by capacitors and reactors. By locating these devices near the source of reactive load, reactive power transfer through the transmission and distribution system can be reduced. This can reduce system loading and losses.

Feeder Reconfiguration

As utility systems have grown over the years, the physical and electrical configuration of distribution networks generally has not been optimized to minimize losses. For example, some distribution feeders may be carrying heavy loads, with attendant high losses, while nearby feeders remain lightly loaded. Loads can be shifted from heavily loaded feeders to more lightly loaded feeders by physical reconfiguration. In some cases, the distance from the substation to the retail customer can be shortened by reconfiguration.

Phase Load Balancing

Primary distribution feeders generally consist of three physically separate conductors, one for each phase. As single-phase customers, such as residences, are added to a feeder, an attempt is made to equalize loads on each phase of the primary feeder. This minimizes losses. But daily and seasonal variation in loads and long-term changes in the load of any single-phase customer may cause imbalance in the loads among feeder phases. Technology is being developed to dynamically balance three-phase feeder loads by use of devices that automatically switch loads among phases. This will minimize losses due to phase imbalance.

Peak Load Control

Because losses are proportional to the square of the load current, reductions in peak load will reduce transmission and distribution losses significantly. Various techniques, including pricing

incentives and interruptible end-use equipment operation, are available for reducing peak loads, and related transmission and distribution system losses.

Distribution Automation

Any of the four measures discussed above (reactive power, feeder configuration, phase load balance and peak load) can be automatically managed to minimize system losses.

Amorphous Metal Core Transformers

Use of amorphous metal in lieu of conventional silicon steel for the magnetic cores of transformers can reduce transformer core energy losses by 60 to 70 percent (EPRI, 1988). Although amorphous core transformers cost more than conventional silicon steel core transformers of equivalent capacity, their use to reduce losses may be cost-effective, particularly in light-load applications where transformer losses are dominated by core losses.

High-Efficiency Silicon Steel Transformers

Transformer losses can also be reduced by replacing conventional silicon steel transformers with improved lower-loss designs, and by sizing conventional units to reduce peak loading.

Conservation Voltage Regulation

Reducing the electrical voltage supplied to customers to the lower half of the standard voltage control band increases the efficiency of certain types of end-use equipment. The energy savings occur at the end use and at distribution transformers. The measures are implemented only on the distribution system.

Improved Insulators

The porcelain insulators used in transmission and distribution systems allow a small amount of current leakage to ground. Polymer-based insulators have lower leakage currents than conventional porcelain units and may reduce system losses.

ENVIRONMENTAL CONSIDERATIONS

Other than local and generally minor disturbances during construction, transmission and distribution system efficiency improvements have few environmental effects. Two environmental issues that may be associated with transmission and distribution system efficiency improvements are electromagnetic field effects and the retirement of equipment containing polychlorinated biphenyl compounds (PCBs).

Electromagnetic Field Effects

The voltage and current associated with the transport and use of electric power create electrical and magnetic fields that have the potential to affect biological processes. Certain epidemiologic studies have indicated a relationship between magnetic fields and adverse health effects. Two studies in the Denver area have shown some statistical correlation between cases of childhood cancer and nearby power lines carrying high-current loads. Other studies have shown some correlation between chronic occupational exposure to strong electromagnetic fields and cases of leukemia and brain cancer. The observed correlations between electromagnetic fields and disease in these studies is weak, and other environmental or social factors may contribute to,

or be responsible for, the observed effects. Moreover, other studies have produced conflicting results. Nevertheless, there is sufficient concern that further research is under way to confirm or deny the hypothetical correlation between electromagnetic fields and health effects.

Certain transmission and distribution efficiency measures can affect magnetic field strength. In particular, upgrading primary distribution feeder operating voltages reduces current flow and thereby the magnetic field associated with the feeder. But the connection between adverse health effects and electromagnetic fields is too uncertain to attribute health benefits to loss reduction measures that also reduce magnetic fields. Further research should better establish the relationship, if any, between magnetic fields and adverse health effects.

Polychlorinated Biphenyl (PCB) Disposal

Some transmission and distribution system components, including transformers and capacitors, are filled with oil for electrical insulation and cooling. The cooling oil of older units contained polychlorinated biphenyl compounds (PCBs), prized for their insulating properties and inflammability. But, PCBs have been found to be carcinogenic and are not allowed in new equipment. Old equipment found to contain PCBs is decontaminated or disposed of under controlled conditions.

Transmission and distribution system loss reduction programs may accelerate the removal of PCB and PCB-contaminated equipment (though many utilities have already removed PCB-containing equipment). This may create some additional interim hazard of inadvertent PCB releases through the handling and disposal of PCB-containing equipment. These can be minimized through proper handling and disposal procedures. In the long run, loss reduction programs should result in more rapid reduction in the overall hazard from PCB compounds as the stock of older, less efficient components containing PCBs is eliminated.

TECHNICAL AND ECONOMIC POTENTIAL IN THE PACIFIC NORTHWEST

This section discusses the potential for transmission and distribution system efficiency improvements in the Northwest. Discussed first are potential savings on the Bonneville system. This is followed by a discussion of potential savings on the region's utility systems.

Bonneville Transmission System

In past years, Bonneville periodically convened a Loss Savings Task Force. This Task Force assessed opportunities for loss reductions through upgrades to the Bonneville transmission system. Promising efficiency opportunities were recommended for inclusion in Bonneville's budget when they were considered cost-effective. In general, cost-effectiveness has been defined under the conditions of surplus electricity that existed when these reports were written.

Non-Bonneville Transmission and Distribution Systems

The assessment of the cost and availability of energy savings through loss reduction on transmission and distribution systems other than those of Bonneville's is based on a customer system efficiency improvement (CSEI) study prepared for Bonneville by Pacific Northwest Laboratory (PNL, 1987). The Council and the Pacific Northwest Utilities Conference Committee conducted a series of consultations with transmission and distribution system staff of regional utilities to verify and update the assumptions and methodology used in the CSEI study.

The Bonneville CSEI study was a "top down'' study intended to produce an approximation of the cost and magnitude of regionwide transmission and distribution system savings potential

for use in long-term regional planning. The results of the study were not intended to be used as the basis for estimating loss reduction potential on any given transmission line or distribution feeder. Assessment of the potential savings on a given transmission line or distribution feeder would require an individual engineering study.

Reduction Measures

The CSEI study assessed the availability and cost of savings from the components that are responsible for most of the transmission and distribution system losses. The following measures were considered the most promising:

- Replacement of existing distribution transformers with more efficient conventional silicon steel core transformers.
- Replacement of existing substation transformers with more efficient conventional silicon steel core transformers.
- Replacement of existing transmission conductors with conductors that are three standard sizes larger.
- Replacement of existing primary distribution feeder conductors with conductors that are three standard sizes larger.
- Upgrading the nominal voltage of 12.5-kilovolt primary distribution feeders to 34.5 kilovolts.

Measure Costs and Performance

Cost information for the CSEI study was derived from utilities, equipment vendors and published literature. For most measures, equations relating the cost of equipment to its physical or electrical characteristics were derived by regression analysis of specific component data. This was done to facilitate estimation of costs for a wide variety of equipment ratings, including systemwide averages not corresponding to standard equipment ratings.

ACHIEVABLE POTENTIAL: TRANSMISSION AND DISTRIBUTION SYSTEM EFFICIENCY IMPROVEMENTS

Barriers to Transmission and Distribution Efficiency Improvements

Several factors may discourage full implementation of the technically available transmission and distribution energy savings potential. Among these factors are the following:

Inaccurate Marginal Resource Price Signals

As with other conservation resources, transmission and distribution system efficiency improvements costing less than the regionally cost-effective level can be viewed as having a price-induced component and a component that may not be achieved through price incentives. The price-induced component of transmission and distribution system efficiency improvements includes measures whose cost is less than the utility's marginal cost of new resources. To the extent that the utility sees a long-term marginal resource cost equivalent to that of the region, the regionally cost-effective transmission and distribution efficiency potential on that utility's system should be fully captured. But, if a utility sees a long-term marginal resource cost less than that of the region as a whole, only a portion of the regionally cost-effective savings potential on that utility's system will be acquired. The remainder of the regionally cost-effective potential must be secured through other incentives.

Some utilities use Bonneville wholesale rates as their long-term marginal resource cost. Because Bonneville wholesale rates are based on average, not marginal, resource cost, only a portion of the transmission and distribution loss reduction potential on these systems can be expected to be acquired by these utilities acting in their self-interest. Utilities using forecast Bonneville wholesale rates as their long-term new resource cost will not have an incentive to capture all regionally cost-effective savings.

Engineering Capability

Large utilities maintain transmission and distribution engineering staff capable of identifying opportunities for cost-effective loss reduction actions and preparing programs for the recovery of these losses. Smaller utilities, however, may lack this in-house engineering expertise. These utilities often rely on outside contractors for transmission and distribution engineering services.

Limited Return on Investment

Transmission and distribution system savings generally come in small increments. The opportunities for efficiency improvements generally arise on a line-by-line basis, and the potential savings from upgrades of an individual feeder or transmission line generally are quite small. For this reason, loss reduction proposals may be a difficult sell in an organization where higher-profile projects compete for funding.

Factors Encouraging Transmission and Distribution System Efficiency Improvements

Other factors may encourage implementation of transmission and distribution loss-reduction actions. These include:

Improved Service

Some distribution system efficiency measures, including reconductoring and feeder voltage upgrade, will reduce voltage drop along distribution feeders. This may alleviate substandard voltage conditions at the far ends of distribution feeder networks.

Reduced Wholesale Power Cost

Transmission and distribution system loss reduction will reduce wholesale power purchase or generating requirements, but will not affect retail sales. Utilities should therefore have an incentive to invest in loss reduction measures that cost less than their marginal power production or purchase costs.

Utility Control Over the Affected System

Unlike end-use conservation measures, a utility owns and operates the equipment affected by transmission and distribution systems efficiency upgrades. This should facilitate implementation of these improvements.

The factors described above must be considered when estimating the achievable potential for cost-effective energy savings from transmission and distribution system efficiency improvements. The principal factors constraining recovery of transmission and distribution losses appear to be the timing constraints imposed by the rebuild/replacement cycle of existing systems and possible low funding priority for transmission and distribution loss recovery activities.

Because loss reduction measures generally are cost-effective only when implemented in conjunction with equipment replacement or rebuilding occurring for other purposes, the energy savings potential will be secured only slowly.

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