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Draft

1991 NORTHWEST CONSERVATION and ELECTRIC POWER PLAN

VOLUME II

Group 4

Includes:

Chapter 7: Conservation Resources
Chapter 12: Model Conservation Standards and Surcharge Methodology

JAMES A. GOLLER
CHAIRMAN
Idaho

Robert (Bob) Saxvik
Idaho

John C. Brenden
Montana

Stan Grace
Montana

NORTHWEST POWER PLANNING COUNCIL

851 S.W. SIXTH AVENUE • SUITE 1100
PORTLAND, OREGON 97204-1348 • (503) 222-5161

Toll free number for Idaho, Montana & Washington: 1-800-222-3355
Toll free number for Oregon: 1-800-452-2324

R. TED BOTTIGER
VICE CHAIRMAN
Washington

Tom Trulove
Washington

Angus Duncan
Oregon

Ted Hallock
Oregon

November 1990

To Interested Parties:

The attached document is a specific part of a larger document entitled, the "Draft 1991 Northwest Conservation and Electric Power Plan--Volume II." If you are interested in ordering any other parts of this plan, you may do so by writing or calling the Council's public involvement division (address and toll-free phone numbers are listed above). Volume I is the basic power plan. It contains all of the plan's major policies, directions and actions. Volume II is the technical, supporting documentation. A complete listing of Volume II is described below for your ordering convenience.

The Council is accepting public comment on this draft plan through 5 p.m., March 15, 1991. Please send comments to the Council's central office at the address above. Comments should be clearly marked. If you are commenting on Volume I, refer to document number 90-18. If you are commenting on Volume II, refer to document number 90-18A. Public hearings also are scheduled in each state. Please call your state at the following numbers for times, locations and to sign up to testify: Idaho: 208-334-2956, Montana: 406-444-3952, Oregon: phone numbers are listed above, and Washington: 509-359-7352.

- Volume I (40 pages)
- Volume II, Group 1 (60 pages)--Chapter 1: Recommended Activities for Implementation of the Power Plan; Chapter 11: Resource Acquisition Process
- Volume II, Group 2 (80 pages)--Chapter 2: Background and History of the Northwest Power System; Chapter 3: The Council's Planning Strategy; Chapter 4: The Existing Regional Electric Power System
- Volume II, Group 3 (210 pages)--Chapter 5: Economic Forecasts for the Pacific Northwest; Chapter 6: Forecast of Electricity Use in the Pacific Northwest
- Volume II, Group 4 (190 pages)--Chapter 7: Conservation Resources; Chapter 12: Model Conservation Standards and Surcharge Methodology
- Volume II, Group 5 (360 pages)--Chapter 8: Generating Resources: Chapter 9: Accounting for Environmental Effects in Resource Planning; Chapter 16: Confirmation Agendas for Geothermal, Ocean, Wind and Solar Resources
- Volume II, Group 6 (120 pages)--Chapter 10: Resource Portfolio; Chapter 13: Financial Assumptions; Chapter 14: Resource Cost-Effectiveness; Chapter 15: Risk Assessment and Decision Analysis

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CHAPTER 7

CONSERVATION RESOURCES

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Overview and Comparison to 1989 Supplement Estimates

Conservation is a key ingredient in the Council's resource portfolio for meeting future electrical energy needs. Each megawatt of electricity conserved is one less megawatt that needs to be generated. The Council has identified close to 3,200 average megawatts of technical conservation in the high demand forecast, available at an average cost of about 4 cents per kilowatt-hour.[1] This is enough energy to replace the output of about six large coal plants, at less than half the cost. While much has been accomplished in acquiring conservation since the conservation estimates were first done by the Council, the remaining conservation is still an extraordinarily cost-effective resource for the region to acquire. 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.

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 ensure 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 tightening require less electricity for heating. These electricity savings mean that fewer power plants must be built 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 discussed in Chapter 8, Generating Resources.

Comparison with Conservation Estimates from the 1989 Supplement

The 1989 Supplement estimated that about 2,900 average megawatts of technical conservation potential were available to the region to reduce loads by the year 2010. The current estimate is about 3,200[2] average megawatts in the high demand forecast at a nominal levelized cost of about 4 cents per kilowatt-hour, as displayed in Table 7-1. In lower demand forecasts, less conservation is

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1./ This average cost includes administration, transmission and distribution adjustments. All costs are in 1990 dollars. Levelized cost calculations are performed using a nominal discount rate. Prior Council analyses were conducted using a real discount rate. In real terms, the average cost of all conservation is 2 cents per kilowatt-hour.

2./ This value is technical potential and has not been increased to reflect conservation's benefit of avoiding line losses when compared to generating resources, nor decreased to reflect expected market penetration rates.

available from many sectors, because the economy is not growing as rapidly, and there are fewer new houses, businesses and appliances that can supply energy savings. Table 7-1 shows that about 2,100 average megawatts are available in the medium forecast. Table 7-2 displays promising resources. These are resources that are commercially available but fall just above the 10 cent per kilowatt-hour avoided cost or were judged to be too uncertain, and others that are not yet commercially available but are in the process of being developed.

Table 7-1
Comparison of Conservation Savings and Costs
Technical Potential

	1989 Supplement		Draft Power Plan			
	High Forecast MWa	Real Levelized Cost (cents/kWh)	High Forecast MWa	Medium Forecast MWa	Nominal Levelized Cost (cents/kWh)	Real Levelized Cost
Residential Sector						
Space Heating:						
Existing Single-Family	150	3.9	140	140	8.1	4.2
Existing Multifamily	50	4.1	50	50	6.1	3.2
New Single-Family	355	3.1	380	150	7.1	3.6
New Multifamily	40	2.4	55	50	5.5	2.6
New Manufactured Housing	210	2.2	140	140	6.5	3.3
Water Heating	385	2.0	335	185	4.6	2.3
Refrigerators	110	1.2	130	100	6.3	3.2
Freezers	35	1.3	45	35	1.8	0.9
Commercial Sector						
Existing	640	2.5	665	470	5.7	2.9
New	555	2.2	655	355	2.6	1.3
Industrial Sector						
Existing	280	2.1	265	265	1.9	1.0
New	0		275	75	1.9	1.0
Irrigation	90		40-90	40-90	4.7	2.4
Total	2,900		3,175-3,225	2,055-2,105		

Table 7-2
Promising Resources
(High-Demand Forecast)

	Promising Resources (MWa)	
	Commercially Available	Emerging Technologies
Residential Sector		
Space Heating:		
Existing Single-Family	0	0
Existing Multifamily	0	0
New Single-Family	230	0
New Multifamily	30	0
New Manufactured Housing	0	0
Water Heating	100-130	0
Refrigerators	0	160
Freezers	0	20
Clothes Dryers	0	110
Lighting	115	0
Commercial Sector	150	0
Industrial Sector	450	0
Irrigation	0	0
Total	1,075 - 1,105	290

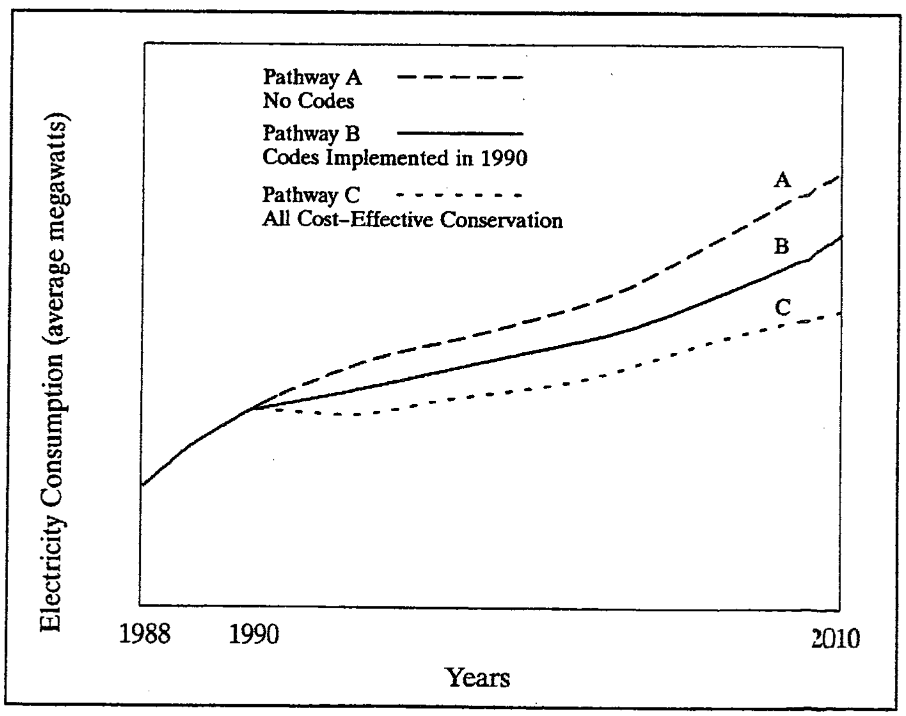
The size of the conservation resource in both the 1989 Supplement and the current plan is significantly lower than the estimate used in the 1986 plan, which was 4,300 average megawatts of technical potential. This is due primarily to significant actions taken over the last few years by various jurisdictions in the region, and in some cases by the federal government, that have already set in motion mechanisms to acquire a large portion of the conservation resource estimated in 1986 to be available over the next 20 years. For example, the states of Oregon and Washington passed building codes that will, as construction occurs over time, capture a good part of the residential space heating conservation resource identified in the 1986 plan. This chapter estimates conservation resources based on savings beyond codes and standards that became effective before 1989.

The estimate of the conservation resource in this chapter assumes that building codes and appliance standards will continue to be implemented over the planning period. Each of these codes means that there is less of the conservation resource left to acquire in the future, because it will be secured through fairly stable mechanisms: building and appliance codes. The energy reductions secured through codes reduce demand in the load forecasts.

Legislation that mandates implementation of conservation, such as building codes and appliance standards, reduces the forecast of electric loads, which--in turn--automatically reduces the amount of conservation potential remaining to be secured. Figure 7-1 depicts the effect on forecast loads and conservation resources of adopting conservation codes and standards. Forecast loads without building and appliance codes result in the highest electricity consumption over the 20-year horizon along "Pathway A." "Pathway C" represents electricity loads if all new houses and appliances purchased were to install all cost-effective conservation. Once building codes and appliance standards are adopted, each new building or appliance is mandated to be more efficient. This results in an intermediate load forecast, because each new unit will consume less electricity than in Pathway A. This intermediate step is depicted as Pathway B in Figure 7-1. The difference between Pathway A and B is the conservation secured through the codes and standards. But often there are still cost-effective conservation measures not included in all of the codes and standards, and many end uses for which there are no codes or standards. The difference between B and C is the remaining conservation potential identified in this plan that still needs to be secured to fill electricity needs. This conservation resource remains a significant and cost-effective resource for the region. Actions to secure this resource are highlighted in the Action Plan.

Load Effects

Figure 7-1
Effect on Loads and Conservation of Building and Appliance Codes



Estimating the Conservation Resource

The following section summarizes the Council's estimates of conservation resources available to the region. The narrative is based on calculations from the Council's high demand forecast. Results for the medium forecast are summarized at the end of each sector. Similar calculations were done for the low, medium-low and medium-high forecasts.

The evaluation of conservation resources involves three major steps. The first step is to develop conservation supply curves based on engineering analysis. This step entails evaluating the levelized life-cycle cost[3] of all conservation measures and ranking them with the least-cost measure first.

The second step is to group all measures into programs[4] with levelized costs less than a given avoided cost, in this case 10 cents per kilowatt-hour, and to evaluate savings from these programs in the context of the Council's forecasting model. The program groupings are thus consistent with the assumptions in the Council's forecast. As part of this step, the measures grouped as programs are compared to any evaluation data available from the field that apply to similar end-uses and are comparable in other characteristics.

The third step involves using the cost and savings characteristics of each program to evaluate the conservation resource's cost-effectiveness and compatibility with the existing power system. Cost-effectiveness is determined by comparing each program against other resources to find which resource provides electric service at the lowest cost. This process is discussed further in Chapter 10.

These three steps are illustrated in Figure 7-2. Typically information on measure costs and, to the extent possible, savings comes from programs operated in the region. This may mean actual weatherization costs incurred over the last few years in the weatherization program, or end-use metered water heating consumption data from the End-Use Load and Conservation Assessment Program (ELCAP). Whenever possible, actual metered or field data are used. This information is combined in an economic analysis to select a group of measures that represent cost-effective efficiency improvements. The economic analysis requires data such as the discount rate and measure life. The economic analysis is described in another chapter of this plan.

3./ 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.

4./ The term program is used loosely here to mean the grouping of identified measures into an end-use. For example, all the measures that can save hot water are identified and then grouped into the hot water end-use. This grouping is called a "program," even though it may take various program delivery mechanisms to secure all the measures

Key Analysis Steps

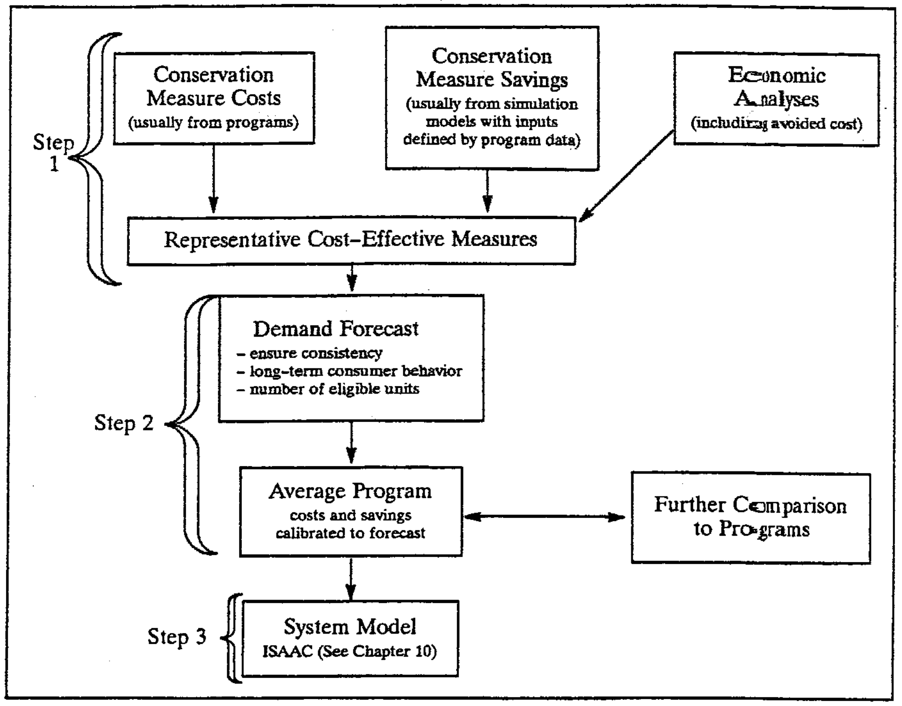


Figure 7-2
Key Steps in Conservation Analysis

Once the package of representative measures is selected, there is a calibration to the demand forecast to ensure that savings are not counted twice (once as a reduction of demand in the forecast and again as a conservation measure) or undercounted. In addition, consumer behavior, such as changing wood heating use in response to changes in electricity prices, are incorporated into the savings estimates. This results in average savings and costs for each end use that are calibrated to the forecast and that incorporate expected long-term consumer behavior.

After the savings are calibrated to the forecast, the package of measures in each end-use are compared to any evaluation data available from the field for comparable programs. This gives an indication of how well the results compare to evaluation data. Both the derived results here and the evaluation data can have problems, and in many cases they are not directly comparable, but each estimate helps assess the reliability and robustness of the other.

The cost and savings data, calibrated to the forecast, along with other characteristics of the end-use savings (such as their seasonal distribution) are used in the system model, called the Integrated System for Analysis of Acquisitions (ISAAC), to be valued in comparison with other electricity options in the development of the resource portfolio. The system model is also described in another chapter of this plan.

The bulk of this chapter deals with steps one and two, which are preliminary cost-effectiveness screens to size the conservation resource used in the resource portfolio. Since the collection of data to be used in deriving the costs and savings of conservation measures is very important, a table appears at the beginning of each end-use section to summarize the key data sets used in the conservation estimates.

Supply Curves

Conservation supply curves are used to determine the amount of conservation available at given costs. 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 3 average megawatts at a cost of 2 cents per kilowatt-hour. This same customer may conserve 5, 7 and 8 average megawatts of electricity for the respective costs of 3, 4 and 5 cents per kilowatt-hour. These figures represent the conservation supply curve for this particular customer. Individual conservation estimates for end uses in each sector are merged to arrive at the regional supply curve for that sector.

The supply curves used in this plan do not distinguish between conservation resulting from specific programs and conservation that results from rising prices of electricity. Whether the consumer or the utility invests in a conservation measure, the region is purchasing those savings at a particular price, and the money is not available for investment in other resources and goods. However, if a customer contributes to the purchase of conservation resources, then the cost to the electricity system will be less than the costs developed in this chapter.

Conservation supply curves are primarily a function of the conservation measure's savings and cost. Each measure's savings and cost are used to derive a levelized cost, expressed in cents per kilowatt-hour, for that measure. The absolute value (in terms of kilowatt-hours per year) of the savings 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 with the least costly measure first,[5] until all measures are evaluated.

The levelized costs used to generate the supply curves are based on the calculations described in Volume II, Chapter 13. To ensure consistency between the conservation supply curves and the system models,[6] financial factors used in the levelized cost calculation are the same ones used in the system models. This

5./ Least costly is defined in terms of a measure's levelized life-cycle cost, stated in terms of cents per kilowatt-hour.

6./ The system models are the Integrated System for Analysis of Acquisitions and the System Analysis Model.

means that the tax benefits, rate requirements and other financial considerations specific to the developer of the resource are accounted for in the levelized cost of the conservation resource.

The models assume that conservation will be financed for 20 years by the Bonneville Power Administration and for 20 years or the life of the conservation measures, whichever is shorter, by the investor-owned utilities. It was assumed that Bonneville would sponsor 40 percent of the conservation acquisition costs, and the investor-owned utilities would sponsor 60 percent, based on their share of total loads.

Conservation Programs for the Resource Portfolio Analysis

After the supply curves are generated for each end use or sector, the amount of conservation to be used in the resource portfolio analysis is first sized by cutting off the supply curve at the point at which the levelized cost of the last measure included is equal to or just slightly less than the avoided cost. This is called the "technical" conservation potential. The technical potential is then reduced by the portion of the conservation resource that is considered not achievable. Achievable conservation is the net energy savings the Council anticipates after taking into account factors such as consumer resistance, quality control and unforeseen technical problems. Historically, the Council has used high achievable conservation rates because it believes that the wide assortment of incentives and regulatory measures the Northwest Power Act makes available can persuade the region's electricity consumers to install a large percentage of the technically available conservation. These same rates were used in this chapter.

Each conservation program consists of the package of measures that cost less than the avoided cost. Costs and savings for this package are taken from the supply curves described in this chapter. The present-value costs of the achievable savings for each program are adjusted in the following manner before they are used in the system models to determine compatibility with the existing power system and to derive a least-cost resource portfolio.

First, since the system models use conservation programs instead of measures in the resource portfolio, capital replacement costs have to be added to those measures with lifetimes shorter than the lifetime of the major measure in the program. For example, caulking and weatherstripping have shorter lifetimes than insulation; therefore, replacement costs are incurred over the expected lifetime of the insulation to maintain the benefits of caulking and weatherstripping.

Second, 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 the 1983 and 1986 Power Plans, the Council used 20 percent of the capital costs of a conservation program to represent administrative costs. This figure is an oversimplification of a complex situation.

Several factors can affect the level of administrative costs needed to run a program. First, programs with different desired rates of acquisition will require different levels of administrative costs, especially for such things as marketing, advertising and contract management.

Furthermore, it is likely that the administrative costs will increase as the megawatts from a discretionary resource become fewer. The first megawatts likely will be acquired from willing homeowners or businesses most interested in energy conservation. Alternatively, the last few megawatts may be very hard to identify and secure.

Finally, administrative costs likely will decrease as the portion of the total cost of conservation that a utility pays increases. Higher payments to individuals and businesses probably will result in lower administrative costs, because customers will require less of a "sales-pitch" to participate.

The Council believes that the administrative cost of a given program is largely independent of the number of measures installed in a house or building. While some additional measures may increase the number of inspections, in general, the administrative expense of requiring an insulation contractor to install full levels of cost-effective ceiling insulation is no more than if the contractor were only required to install half the cost-effective amount. Processing of contracts, quality checks and other administrative actions still need to be taken, regardless of the number of measures installed.

Some evidence suggests that administrative costs in the commercial sector might exceed those in the residential sector, for several reasons. First, the commercial sector is far more diverse than the residential sector; therefore much more difficult to target and work with. Furthermore, more barriers probably exist to adopting energy conservation measures in the commercial sector. These barriers include such things as absentee landlords. In the existing commercial sector in particular, where daily business activities might have to be interrupted in order to install all cost-effective energy conservation measures, the administrative costs of convincing owners to participate in a program could be considerable. The perception of lost productivity or business may prevent them from taking cost-effective energy actions.

Countering some of these barriers is the fact that the Northwest Power Act provided significant mechanisms and incentives for this region to promote conservation. For example, the Council was authorized to develop model conservation standards for multiple end uses and to recommend that Bonneville assess a surcharge if those standards are not adopted. The Bonneville administrator can acquire the electrical output of conservation measures through direct purchase, through authorizing loans and grants to consumers, by providing technical and financial assistance, by aiding in the implementation of the model conservation standards, and by funding demonstration projects to determine the cost-effectiveness of conservation measures. In terms of administrative costs, the region still has little experience with programs that fall within the range of options that are authorized by the Act.

The data concerning administrative costs, even for currently operated programs, are still scarce. Puget Sound Power and Light provided the Council with two estimates of administrative costs: 5 percent of capital costs for its commercial lighting program[7] and 30 percent for its Audit Incentive Program. The Oregon Department of Energy found about a 25-percent administrative cost for its business energy tax credits program. Bonneville has found 25-percent administrative costs in its commercial Purchase of Energy Savings (PES) program and Commercial Incentive Pilot Program (CIPP). The Energy Edge program, which has a significant research component, incurred 37-percent administrative costs. Other programs with some data on administrative costs were reviewed in the Council's report on progress with conservation after five years with the Northwest Power Act.[8] These were primarily residential sector programs, and their administrative costs ranged from 15 percent to 28 percent. Oak Ridge National Laboratory recently conducted a review of administrative costs. They concluded that administrative costs for residential weatherization programs were about 20 percent. Commercial audit and incentive programs had costs of 25 to 35 percent and commercial lighting about 10 to 15 percent. The Council's current choice of 20 percent falls within the range of costs experienced in the region to date. At this time, there is no evidence that argues strongly for an estimate of administrative costs different from the 20 percent assumed in the 1986 plan. Therefore, the average cost of the conservation programs is increased 20 percent before the conservation is compared to generating resources to determine which is more cost-effective. The Council is committed to continued monitoring of the administrative costs of regional conservation programs to see if this estimate can be refined.

A third factor that must be accounted for when comparing conservation programs with other generating resources is the 10-percent credit given to conservation in the Northwest Power Act and continued by Bonneville in response to the Council's five-year review of conservation. This credit means that conservation can cost 10 percent more than the next lowest-cost resource and still be considered cost-effective under the Act.

Finally, to ensure that conservation and generating resources are being 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 evaluated at the point of use, for example, in the house. In contrast, the costs and generation from a power plant are evaluated at the generator (busbar) itself. Thus, to make conservation and the traditional forms of generation comparable, the costs of the generation plant must be adjusted to include transmission system losses (7.5 percent) and transmission costs (2.5 percent).

The net effect of all these adjustments is different for the marginal conservation measure than for the average program, because administrative costs are assessed on the average program and not the marginal measure. As mentioned above, the Council determined that the administrative cost of a given

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7./ In this program, which was operated through contractors, there was some suspicion that a portion of the administrative costs were hidden in the seemingly high costs of the measures.

8./ The report is called *A Review of Conservation Costs and Benefits--Five Years of Experience under the Northwest Power Act.* (Order publication number 87-6.)

program is largely independent of the number or amount of measures installed. The cost threshold for investment in the marginal conservation measure is the busbar cost of coal plants, the resource that generally establishes the avoided cost, plus 20 percent. The 20 percent consists of 10 percent for the Act's credit, 7.5 percent for transmission system losses and 2.5 percent for transmission costs.

The effect on the average cost of conservation programs that are compared to generating resources is to increase the average cost of the conservation programs by 7.5 percent--20 percent added for administrative costs minus 10 percent for the Act's conservation credit and 2.5 percent saved in transmission and distribution costs--and to increase the average savings from the program by 7.5 percent to account for line-loss credits.

The adjustments to the average costs and savings from conservation programs were made for purposes of comparing conservation resources with generating resources, as is done in the models used by the Council to simulate system responses. However, in this chapter, the 10-percent benefit from the Act is not included in the average cost calculations, in order to portray the true cost of conservation programs. As a consequence, the levelized program costs in this chapter are 10 percent higher than those used in the system models. In addition, this chapter is based on conservation savings at the end use, so the savings presented are 7.5 percent lower than those used in the resource portfolio.

Compatibility with the Power System

After these adjustments are made, each conservation program is evaluated in terms of its compatibility with the existing power system and is compared to the cost and savings characteristics of other electricity resources. To assess compatibility, and ultimately the cost-effectiveness of the conservation programs, the Council used two complex computer programs, called the Integrated Systems for Analysis of Acquisitions (ISAAC) and the System Analysis Model (SAM). These models served as a final screen for judging whether a conservation program was regionally cost-effective.

Like the previous Decision Model, the Integrated Systems for Analysis of Acquisitions model determines how many resources are needed to serve the loads described by each of the Council's forecasts. The Integrated Systems for Analysis of Acquisitions model includes several variables that describe the characteristics of different resources, both generating and conservation resources. The key conservation variables are program ramp rates, program type, conservation ownership assumptions, seasonal distribution of savings and percent payments for conservation acquisition. These variables are described next.

Ramp Rates: The discretionary conservation resources that the model secures in any one year to meet energy needs depend on how fast a program can become operational and on the ultimate amount of cost-effective conservation available. The rate at which a program can be brought online is sometimes known as the program ramp rate. If the region is surplus 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. This issue was discussed in an issue paper leading to the development of this document. At that time, it was decided to adopt new ramp rates. For further information, please see staff issue paper 89-26, *Three Key Conservation Assumptions: Conservation Flexibility, Achievable Conservation and Residential Standard Operating Conditions.*

Program Type: The Integrated Systems for Analysis of Acquisitions models four types of conservation programs. The first one, called non-discretionary programs, is modeled as savings that are secured automatically, regardless of the status of the power system. This is exemplified by conservation that is secured through codes. The second program type is very similar to the first, because the conservation is secured as new end uses of electricity are purchased, but the savings may not be the result of codes, but programs. This second program type is known as voluntary programs that operate on newly purchased appliances, houses and businesses. The third program type is a discretionary program that secures savings from existing end uses, such as residential weatherization. The fourth program type is a mixture of two programs, where the conservation is initially secured without a program or code by homeowners or business managers on their own, and where the end use is later transitioned into a particular program to secure the remaining conservation.

Resource Ownership: In addition to program types, the model needs to know the distribution of the ownership of the conservation savings among various parties in the region, particularly the investor-owned utilities, generating public utilities and non-generating public utilities. Ownership splits are based on the estimated number of customers in each electricity-consuming sector in each of these utilities' service territories.

Seasonal Distribution of Savings: The model also uses the seasonal distribution of the savings over the months of the year when assessing compatibility. In general, end-use monitored data from the End-Use Load and Conservation Assessment Program is used to model the seasonal distribution of savings from residential space heating and appliances. For lack of data, commercial and industrial savings will be assumed to be evenly distributed throughout the year. Finally, agricultural savings will be modeled as being highest in April, May and June, with a smaller peak in September, and as non-existent at other times of the year.

Payments: Finally, the model can accommodate different levels of incentive payments for the acquisition of different types of conservation programs. These vary depending on the types of studies being conducted, and are primarily used to model rate impacts.

The technical discussion that follows describes the evaluation of conservation resources conducted by the Council. The narrative is illustrated with calculations from the high demand forecast, and the summary includes the results from the medium forecast. Similar calculations were conducted for all of the Council's forecasts. All costs are in 1990 dollars. This discussion, and the technical exhibits listed at the end of each sector, display the capital costs, energy savings and measure life used by the Council. Bonneville is expected to use comparable assumptions and procedures in any calculation of cost-effectiveness.

Residential Sector

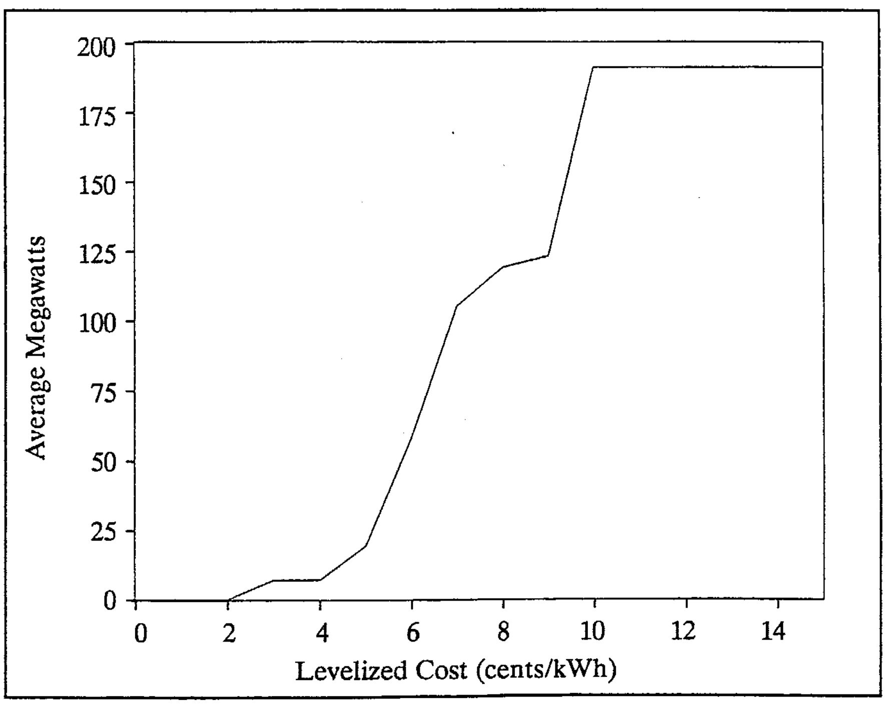
In 1989, the region's residential sector consumed 5,790 average megawatts of electricity when adjusted for weather, which is about 34 percent of the region's total firm electrical consumption. Space heating is the largest single category of consumption in the residential sector; water heating is second.

Space Heating Conservation in Existing Residential Buildings

Figure 7-3 shows the estimated space heating savings available from existing residences at various electricity prices. The technical conservation potential available with no single measure exceeding 10 cents per kilowatt-hour is approximately 190 average megawatts. The estimated average cost of insulating and weatherizing existing residences is about 7 cents per kilowatt-hour for single-family houses and 6 cents per kilowatt-hour for multifamily. These values escalate to 8 cents per kilowatt-hour for single-family houses, but still round to 6 cents per kilowatt-hour, if administrative costs and transmission and distribution adjustments are incorporated.

Space Heating Potential

Figure 7–3
Technical Conservation Potential from Space Heating Measures in Existing Residences



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 dwellings;

2. develop savings estimates and conservation supply functions that are consistent with the Council's forecasting model, and incorporate the forecasting model's estimates of the effect of consumer behavior on savings using the thermal integrity changes identified in Step 1;

3. compare projected cost and savings estimates with historically observed cost and savings data; and,

4. estimate realizable conservation potential.

The key data sources used in this analysis come from the diverse programs operated in the region. These sources are summarized in Table 7-3.

Table 7-3
Key Data Sources for Existing Space Heating Measures

Costs		
Puget Power's Weatherization Program	-	Measure costs
Bonneville's Weatherization Program (Data Gathering Project)	-	Measure costs
Consumption and Savings		
End-Use Load and Conservation Assessment Program (ELCAP)	-	Unretrofit insulation levels, space heating consumption
Residential Standards Demonstration Program	-	Test of simulation model
Evaluation Reports from Weatherization Programs	-	Use and savings comparison test of simulation inputs
1987 Oregon Survey	-	Insulation levels of houses remaining to weatherize
Pacific Northwest Residential Energy Surveys	-	Wood heat/electric splits, house size, unweatherized energy use

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-family home weatherization costs are based on information provided by Bonneville and utilities on the costs they have incurred in recent years to weatherize single-family residences. The actual costs of measures installed by the programs are shown in Table 7-4. Costs in the Hood River project are typically higher than costs experienced in regionwide, longer-running programs. Information from Hood River was used for those measures not widely used in the regionwide weatherization program. This included the costs of insulating floors to R-30 if additional joist space had to be added to accommodate the depth of the insulation, and for triple glazed windows. As can be seen from the table, the region currently has a large data base of costs for common weatherization measures.

The manner in which the information was collected from the weatherization projects is not completely compatible with the prototype analysis that is required here. Consequently, the data was put in a format that reflected incremental steps from, for example, R-0 to R-19 ceiling insulation and then from R-19 to R-30 and R-30 to R-38, instead of from R-0 to R-38 in one step. This required making an estimate of the cost that is incurred to initially set up an insulation job, compared to the cost of adding additional insulation once the contractor is already incurring the labor to get to the house and set up. The costs from Puget Power and Bonneville are averaged together using the estimated proportion of houses in private and public service territories still eligible for a weatherization program. These costs are then allocated between job set-up costs and add-on costs for each measure. The results are displayed in Table 7-5 for those measures where costs had to be constructed from the actual measure data.

The costs of weatherizing multifamily units are based on costs reported by Bonneville and Puget Power to weatherize multifamily buildings in their service territories. While the data base for the multifamily weatherization measures is not as large as that for single-family weatherization, it is still quite large. The costs as reported by Bonneville and Puget are shown in Table 7-6. As with single-family costs, this information had to be summarized in a manner that was compatible with the prototype analysis. This information, after Bonneville and Puget costs were weighted together, is displayed in Table 7-7 for ceiling insulation. The costs for insulating floors from R-19 to R-30 are taken from information on single-family buildings.

No savings or costs were estimated for weatherizing or insulating existing manufactured homes since there were significant questions about remaining life, and the total potential was small. However, it is expected that questions surrounding the weatherization of manufactured homes will be investigated further over the next few years.

Table 7-4
Cost to Weatherize Single-family Houses:
Actual Program Data[a]

	Puget Power ($/sq. ft.)	(N)	Bonneville Data Gathering Project ($/sq. ft.)	(N)	Other Source ($/sq. ft.)	(N)
Ceiling Insulation						
R-0 to R-38	0.71	1,761	0.83	778		
R-11 to R-38	0.56	6,513	0.57	1,951		
R-19 to R-38	0.48	2,379	0.50	881		
R-30 to R-38	0.48	79	0.73	149		
Wall Insulation						
R-0 to R-11	0.52	3,075	0.86	1,296		
R-0 to R-19			0.86	184		
Floor Insulation						
R-0 to R-11	0.78	9,117	0.85	2,081		
R-0 to R-30	--	--	0.96	9		
Doors					15.36[b]	
Caulking and Weatherstripping			109/house	1,600[c]		
Glass						
Single to double	8.06	10,763	8.97	2,624		
Single to triple	10.69	55			14.67	768[d]

[a] These costs were incurred over a three- to five-year period. However, they are estimated to be approximately 1985 dollars. Here they are escalated to 1990 dollars.

[b] Taken from the 1983 Power Plan, and escalated to 1990 dollars.

[c] Approximate sample size.

[d] Approximate sample size. These costs are from the Hood River Conservation Project.

Table 7-5
Costs to Weatherize Single-family Houses Individual Measure Costs Constructed from Actual Program Data

	Set-up[a] Costs	Add-on[b] Costs
Ceiling Insulation	$/sq. ft.	$/sq. ft.
R-0 to R-19	0.52	--
R-19 to R-30	0.38	0.17
R-30 to R-38	0.34	0.13
R-38 to R-49	--	0.17[c]
Floor Insulation		
R-0 to R-19	0.89	--
R-19 to R-30	--	0.16
R-19 to R-30 w/added joist	0.77[d]	--

[a] Set-up costs are the costs of installing insulation, assuming the contractor has to be called to the site.

[b] Add-on costs represent the incremental cost of adding insulation assuming the contractor is already installing insulation for that building component.

[c] Costs taken from the 1986 Power Plan, and escalated to 1990 dollars.

[d] Estimated cost for the measure if additional joist space must be added to accommodate the R-30 insulation.

Table 7-6
Costs to Weatherize Multifamily Dwellings: Actual Program Data[a]
(N = sample size)

	Puget Power ($/sq. ft.)	(N)	Bonneville Data Gathering Project ($/sq. ft.)	(N)	Other Source ($/sq. ft.)	(N)
Ceiling Insulation						
R-0 to R-38	0.54	933	0.91	62		
R-11 to R-38	0.54	2,079	0.50	159		
R-19 to R-38	0.44	1,199	0.57	50		
R-30 to R-38	0.51	23	0.31	10		
Wall Insulation						
R-0 to R-11	0.67	184	0.84	42		
R-0 to R-19			0.65	12		
Floor Insulation						
R-0 to R-19	0.75	2,717	0.82	145		
Doors					15.35[b]	
Caulking and Weatherstripping			141/dwelling unit	115[c]		
Glass						
Single to double	7.54	4,395	7.17	217		
Single to triple	7.61	50	16.19	32		

[a] These costs were incurred over a three- to five-year period. However, they are estimated to be approximately 1985 dollars. Here they are escalated to 1990 dollars.

[b] Taken from the 1983 Power Plan, and escalated to 1990 dollars.

[c] Approximate sample size.

Table 7-7
Costs to Weatherize Multifamily Dwellings Individual Measure Costs Constructed from Actual Program Data

	Set-up[a] Costs	Add-on[b] Costs
Ceiling Insulation	$/sq. ft.	$/sq. ft.
R-0 to R-19	0.55	--
R-19 to R-30	0.50	0.09
R-30 to R-38	0.48	0.05

[a] Set-up costs are the costs of adding insulation, assuming the contractor has not been called to the site already.

[b] Add-on costs represent the incremental cost of adding insulation, assuming the contractor is already installing insulation for that building component.

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. It turns out, for example, that it is cost-effective to set up a contractor to increase ceiling insulation to R-38 from a base of R-19, and it is also cost-effective to continue adding insulation to R-49, if the contractor is already there. Thus, the regional cost-effectiveness limit is R-49 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 and no lost-opportunity measure has already been created, the following measures would be recommended for installation in single-family houses: R-49 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 triple pane windows, if single panes are present, but not if the windows are already double paned. The current analysis indicates that if the house is already at R-30 in the ceiling, has some wall insulation, has R-19 or more in the floor and double pane windows, it is not cost-effective to weatherize further.

These results have important implications for the design of weatherization programs. For example, if a utility runs a weatherization program that takes the ceiling insulation to R-30 only, the savings from going beyond R-30 are lost to the region, even though it would have been cost-effective to go further at the time the house was weatherized. Additionally, these results lead to a weatherization program design that could be modeled after the oil dipstick in a car. If an audit shows that the house already has R-30 in the ceiling, it is only half a quart low and no oil--that is, insulation--should be added. On the other hand, if the audit shows that the ceiling is only at R-19, it is a full quart low, and insulation should be added to the full cost-effectiveness level (R-49), or as close as structural barriers permit.

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 2,100-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: Similarly, while an effective triple glazed window appears cost-effective if single glazing is the base, it is very difficult to find double storm windows on the market today. As a consequence of these limitations, the current analysis of single-family residential weatherization savings only uses R-30 floors and triple glazing on one of the three prototypes. Less information is known about multifamily buildings. As a consequence, the multifamily prototypes were modeled with only double glazing, but with floors that could go to R-30 insulation without the increased joist cost. In addition, recent draft 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 0.6 air changes per hour. If some air infiltration reduction measures are taken, this is assumed to drop to 0.5 air changes per hour. This is a fairly small drop in infiltration, because costs which are taken from current programs only represent some fairly small amount of air infiltration reduction measures.

Savings from weatherization measures installed in all four house designs were estimated using a two-step process. The first step is to estimate all of the measures that are cost-effective to install starting from an uninsulated house and to develop a relative efficiency improvement from a base case if all cost-effective measures are installed. This first step is done assessing 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 engineering-based SUNDAY computer model,[9] 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, internal gains consistent with the efficient

9./ 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.

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 often called 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 that significantly lower utility bills. Curtailment activities, such as room closure and reduced temperature settings, are less likely to continue after efficiency measures are installed. If the house ends up being operated in the long run at reduced amenity, then potentially a measure was included in the program that should not have been there. However, if less than full amenity were assumed in this step of the analysis, then measures that might have been cost-effective would be lost. The Council has selected the former condition as preferable to the latter, partially to protect against the high load growth scenarios, where every conservation measure is important. The effect on the last measure of changing standard operating conditions is discussed in Step 3 of this section.

It is important to emphasize here that the engineering models are 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 7-8 through 7-10 for single-family and Table 7-13 for multifamily houses show the costs, levelized in mills (tenths of a cent) per kilowatt-hour, and the engineering savings assuming standard operating conditions from weatherizing the typical prototype houses in three representative climate zones in the region. The purpose of these tables is to show the expected reduction in space heating use as weatherization measures are installed. The precise order of the measures, and their location in the list is a function of which one has the least expected cost per 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.

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 lasts the lifetime of the residence, which for existing stock is expected to be an average of about 60 years or more. ~~This was reduced~~ to 50 years. Storm windows and prime replacement windows are assumed to last an average of about 30 years, as are replacement doors. Infiltration reduction measures were assumed to last 10 years.

Table 7-8
Representative Thermal Integrity Curve
for Single-family House Weatherization Measures
Zone 1 - Seattle

Measures	UA	Capital Cost Total	Capital Cost ($/sq. ft.)	Annual Use (kWh/yr.)	Annual Use (kWh/sq. ft.)	Present-Value Capital Cost	Levelized Nominal (mills/kWh)
HOUSE SIZE - 850 SQUARE FEET							
Base Case	694.92	$0	0.00	19,282	22.69	$0	0.0
Ceiling R-0 to R-19	503.67	$447	0.53	12,241	14.40	$500	5.4
Walls R-0 to R-11	418.62	$1,169	1.38	9,223	10.85	$1,308	20.5
Crawl Space R-0 to R-19	342.12	$1,921	2.26	6,575	7.74	$2,149	24.3
Ceiling R-19 to R-30	327.67	$2,073	2.44	6,099	7.18	$2,320	27.4
Crawl Space R-19 to R-30	320.87	$2,215	2.61	5,878	6.92	$2,479	55.2
Single to Double Glass	275.75	$3,092	3.64	4,424	5.21	$3,813	70.2
ACH .6 to .5	263.51	$3,211	3.78	4,043	4.76	$4,216	80.9
Ceiling R-30 to R-38	260.11	$3,323	3.91	3,937	4.63	$4,341	90.3
Wood to Metal Door	248.91	$3,994	4.70	3,589	4.22	$5,363	225.1
HOUSE SIZE - 1,350 SQUARE FEET							
Base Case	1,065.48	$0	0.00	31,810	23.56	$0	0.0
Ceiling R-0 to R-19	761.73	$710	0.53	20,937	15.51	$794	5.6
Walls R-0 to R-11	655.58	$1,628	1.21	17,036	12.62	$1,821	20.2
Crawl Space R-0 to R-19	534.08	$2,822	2.09	12,624	9.35	$3,157	23.2
Ceiling R-19 to R-30	511.13	$3,064	2.27	11,802	8.74	$3,428	25.2
ACH .6 to .5	491.69	$3,183	2.36	11,117	8.24	$3,831	45.1
Ceiling R-30 to R-38	486.29	$3,361	2.49	10,927	8.09	$4,030	79.9
Single to Triple Glass	414.77	$5,432	4.02	8,471	6.28	$7,182	98.3
Wood to Metal Door	403.57	$6,103	4.52	8,093	6.00	$8,204	207.0
Crawl Space R-19 to R-30	392.77	$7,136	5.29	7,729	5.73	$9,359	242.6
HOUSE SIZE - 2,100 SQUARE FEET							
Base Case	1,224.86	$0	0.00	32,472	15.46	$0	0.00
Ceiling R-0 to R-19	1,067.36	$368	0.18	27,306	13.00	$412	6.10
Walls R-0 to R-11	908.28	$1,798	0.86	21,663	10.32	$2,012	21.71
Ceiling R-19 to R-30	896.38	$1,924	0.92	21,248	10.12	$2,153	25.88
ACH .6 to .5	863.62	$2,043	0.97	20,104	9.57	$2,556	27.00
Single to Double Glass	712.42	$4,980	2.37	14,962	7.13	$7,026	66.54
Ceiling R-30 to R-38	709.62	$5,072	2.42	14,869	7.08	$7,129	84.72
Wood to Metal Door	698.42	$5,743	2.73	14,497	6.90	$8,150	210.23

[a] The costs of this measure include an estimate for extending the joist to accommodate R-30 insulation.

Table 7-9
Representative Thermal Integrity Curve
for Single-family House Weatherization Measures
Zone 2 - Spokane

Measures	UA	Capital Cost Total	Capital Cost ($/sq. ft.)	Annual Use (kWh/yr.)	Annual Use (kWh/sq. ft.)	Present-Value Capital Cost	Levelized Nominal (mills/kWh)
HOUSE SIZE - 850 SQUARE FEET							
Base Case	694.92	$0	0.00	26,245	30.88	$0	0.00
Ceiling R-0 to R-19	503.67	$447	0.53	17,317	20.37	$500	4.29
Walls R-0 to R-11	418.62	$1,169	1.38	13,432	15.80	$1,308	15.92
Crawl Space R-0 to R-19	342.12	$1,921	2.26	9,968	11.73	$2,149	18.59
Ceiling R-19 to R-30	327.67	$2,073	2.44	9,332	10.98	$2,320	20.53
Crawl Space R-19 to R-30	320.87	$2,215	2.61	9,036	10.63	$2,479	41.12
Single to Double Glass	275.75	$3,092	3.64	7,074	8.32	$3,813	52.04
ACH .6 to .5	263.51	$3,211	3.78	6,556	7.71	$4,216	59.59
Ceiling R-30 to R-38	260.11	$3,323	3.91	6,412	7.54	$4,341	66.50
Wood to Metal Door	248.91	$3,994	4.70	5,940	6.99	$5,363	165.68
HOUSE SIZE - 1,350 SQUARE FEET							
Base Case	1,065.48	$0	0.00	42,028	31.13	$0	0.00
Ceiling R-0 to R-19	761.73	$710	0.53	28,322	20.98	$794	4.44
Walls R-0 to R-11	655.58	$1,628	1.21	23,389	17.33	$1,821	15.94
Crawl Space R-0 to R-19	534.08	$2,822	2.09	17,806	13.19	$3,157	18.32
Ceiling R-19 to R-30	511.13	$3,064	2.27	16,763	12.42	$3,428	19.87
ACH .6 to .5	491.69	$3,183	2.36	15,887	11.77	$3,831	35.25
Ceiling R-30 to R-38	486.29	$3,361	2.49	15,644	11.59	$4,030	62.47
Single to Triple Glass	414.77	$5,432	4.02	12,460	9.23	$7,182	75.79
Wood to Metal Door	403.57	$6,103	4.52	11,964	8.86	$8,204	157.94
Crawl Space R-19 to R-30	392.77	$7,136	5.29	11,487	8.51	$9,359	185.16
HOUSE SIZE - 2,100 SQUARE FEET							
Base Case	1,224.86	$0	0.00	43,945	20.93	$0	0.00
Ceiling R-0 to R-19	1,067.36	$368	0.18	37,387	17.80	$412	4.81
Walls R-0 to R-11	908.28	$1,798	0.86	30,147	14.36	$2,012	16.92
Ceiling R-19 to R-30	896.38	$1,924	0.92	29,610	14.10	$2,153	20.00
ACH .6 to .5	863.62	$2,043	0.97	28,130	13.40	$2,556	20.87
Single to Double Glass	712.42	$4,980	2.37	21,423	10.20	$7,026	51.01
Ceiling R-30 to R-38	709.62	$5,072	2.42	21,300	10.14	$7,129	64.41
Wood to Metal Door	698.42	$5,743	2.73	20,811	9.91	$8,150	159.83

[a] The costs of this measure include an estimate for extending the joist to accommodate R-30 insulation.

Table 7-10
Representative Thermal Integrity Curve
for Single-family House Weatherization Measures
Zone 3 - Missoula

Measures	UA	Capital Cost Total	($/sq. ft.)	Annual Use (kWh/yr.)	Annual Use (kWh/sq. ft.)	Present-Value Capital Cost	Levelized Nominal (mills/kWh)
HOUSE SIZE - 850 SQUARE FEET							
Base Case	694.92	$0	$0.00	30,442	35.81	$0	0.0
Ceiling R-0 to R-19	503.67	$447	$0.53	20,198	23.76	$500	3.7
Walls R-0 to R-11	418.62	$1,169	$1.38	15,732	18.51	$1,308	13.8
Crawl Space R-0 to R-19	342.12	$1,921	$2.26	11,715	13.78	$2,149	16.0
Ceiling R-19 to R-30	327.67	$2,073	$2.44	10,976	12.91	$2,320	17.7
Crawl Space R-19 to R-30	320.87	$2,215	$2.61	10,639	12.52	$2,479	36.1
Single to Double Glass	275.75	$3,092	$3.64	8,402	9.89	$3,813	45.7
ACH .6 to .5	263.51	$3,211	$3.78	7,809	9.19	$4,216	52.0
Ceiling R-30 to R-38	260.11	$3,323	$3.91	7,644	8.99	$4,341	58.0
Wood to Metal Door	248.91	$3,994	$4.70	7,106	8.36	$5,363	145.4
HOUSE SIZE - 1,350 SQUARE FEET							
Base Case	1,065.48	$0	$0.00	48,709	36.08	$0	0.0
Ceiling R-0 to R-19	761.73	$710	$0.53	33,032	24.47	$794	3.9
Walls R-0 to R-11	655.58	$1,628	$1.21	27,354	20.26	$1,821	13.8
Crawl Space R-0 to R-19	534.08	$2,822	$2.09	20,889	15.47	$3,157	15.8
Ceiling R-19 to R-30	511.13	$3,064	$2.27	19,675	14.57	$3,428	17.1
ACH .6 to .5	491.69	$3,183	$2.36	18,656	13.82	$3,831	30.3
Ceiling R-30 to R-38	486.29	$3,361	$2.49	18,373	13.61	$4,030	53.7
Single to Triple Glass	414.77	$5,432	$4.02	14,682	10.88	$7,182	65.4
Wood to Metal Door	403.57	$6,103	$4.52	14,110	10.45	$8,204	136.8
Crawl Space R-19 to R-30	392.77	$7,136	$5.29	13,559	10.04	$9,359	160.4
HOUSE SIZE - 2,100 SQUARE FEET							
Base Case	1,224.86	$0	$0.00	51,223	24.39	$0	0.0
Ceiling R-0 to R-19	1,067.36	$368	$0.18	43,675	20.80	$412	4.2
Walls R-0 to R-11	908.28	$1,798	$0.86	35,303	16.81	$2,012	14.6
Ceiling R-19 to R-30	896.38	$1,924	$0.92	34,681	16.52	$2,153	17.3
ACH .6 to .5	863.62	$2,043	$0.97	32,969	15.70	$2,556	18.0
Single to Double Glass	712.42	$4,980	$2.37	25,235	12.02	$7,026	44.2
Ceiling R-30 to R-38	709.62	$5,072	$2.42	25,094	11.95	$7,129	56.1
Wood to Metal Door	698.42	$5,743	$2.73	24,531	11.68	$8,150	139.1

[a] The costs of this measure include an estimate for extending the joist to accommodate R-30 insulation.

Table 7-11
Representative Thermal Integrity Curve
for Multifamily House Weatherization Measures

Measure	UA (per unit)	Incremental Capital Cost	Cumulative Capital Cost	Cumulative Present Value Cost	Annual Use (kWh/yr.)	(kWh/ sq. ft.)	Levelized Cost Nominal
			ZONE 1 - SEATTLE				
Base Case	376	0	0	0	8,891	10.6	0
Ceiling R-0 to R-19	304	$175	$175	$196	6,700	8.0	6.8
Ceiling R-19 to R-30	299	$27	$202	$226	6,510	7.8	12.0
Walls R-0 to R-11	255	$365	$566	$634	5,014	6.0	20.9
Crawl Space R-0 to R-19	229	$270	$837	$936	4,134	4.9	26.3
Ceiling R-30 to R-38	227	$19	$856	$958	4,092	4.9	39.1
Crawl Space R-19 to R-30	225	$53	$909	$1,017	3,998	4.8	48.7
Single to Double Glass	179	$772	$1,681	$2,192	2,584	3.1	63.6
ACH .4 to .3	165	$154	$1,835	$2,713	2,180	2.6	98.4
Wood to Metal Door	162	$176	$2,012	$2,981	2,093	2.5	237.7
			ZONE 2 - SPOKANE				
Base Case	376	0	0	0	12,424	14.8	0
Ceiling R-0 to R-19	304	$175	$175	$196	9,635	11.5	5.4
Ceiling R-19 to R-30	299	$27	$202	$226	9,393	11.2	9.4
Walls R-0 to R-11	255	$365	$566	$634	7,450	8.9	16.1
Crawl Space R-0 to R-19	229	$270	$837	$936	6,289	7.5	19.9
Ceiling R-30 to R-38	227	$19	$856	$958	6,233	7.4	29.3
Crawl Space R-19 to R-30	225	$53	$909	$1,017	6,108	7.3	36.5
Single to Double Glass	179	$772	$1,681	$2,192	4,193	5.0	47.0
ACH .4 to .3	165	$154	$1,835	$2,713	3,636	4.3	71.6
Wood to Metal Door	162	$176	$2,012	$2,981	3,518	4.2	172.7
			ZONE 3 - MISSOULA				
Base Case	376	0	0	0	14,594	17.4	0
Ceiling R-0 to R-19	304	$175	$175	$196	11,339	13.5	4.6
Ceiling R-19 to R-30	299	$27	$202	$226	11,055	13.2	8.0
Walls R-0 to R-11	255	$365	$566	$634	8,800	10.5	13.8
Crawl Space R-0 to R-19	229	$270	$837	$936	7,460	8.9	17.3
Ceiling R-30 to R-38	227	$19	$856	$958	7,396	8.8	25.5
Crawl Space R-19 to R-30	225	$53	$909	$1,017	7,252	8.6	31.7
Single to Double Glass	179	$772	$1,681	$2,192	5,032	6.0	40.5
ACH .4 to .3	165	$154	$1,835	$2,713	4,383	5.2	61.4
Wood to Metal Door	162	$176	$2,012	$2,981	4,245	5.1	148.3

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 according to percentages listed in Table 7-12. The regional average thermal integrity curves for each typical house design appear in Tables 7-13 and 7-14.

Table 7-12
Weights Used to Reflect Regional Weather for Existing Space Heating

	Climate Zone 1	Climate Zone 2	Climate Zone 3
Single-family Houses	84%	11%	5%
Multifamily Houses	73.1%	22.1%	4.8%

Table 7-13
Regionally Weighted Thermal Integrity Curve
for Single-family House Weatherization Measures

	Levelized Cost (mills/kWh)	Capital Cost ($/sq. ft.)	Use (kWh/sq. ft.)	Present-Value Cost	UA
HOUSE SIZE - 850 SQUARE FEET					
Base Case	0.00	$0.00	24.24	$0	694
Ceiling R-0 to R-19	5.23	$0.53	15.53	$500	503
Walls R-0 to R-11	19.66	$1.38	11.78	$1,308	418
Crawl Space R-0 to R-19	23.27	$2.26	8.48	$2,149	342
Ceiling R-19 to R-30	26.17	$2.44	7.88	$2,320	327
Crawl Space R-19 to R-30	52.72	$2.61	7.60	$2,479	320
Single to Double Glass	67.00	$3.64	5.78	$3,813	275
ACH .6 to .5	77.14	$3.78	5.30	$4,216	263
Ceiling R-30 to R-38	86.09	$3.91	5.17	$4,341	260
Wood to Metal Door	214.54	$4.70	4.73	$5,363	248
HOUSE SIZE - 1,350 SQUARE FEET					
Base Case	0.00	$0.00	25.02	$0	1065
Ceiling R-0 to R-19	5.38	$0.53	16.56	$794	761
Walls R-0 to R-11	19.37	$1.21	13.52	$1,821	655
Crawl Space R-0 to R-19	22.28	$2.09	10.08	$3,157	534
Ceiling R-19 to R-30	24.22	$2.27	9.44	$3,428	511
ACH .6 to .5	43.28	$2.36	8.90	$3,831	491
Ceiling R-30 to R-38	76.71	$2.49	8.75	$4,030	486
Single to Triple Glass	94.15	$4.02	6.83	$7,182	414
Wood to Metal Door	198.06	$4.52	6.53	$8,204	403
Crawl Space R-19 to R-30	232.20	$5.29	6.25	$9,359	392
HOUSE SIZE - 2,100 SQUARE FEET					
Base Case	0.00	$0.00	16.51	$0	1224
Ceiling R-0 to R-19	5.87	$0.18	13.92	$412	1067
Walls R-0 to R-11	20.83	$0.86	11.09	$2,012	908
Ceiling R-19 to R-30	24.80	$0.92	10.88	$2,153	896
ACH .6 to .5	25.88	$0.97	10.30	$2,556	863
Single to Double Glass	63.72	$2.37	7.71	$7,026	712
Ceiling R-30 to R-38	81.06	$2.42	7.66	$7,129	709
Wood to Metal Door	201.13	$2.73	7.47	$8,150	698

[a] The costs of this measure include an estimate for extending the joist to accommodate R-30 insulation.

Table 7-14
Regionally Weighted Thermal Integrity Curve
for Multifamily House Weatherization Measures

Measure	UA (Per unit)	Incremental Capital Cost	Cumulative Capital Cost	Present Value Cost	Annual Use kWh/yr.	Annual Use kWh/ Sq. ft.	Levelized Cost Nominal
Base Case	376	$0	$0	$0	9,953	11.8	0.0
Ceiling R-0 to R-19	304	$175	$175	$196	7,578	9.0	6.4
Ceiling R-19 to R-30	299	$27	$202	$226	7,371	8.8	11.3
Walls R-0 to R-11	255	$365	$566	$634	5,739	6.8	19.5
Crawl Space R-0 to R-19	229	$270	$837	$936	4,774	5.7	24.5
Ceiling R-30 to R-38	227	$19	$856	$958	4,728	5.6	36.3
Crawl Space R-19 to R-30	225	$53	$909	$1,017	4,625	5.5	45.2
Single to Double Glass	179	$772	$1,681	$2,192	3,061	3.6	58.8
ACH .4 to .3	165	$154	$1,835	$2,713	2,610	3.1	90.7
Wood to Metal Door	162	$176	$2,012	$2,981	2,514	3.0	218.9

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 1979 Pacific Northwest survey indicated that the average pre-1980 house was approximately 1,350 square feet. The 2,100 square foot, 1,350 square foot, and 850 square foot houses were weighted to represent approximately 22, 46 and 32 percent, respectively, of the regional stock to achieve the appropriate average house size. These weights result in an average house size of 1,355 square feet. Tables 7-15 and 7-16 show the curve of regionally weighted costs and space heating use for single-family and multifamily houses.

The information from Table 7-15 is displayed graphically in Figure 7-4. The curve represents thermal integrity improvements starting with an uninsulated house. Space heating use is reduced and present-value costs increase from adding more insulation to the house. The space heating use of the solid line is based on the SUNDAY model with the assumed standard operating conditions described above. If, for example, a reduced thermostat set point were used instead of the currently assumed standard operating conditions, the curve would be displaced to a lower use for a given amount of conservation investment. The level of use that is predicted at the 10 cent cost-effectiveness cut-off, labelled point C, is also identified in Figure 7-4. The forecasting model predicts a lower usage in the pre-weatherization condition than standard operating conditions. This is illustrated by point B. This put the houses on a lower amenity curve, below the one depicted. However, after weatherization, the forecast predicts that space heat use is fairly close to the line represented by standard operating conditions, depicted by point D. This means that behavior has changed, and the occupants now operate the house at an energy use that is more similar to those assumed in standard operating conditions.

The purpose of the thermal integrity curve is to identify the relative efficiency level that is cost-effective, holding amenities constant. That efficiency level is the ratio of the use at the 10 cent cut-off divided by the estimated base case use of a house. This is consumption at point C divided by consumption at point A. As noted earlier, these curves start with an uninsulated house, while 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 relative efficiency change is calculated cannot be taken from the uninsulated case, but must be estimated based on the average energy consumption or average existing insulation levels in the eligible stock.

Savings for the residential weatherization program after calibration to the forecast are the difference in usage between point B and point D. The costs between A and C are a conservative estimate of average costs because they include only the most expensive measures. It is known that consumers do not install just the cheapest measures first, leaving only the most expensive remaining.

The data used in the development of the relative efficiency level are described for multifamily buildings first. The Council used work done for the Bonneville Power Administration by ICF, Inc. et al., to determine the base case insulation values for multifamily units. These base case values for pre-1979 unweatherized stock translated into a heat loss rate per unit of 255 UA.[10] Under standard operating conditions, this implies a use of 5,716 kilowatt-hours per year. If all cost-effective measures are added to the structure, the use under standard operating conditions drops to 2,610 kilowatt-hours per year.

Table 7-15
Regionally Weighted Single-family House
Thermal Integrity Curve by Levelized Cost Category

Levelized Cost (mills/kWh) Nominal	Cost ($/sq. ft.)	Use/Yr (kWh/sq. ft.)	Present-Value Capital	UA	Use (kWh/yr.)	Capital Cost
0	$0.00	22.90	$0	981	31,029	$0
10	$0.45	15.65	$616	746	21,203	$608
20	$1.03	13.05	$1,347	670	17,683	$1,400
30	$2.04	9.13	$2,881	529	12,370	$2,762
40	$2.04	9.13	$2,881	529	12,370	$2,762
50	$2.08	8.88	$3,067	521	12,037	$2,817
60	$2.13	8.80	$3,118	518	11,917	$2,890
70	$2.77	7.64	$4,528	471	10,354	$3,754
80	$2.88	7.42	$4,748	464	10,054	$3,897
90	$2.93	7.37	$4,811	463	9,982	$3,967
100	$3.63	6.48	$6,261	430	8,783	$4,923
110	$3.63	6.48	$6,261	430	8,783	$4,923
120	$3.63	6.48	$6,261	430	8,783	$4,923
130	$3.63	6.48	$6,261	430	8,783	$4,923
140	$3.63	6.48	$6,261	430	8,783	$4,923
150	$3.63	6.48	$6,261	430	8,783	$4,923
160	$3.63	6.48	$6,261	430	8,783	$4,923
170	$3.63	6.48	$6,261	430	8,783	$4,923
180	$3.63	6.48	$6,261	430	8,783	$4,923
190	$3.63	6.48	$6,261	430	8,783	$4,923
200	$3.86	6.35	$6,731	424	8,598	$5,233

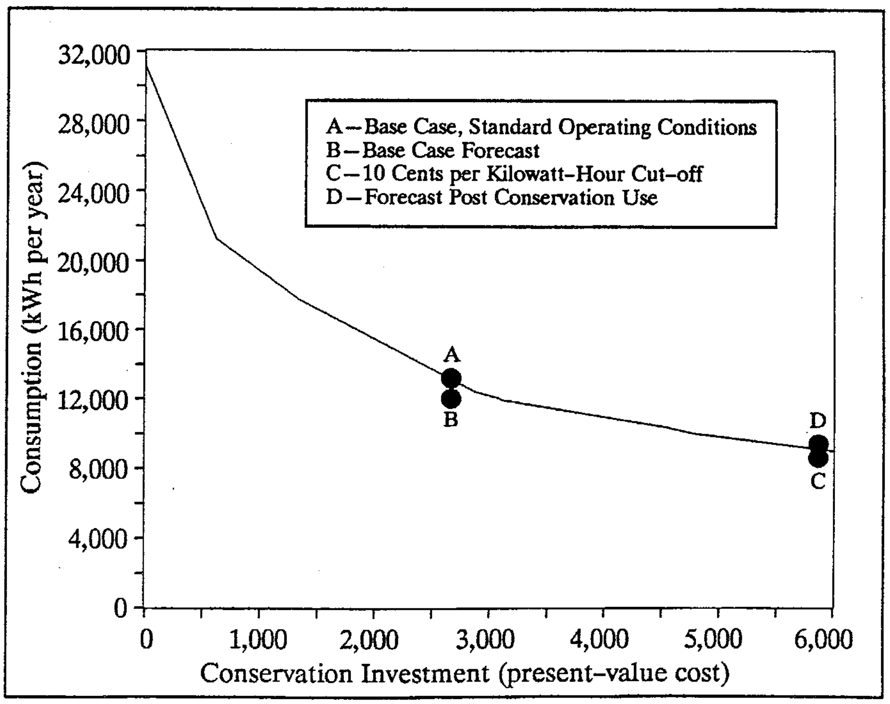
10./ UA is the heat loss rate of a building (expressed as a U-value) times the area of the component. A U-value has units of Btu per fahrenheit degree per square foot.

Table 7-16
Regionally Weighted Multifamily House
Thermal Integrity Curve by Levelized Cost Category

Levelized Cost	Capital Cost	Present-Value Cost	Annual Use (kWh/yr.)	(kWh/sq. ft.)
0	$0	$0	9,953	11.8
10	$175	$196	7,578	9.0
20	$566	$634	5,739	6.8
30	$837	$936	4,774	5.7
40	$856	$958	4,728	5.6
50	$909	$1,017	4,625	5.5
60	$1,681	$2,192	3,061	3.6
70	$1,681	$2,192	3,061	3.6
80	$1,681	$2,192	3,061	3.6
90	$1,681	$2,192	3,061	3.6
100	$1,835	$2,713	2,610	3.1
110	$1,835	$2,713	2,610	3.1
120	$1,835	$2,713	2,610	3.1
130	$1,835	$2,713	2,610	3.1
140	$1,835	$2,713	2,610	3.1
150	$1,835	$2,713	2,610	3.1
160	$1,835	$2,713	2,610	3.1
170	$1,835	$2,713	2,610	3.1
180	$1,835	$2,713	2,610	3.1
190	$1,835	$2,713	2,610	3.1
200	$1,835	$2,713	2,610	3.1

Thermal Integrity

Figure 7–4
Existing Single-family House Thermal Integrity Curve



The relative use, after all cost-effective measures are installed with amenity and behavior held constant is 0.46 (2,610/5,716). As described in the next section, this efficiency improvement will be used in the forecasting model to incorporate behavioral changes into the estimate of average savings. For single-family houses, the method to determine a relative efficiency level is quite similar.

Some information is available on the average insulation level in pre-1979 vintage unweatherized single-family houses. The best estimate 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.[11] 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. If a house with a 550 UA was operated assuming standard operating conditions, it would consume approximately 13,128 kilowatt-hours per year for space heating. If this is the base case, and 8,783 kilowatt-hours per year is the predicted consumption if all cost-effective measures are installed, then the relative electric energy use of the weatherized houses is 0.67. This estimate is for efficiency changes only, and does not incorporate behavioral changes, since amenity and behavior were held 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.

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

The Council's supply function for the total amount of conservation available in existing residential buildings was developed for the year 2010. 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 2010, 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 new selections of heating fuel. By developing its retrofit supply function for the year 2010, 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.

As noted by reviewers of the supply curves, the estimates are based on the size of the existing housing stock and savings per house that will be expected in the year 2010. 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

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11./ 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.

expected equipment changes in residential households. For example, over this time 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 than at the beginning of the forecast period. However, the magnitude of this effect is small. In addition, the savings expected in the year 2010 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 2010 and could still be retrofitted. Houses built after 1979 are not included as weatherization potential. These houses represent a lost-conservation opportunity 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 only based on houses primarily heated with electricity.

In 1979, the stock of primarily electric space heated single-family houses amounted to 871,600 houses. The same value for multifamily units 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 20 years. By the year 2010, 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 time period, as modeled in the forecast. Consequently, the remaining pre-1980 vintage stock in 2010, given the Council's average lifetime estimates and fuel choice is approximately 643,829 single-family houses and 250,975 multifamily units.

One of the assumptions in this method of counting is that significantly weatherized houses are not as likely to be removed from the housing stock between now and 2010 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 2010 have already been weatherized through either utility-sponsored weatherization programs or by their owner. Therefore, the remaining conservation potential consists only of those houses that have not been fully weatherized. A study conducted for the Pacific Northwest Utilities Conference Committee indicated that the public utilities have weatherized approximately 184,237 single-family houses and approximately 28,845 multifamily houses. The private utilities in the region have completed approximately 139,759 single-family and 38,555 multifamily weatherization jobs.

Not all of these houses use electricity as the primary fuel for space heating, but all of them had electric space heating installed. The number of houses that were weatherized through a utility program because they had electric space heating equipment installed but used primarily wood heat was estimated using the forecast. It was assumed that the same proportion of wood heaters were weatherized by utility programs as the proportion of primary wood heated houses with electricity as backup represented in the forecast. This means that approximately 85 percent of single-family weatherizations accomplished by utilities were primary electric space heaters, and the other 15 percent used primarily wood with electricity as backup. These wood heated houses were subtracted from the utility weatherizations for single-family houses. For multifamily houses, the wood heating portion was estimated to be negligible.

In addition, there is some initial indication from the 1987 Oregon Weatherization Study that some homeowners have done some weatherization on their own. This data indicates that for every 100 single-family houses that went through a significant utility weatherization program, an additional 25 single-family households have done something on their own. If this assumption proved to be closer to zero households that weatherized on their own, there would be an additional 14 average megawatts in the supply curve. Zero would be a lower bound, and given information from the Oregon Weatherization Study, an assumption of 25 percent seems prudent. In multifamily dwellings, the number that have done significant weatherization on their own is assumed to be zero.

The next question to resolve is whether every household that participated in a program, or weatherized significantly on its own, secured the majority of conservation measures. If they had done many of the major measures, but not all, it would not only be extremely difficult to locate them, but also additional measures might not be cost-effective due to additional administration and set-up costs. Information collected by Bonneville in the Data Gathering Project that pertains to the public service territory indicates that the public utilities achieve approximately 85 percent of the measures that are recommended in the audit and about 90 percent of the savings identified in the audit for single-family households. Furthermore, Bonneville staff has indicated that the audits generally approximate measures that are missing from a full cost-effectiveness package that would be something like R-38 ceiling insulation, R-11 or R-19 wall insulation, R-19 floor insulation, double glazing, caulking and weatherstripping. A house that achieved even 85 percent of this level of weatherization would likely not have any further potential. Consequently, this analysis assumes that single-family houses already weatherized under the public utilities' programs achieved approximately 90 percent of all cost-effective savings, and that the remaining 10 percent savings per house cannot be secured through future programs.

Less information is available from the private utilities on the levels of weatherization secured by their programs. Initial information from Puget indicates that it appears to have weatherization patterns similar to Bonneville's, which would indicate little, if no, further potential to secure. However, most of the other private utilities appear to have spent fewer dollars per weatherized house, and probably installed fewer measures. For Pacific Power and Light's territory in Oregon and Portland General Electric, the 1987 Oregon Survey supports preliminary indications that about one-third of the houses that went through the utilities' weatherization programs still have multiple major measures remaining to be secured. The Council is currently assuming that half of the houses weatherized under the private utilities' programs only went half of the way to the full cost-effectiveness level. This means that approximately half of the houses already counted in a private utility weatherization program still have half of the savings left to acquire. Since it is quite possible that some lost opportunities were created when the house was initially weatherized, the analysis assumes that these houses, which have already secured 50 percent of the cost-effective savings, can only secure 40 percent more, which ultimately would put them at a level that is being achieved by Bonneville's program.

Finally, there was very little information available on how much insulation was installed by single-family homeowners who weatherized on their own. It was assumed that these homeowners went half way on their own, and still have 40 percent of the cost-effective savings remaining to secure.

For multifamily units, it was assumed that if the unit was weatherized under any utility program there was nothing remaining to be secured.

For single-family houses, the above discussion results in a total of 274,316 primarily electrically heated houses being weatherized in a program and an additional 68,580 households taking some action on their own. This leaves a potential of 300,933[12] households that can still secure the full savings. In addition, the 68,580 houses that went part way on their own, combined with 58,489 houses weatherized only part way in the private utilities' territories, leaves 125,420 houses that still have an assumed 40 percent of the total savings remaining. For multifamily houses, the potential is 250,975 electrically heated units surviving until 2010 minus 67,400 units already weatherized through a program. The potential is therefore 183,575 multifamily units still to weatherize with the full potential.

The cost-effective efficiency levels derived for single-family and for multifamily houses are installed in the forecasting model, and the model modifies electricity intensity due to behavioral responses. These are responses to the effect of lower bills now that the house is weatherized, and to changing electricity prices and incomes. The cost-effective efficiency levels resulted in a consumption of electric space heating use from the forecast in 2010 of 8,951 kilowatt-hours per year for a fully retrofit single-family house and 2,649 kilowatt-hours per year for multifamily houses. Overall savings for the efficiency improvements are derived by subtracting 2010 consumption, including behavior as predicted in the forecast with the efficiency improvements installed, from consumption in 2010 with efficiency held frozen at the pre-conservation level. The values from the forecast for the pre-conservation, frozen-efficiency level are 12,432 and 5,192 kilowatt-hours per year, respectively. The total technical potential of average megawatt savings for all forecasts can then be calculated:

12./ This equals 643,829 electrically heated houses left in 2010 minus 342,896 with some weatherization, which equals 300,933 houses left with full potential.

$$\begin{aligned} SFS_f &= HH \times S_f \div C \\ &= 300{,}933 \times (12{,}432\text{-}8{,}951) \div 8{,}760{,}000 \\ &= 119 \text{ average megawatts} \end{aligned}$$

$$\begin{aligned} SFS_p &= HH \times S_p \div C \\ &= 125{,}420 \times (10{,}210\text{-}8{,}864) \div 8{,}760{,}000 \\ &= 19 \text{ average megawatts} \end{aligned}$$

$$\begin{aligned} MFS &= HH \times S \div C \\ &= 183{,}575 \times (5{,}192\text{-}2{,}649) \div 8{,}760{,}000 \\ &= 53 \text{ average megawatts} \end{aligned}$$

$$\begin{aligned} TWxS &= SFS_f + SFS_p + MFS \\ &= 119 + 19 + 53 \\ &= 191 \text{ average megawatts} \end{aligned}$$

Where:

SFS_f = single-family savings from houses with full weatherization potential, expressed in average megawatts

HH = number of households with full weatherization potential

S_f = savings per house from houses with full weatherization potential, expressed in kilowatt-hours (pre-weatherization use minus post-weatherization use)

C = conversion factor from kilowatt-hours to average megawatts (8,760,000 kilowatt-hours per average megawatts)

SFS_p = single-family savings from houses with partial weatherization potential, expressed in average megawatts

HH = number of households with partial weatherization potential

S_p = savings per house from houses with partial weatherization potential, expressed in kilowatt-hours

MFS = multifamily savings, expressed in average megawatts

HH = number of multifamily households

S = savings per multifamily house, expressed in kilowatt-hours

TWxS = total weatherization savings, expressed in average megawatts

The supply curve shown in Table 7-17 reflects the distribution of savings that is expected, given the thermal integrity curve from the engineering model. The cheapest measures were assumed to be used to reduce consumption from the uninsulated house to the base case level used in the forecast.

Table 7-17
Technical Conservation From Existing Space Heating

Levelized Cost (cents/kWh)		Cumulative Technical Potential (Average Megawatts)		
Nominal	Real	Single-family Houses	Multifamily Houses	Total
0	0	0	0	0
1	0.5	0	0	0
2	1	0	0	0
3	1.5	3	3	7
4	2	3	4	7
5	2.5	12	7	19
6	3	15	43	58
7	3.5	62	43	105
8	4	76	43	119
9	4.5	80	43	123
10	5	138	53	191
11	5.5	138	53	191
12	6	138	53	191
13	6.5	138	53	191
14	7	138	53	191
15	7.5	138	53	191

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

This section compares measured end use of electricity and other estimates of residential space heating consumption to that projected by the engineering model (SUNDAY) used by the Council. Two questions are addressed:

1. Does the space heating energy use projected by the engineering model agree with measured usage for homes with a wide range of energy efficiency?

2. Do the Council's estimates of single-family weatherization savings agree with savings estimates obtained from the evaluation of regional weatherization programs?

1. Engineering Use Estimates vs. Measured Use.

The annual space and water heating requirements of over 800 houses were measured in the Residential Standards Demonstration Program (RSDP). Houses that were built to the prevailing building practice between 1979 and 1983, as well as houses that met the Council's model conservation standards, were monitored. Houses that were built to the prevailing building codes and practices between 1979 and 1983 are referred to as "control" dwellings. These houses spanned a wide range of efficiencies and sizes. Some control houses in the RSDP, due to their size and overall insulation levels, had heat loss rates similar to the Council's estimate of a house that has not been through a weatherization program (approximate UA of 550). Other control houses in the RSDP, either due to their small size or insulation levels, were representative of fully weatherized residences and were as efficient as the Council's model conservation standards.

Staff from the Council's Montana office, using a data base prepared by Lawrence Berkeley Laboratories for Bonneville, developed the estimates shown in Table 7-18 of actual space heating demand for 422 houses in the RSDP. Houses that were built at least as efficiently as the Council's residential model conservation standards (MCS) are referred to as "RSDP/MCS" dwellings. These houses all had at least 300 days of measured electricity used for space heating.

Table 7-18
Measured Space Heating Demand for RSDP Houses

House Type	Number	Annual Use (kWh/sq. ft.)			
		Zone 1	Zone 2	Zone 3	Regional Avg.
Control	244	5.8	5.9	6.4	5.8
RSDP/MCS	178	3.3	3.7	2.9	3.3
Difference		2.5	2.2	3.5	2.5

In its evaluation of the cost effectiveness of the model conservation standards, Bonneville also developed an estimate of the measured space heating use observed in the RSDP. These estimates, shown in Table 7-19, were based on a sample of 233 houses for which there were at least 330 days of measured electricity used for space heating.

Table 7-19
Measured Space Heating Demand for RSDP Houses

House Type	Number	Annual Use (kWh/sq. ft.)			
		Zone 1	Zone 2	Zone 3	Regional Avg.
Control	126	5.8	6.1	7.0	5.9
RSDP/MCS	107	3.4	3.7	3.6	3.4
Difference		2.4	2.4	3.5	2.5

The Council's and Bonneville's estimates of measured use are in close agreement for Zones 1 and 2, although they vary significantly for Zone 3. This may be due to differences in the size of the sample and the number of days of measured data. However, both the Council's and Bonneville's estimates of the regionally weighted average are within 0.1 kilowatt-hours per square foot, per year, for both RSDP/MCS and control dwellings. Furthermore, the Council staff's and Bonneville's estimates of the average difference in space heating use observed between the RSDP/MCS and control dwellings are identical and are equal to 2.5 kilowatt-hours per square foot, per year.

The SUNDAY thermal simulation was run using weather data from Seattle, Spokane and Missoula to represent the three climate zones found in the region. Three combinations of inputs to SUNDAY were tested. These input sets varied in their assumptions regarding thermostat set point and the amount of heat loss caused by infiltration. Two thermostat set points were tested, a 65°F constant set point, as had been assumed by the Council and by Bonneville in its cost-effectiveness analysis, and the set points reported by the occupants. Three levels of infiltration losses were tested. The first level was equivalent to that calculated from fan pressurization (blower door) test results using the Lawrence Berkeley Laboratory's infiltration prediction model. These averaged 0.32 air changes per hour for the RSDP/MCS houses and 0.54 air changes per hour for the control houses. The second level of infiltration losses assumed was a constant 0.35 air changes per hour. This level was adopted by Bonneville in its cost-effectiveness analysis for both control and RSDP/MCS houses. The third infiltration level tested was derived from a weather adjustment made to the Lawrence Berkeley Laboratory's model's predictions based on blower test results. This level assumed that control houses had 0.5 air changes per hour and that RSDP/MCS had 0.3 air changes per hour. The conductance heat loss rates (UAs) assumed for all three sets of infiltration inputs were calculated as they were by the Council in its 1986 plan.

Table 7-20 shows the space heating demand predicted by SUNDAY when thermostat set points are equivalent to those reported by the occupant.[13] These reported set points are 63.7°F for control houses and 67.3°F for RSDP/MCS houses. Infiltration losses underlying the calculations in Table 7-20 are estimated from blower door tests. Table 7-21 shows the space heating use predicted by SUNDAY when thermostat set points are 65°F and infiltration losses are 0.35 air changes per hour for both control and RSDP/MCS houses. Conductance losses, except for differential air change rates and internal gains assumptions, are the same in both cases.

Table 7-22 shows the space heating use predicted by SUNDAY when the thermostat set points are equivalent to those reported by the occupants, and heat loss rates from infiltration are based on an average 0.5 air changes per hour for the control houses and 0.3 air changes per hour for the RSDP/MCS dwellings. These infiltration rates are slightly lower than those actually measured because the winter of 1985/1986 was slightly warmer and less windy than the 30-year average, which is used in the Lawrence Berkeley Laboratory model. This adjustment was estimated by comparing the weather from 1985/1986 to the 30-year average.

13./ Thermostat set points used are the average, wintertime temperature settings considering the occupants daytime and weekend activities. This temperature setting was chosen because the SUNDAY model uses the mean thermostat set point for all hours during the heating season to compute space heating use.

Table 7-20
SUNDAY Predicted Space Heating Use
with Occupant Reported Thermostat Setting, 3,000 Btu/hr
Internal Gains, and Blower Door Derived Infiltration Rate

House Type	Annual Use (kWh/sq. ft.) Zone 1	Zone 2	Zone 3	Regional Avg.
Control	5.8	7.8	6.7	6.1
RSDP	2.8	3.7	4.3	3.0
Difference	3.0	4.1	2.4	3.1

Table 7-21
SUNDAY Predicted Space Heating Use
with 65°F Thermostat set point, 3,000 Btu/hr Internal Gains
and Infiltration Losses Based on 0.35 ach

House Type	Annual Space Heating Use (kWh/sq. ft.) Zone 1	Zone 2	Zone 3	Regional Avg.
Control	5.4	7.8	6.6	5.8
RSDP/MCS	2.5	3.5	4.1	2.7
Difference	2.9	4.2	2.5	3.1

Table 7-22
SUNDAY Predicted Space Heating Use
with Occupant Reported Thermostat Set Points, 3,000 Btu/hr
Internal Gains and Infiltration Losses for Control of 0.5 ach
and for RSDP/MCS of 0.3 ach

House Type	Annual Space Heating Use (kWh/sq. ft./yr) Zone 1	Zone 2	Zone 3	Regional Avg.
Control	5.6	6.4	7.6	5.8
RSDP/MCS	3.0	3.9	4.7	3.2
Difference	2.5	2.3	3.5	2.6

Note: Numbers may not add, due to rounding.

A comparison of Table 7-20 and Table 7-21 shows that very similar SUNDAY results for annual space heating demand are obtained for the two different sets of inputs. The lower set points reported by homeowners are offset by the higher infiltration rate of .54 air changes per hour underlying the calculations in Table 7-20. On a regional average basis, both sets of model inputs produce an identical estimate of the expected difference in annual space heating needs of the control and RSDP/MCS houses. The differences estimated for any of the three climate zones do not exceed 0.1 kilowatt-hours per square foot, per year. Also, both sets of input assumptions produce results that are in good agreement with the measured space heating use shown in Tables 7-18 and 7-19.

As shown in Table 7-22, once the infiltration rates have been adjusted to reflect the milder winter of 1985/1986, the agreement between the SUNDAY predictions and the measured space heating use for both the control and RSDP/MCS houses improves. While there is some variance between measured and predicted within individual climate zones, the regional average predictions of SUNDAY are within 0.2 kilowatt-hours per square foot, per year, of the monitored space heating use for both the RSDP/MCS houses and control houses. This is remarkably good agreement given how little is known about the accuracy of the inputs.

SUNDAY space heating predictions for RSDP houses in Washington were found to agree very well with measured use when input assumptions were estimated for the actual efficiency of the building, weather conditions on the building site and known occupant behavior. Figure 7-5 shows the measured annual space heating consumption of 278 RSDP houses located in Washington state as a function of their estimated heat loss rate, or UA. Also shown in Figure 7-5 is the predicted space heating consumption from SUNDAY for these same houses. Over the range of heat loss rates exhibited by these houses, there is very good agreement between the predicted space heating use and the monitored use.[14] For all houses, the average difference between the measured and simulated space heating use was approximately 8 percent.

14./ The range of heat loss rates shown in Figure 7-5 encompasses the range being analyzed by the Council for both new and existing residential space heating conservation programs.

Space Heating Use

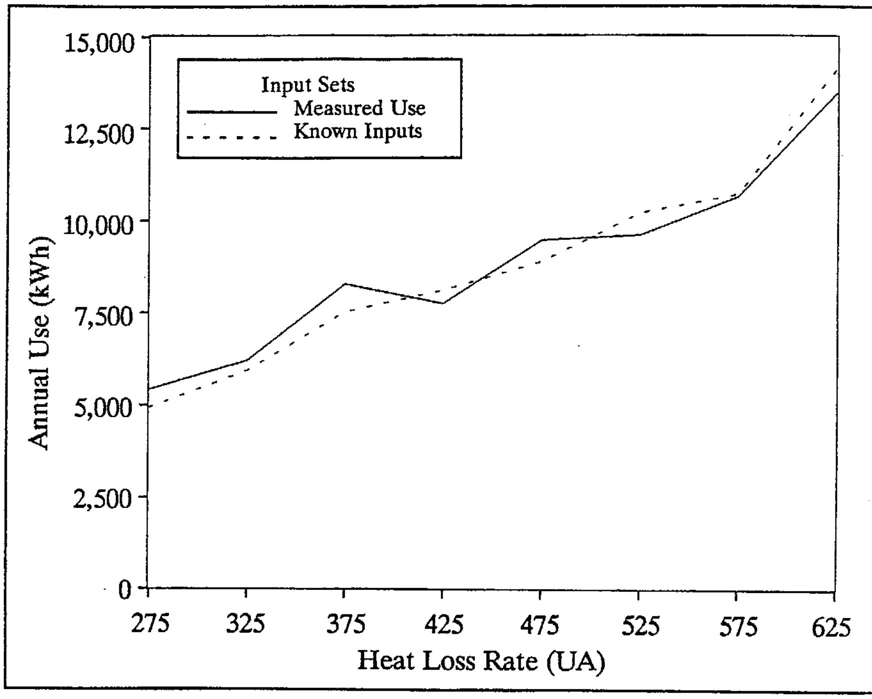

Figure 7-5
SUNDAY Predicted vs. Monitored Space Heating Use in Washington RSDP Houses

The SUNDAY simulation model has also been compared to measured space heating consumption in a small sample of houses (20 houses) in Hood River, before the houses were weatherized in the Hood River Conservation Project. This analysis found that room closure patterns and temperature setbacks had to be modeled in the inputs before SUNDAY, which represents a house as a single temperature zone, matched the monitored space heating use.

2. Weatherization Program Costs and Savings vs. Engineering Estimates.

The Bonneville residential weatherization program has operated in various forms since 1980. Oak Ridge National Laboratory (ORNL), under contract to Bonneville, has evaluated this program's costs and savings. It assessed the effect of the installation of conservation measures on the amount of electricity used for space heating. Oak Ridge National Laboratory used a statistical regression technique (called PRISM)[15] to estimate space heating use from known total electric consumption. For each participating house, annual electricity use, normalized to long-term weather conditions, was compared to its pre-weatherization use. Table 7-23 shows the average estimated use for space heating for pre- and post-retrofit conditions for the four different phases of the Bonneville residential weatherization

15./ PRISM is the Princeton Scorekeeping Model.

program. This table also shows the average weatherization package cost of each program phase converted to 1990 dollars.

Table 7-23
Estimated Pre- and Post-Program Participation Energy Use and Retrofit Cost In Bonneville Residential Weatherization Programs

Program Phase/ Year Participating	Pre-Program Use (kWh/sq. ft.)	Post-Program Use (kWh/sq. ft.)	Savings	Cost ($/sq. ft.) (1990 $)
Pilot/1981	12.1	7.7	4.4	$2.07
Interim/1982	8.9	6.6	2.3	$1.32
Interim/1983	8.0	5.9	2.1	$1.41
Long-Term/1985[a]	8.2	6.5	1.7	$1.72

[a] Floor areas used to calculate the average use and cost per square foot assume that homes weatherized in the long-term program are the same size as those weatherized in the interim program in 1983.

The first step in determining how well the Council's engineering estimates for residential weatherization savings agree with those estimated for Bonneville's program is to compare the estimates of post-retrofit space heating use. Figure 7-6 shows the post-program space heating use estimated by PRISM in Bonneville's evaluations compared to five engineering projections based on five different sets of input assumptions to the SUNDAY thermal simulation model. The five sets of input to SUNDAY are:

Set 1 65°F with 2,000 Btu per hour internal gains: The Council's current assumptions for long-term household behavior. Thermostat setting at 65°F for 24 hours per day. Efficient appliances generating 2,000 Btu per hour internal gains.

Set 2 65°F with 3,000 Btu per hour internal gains: Same as Set 1, except current appliance efficiencies are assumed to generate 3,000 Btu per hour of internal gains.

Set 3 68°F with 2,000 Btu per hour internal gains: Same as Set 1, except occupants are assumed to set their thermostats at 68°F for 24 hours per day.

Set 4 62°F with 3,000 Btu per hour internal gains: Occupants are assumed to set their thermostats at 62°F for 24 hours per day and use appliances with current efficiencies generating 3,000 Btu per hour of internal gains. The thermostat set point of 62°F assumes that either approximately 25 percent of the time or 25 percent of the heated area of the home has a thermostat setting of 55°F, and the remainder of the time or heated area of the home has a thermostat setting of 65°F.

Set 5 65oF with WOOD: Same as Set 4, except that occupants are assumed to use approximately two cords of wood per year as supplemental heating. A wood stove/fireplace insert conversion efficiency of 50 percent has been assumed resulting in approximately 15 million Btu (4,400 kilowatt-hours per hour) of useful heat.[16] Wood use is assumed to be proportional to monthly space heating needs, i.e., the months that have the greatest heating demands are the months of greatest wood use.

Space Heating Use

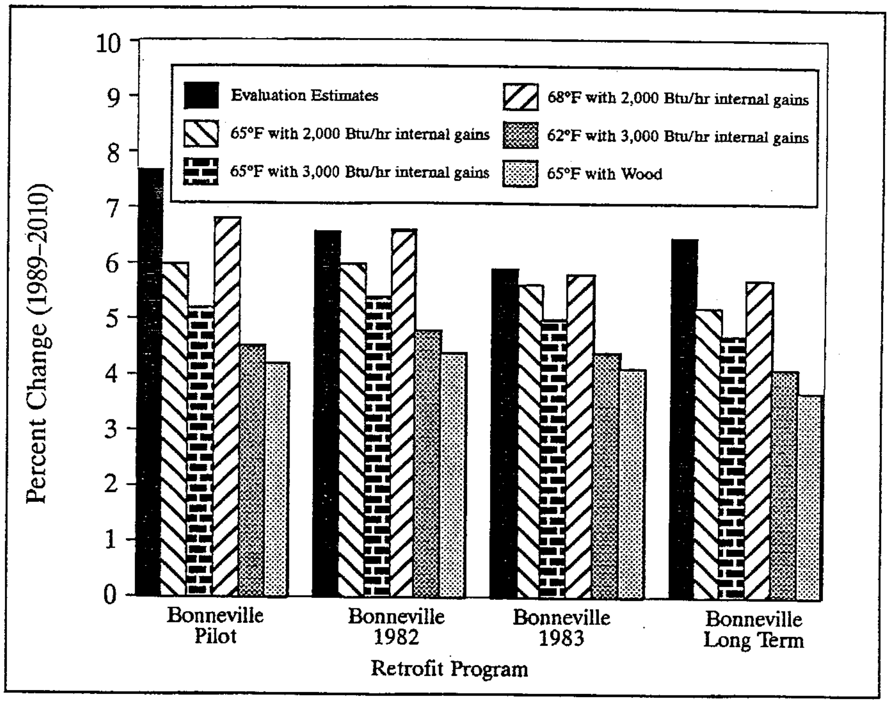

Figure 7–6
Post–Weatherization Space Heating Use

The engineering prediction of post-retrofit program use shown in Figure 7-6 is based on pre-program use being equal to the pre-program use estimated in the program evaluation. The engineering estimate of post-program use was determined by assuming that the retrofit costs reported in the evaluations were used to purchase the same measures, in the same order and at the same cost as those identified in the Council's space heating supply curve for existing single-family houses.

As shown in Figure 7-6, the post-retrofit space heating use estimated by PRISM for the Bonneville weatherization program evaluations are higher than the engineering model estimates based on all five input assumption sets. The SUNDAY estimates that most closely match the PRISM estimates of post-retrofit

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16./ A Bonneville study of residential wood use in the region found that the occupants of single-family electrically heated homes reported approximately two cords of wood use per year on average.

use are based on Sets 1 and 3, with Set 3 the closest. Set 3 uses a three degree higher thermostat setting both pre- and post-retrofit than is presently assumed by the Council. The other three input sets, which assume either lower amenity levels (i.e., lower thermostat settings) or supplemental wood use underpredict post-retrofit use.

Figure 7-7 compares the estimated space heating savings that were obtained from PRISM for the Bonneville weatherization program to SUNDAY estimates of savings based on the five input assumption sets. In all cases, estimates of savings from SUNDAY are higher than those obtained from the PRISM estimates. As was the case with post-retrofit use, the two input sets that produce savings estimates that most closely agree with the PRISM estimates are Sets 1 and 3, with Set 3 once again being in best agreement. For all other input sets, which assume either lower amenity levels or supplemental wood, the SUNDAY estimates of savings are higher than the PRISM estimates.

Weather–ization Savings

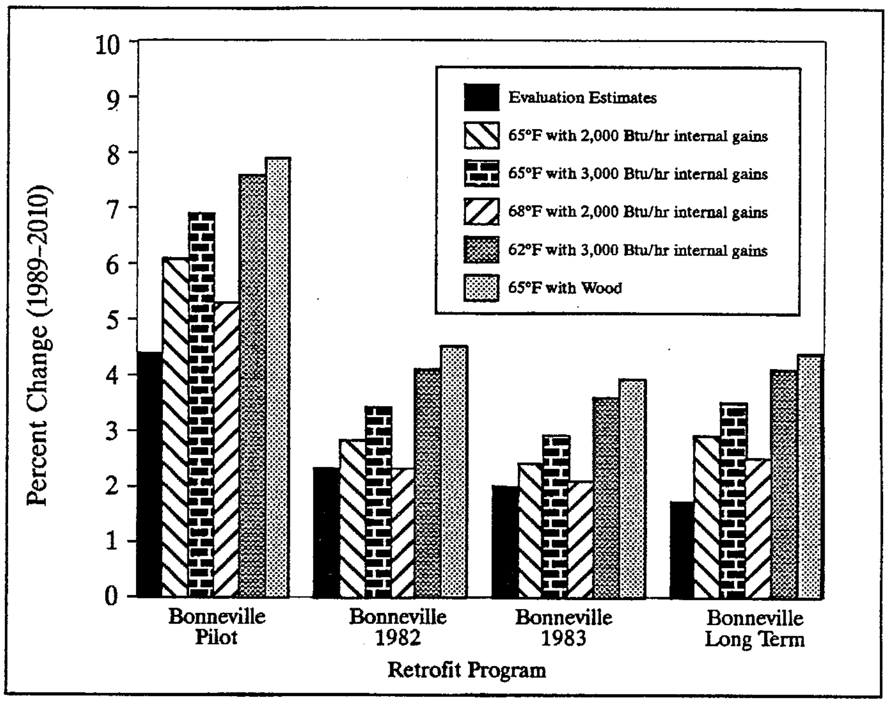


Figure 7-7
Weatherization Savings from Various Estimates

If the PRISM estimates are accurate, and occupant behavior is projected to remain the same over the long term, then the Council should probably revise its assumptions on thermostat setting. However, prior to adopting a revised thermostat set point, several factors must be taken into consideration. First, it has been shown that PRISM systematically overestimates space heating energy use. This is due to the fact that a portion of the increased electricity use caused by colder winter weather results from greater lighting, water heating and cooking use. As the PRISM estimate of electricity used for heating is really an estimate of weather sensitive loads, it is possible and likely that PRISM is including at least a part of this electricity in its heating estimate. Consequently, it is very likely that both pre-retrofit and the post-retrofit use shown in Figure 7-6 based on PRISM are too high. If both pre- and post-retrofit use are overestimated by equivalent amounts, this would not affect savings estimates. Unfortunately, there is conflicting evidence on whether PRISM's overestimates of space heating use for well insulated buildings differs from its overestimates of space heating for buildings that are poorly insulated.[17]

Second, as stated previously, the SUNDAY estimate of both post-retrofit use and program savings are based on the presumption that participants installed the same measures, in the same order and at the same costs as those included in the Council's conservation supply curve for space heating in existing single-family homes. If measures were selected out of their least-cost order, then the PRISM estimates of savings would be less for the same expenditure. Indeed, Bonneville staff have observed that program participants have not always chosen the lowest cost conservation measures to improve efficiency. For aesthetic reasons, for example, many participants make expensive window replacements when a storm window would achieve the same level of efficiency. As a result, because these program participants have deviated from the idealized supply curve, both in terms of the measures selected and the costs of the measures, their post-retrofit use is higher than was predicted, their savings are lower than predicted, and the savings appear to have higher levelized costs.[18] Consequently, the fact that SUNDAY estimates do not align perfectly with PRISM estimates of savings and post-retrofit use is not sufficient justification to indict either estimation technique.

A third issue is the effect of conservation on a consumer's electric bill, which will be lower following weatherization. This may lead to changes in behavior. For example, Figure 7-8 shows the measured space heating energy use in Washington RSDP houses compared to SUNDAY model projections based on four sets of alternative operating conditions described above and model inputs derived from occupant surveys and building audits. Each of the curves shows the predicted annual space heating use for houses as a function of heat loss rates. The two top curves assume efficient appliances and thermostat settings of either 68°F or 65°F. The bottom two curves show the predicted space heating for houses with inefficient appliances and thermostat settings of either 62°F or 65°F. These sets of assumptions bracket the measured use observed in the RSDP houses, shown by the solid line.

An interesting finding is that estimates of space heating use assuming efficient appliances and thermostat settings of either 65°F or 68°F are in better agreement with the measured use in well-insulated houses (low UAs); whereas, estimates assuming lower thermostat settings and/or inefficient appliances, more closely match the measured use of high heat loss buildings.

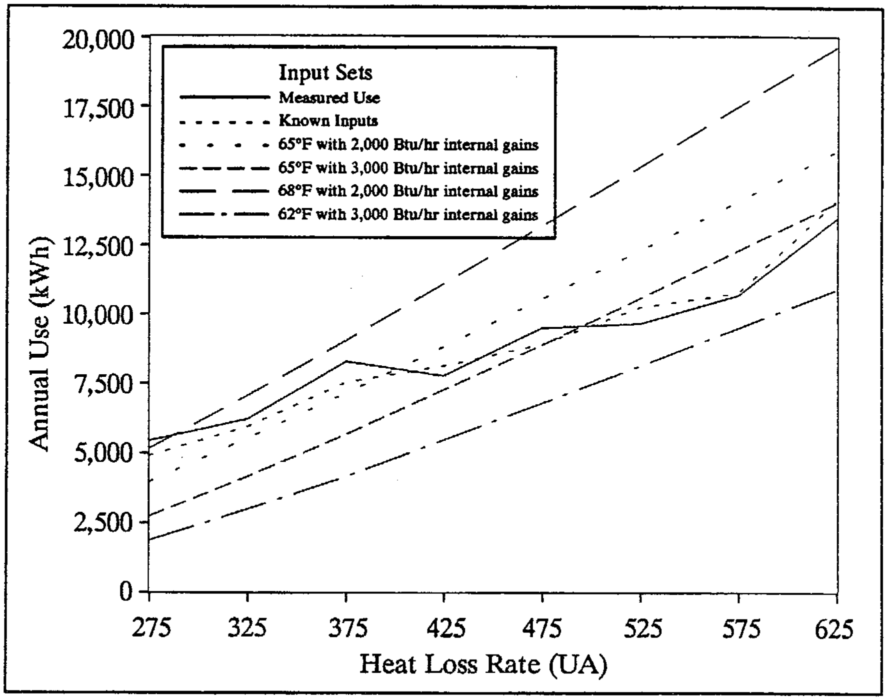
17./ It presently appears that PRISM overstates the space heating use of well-insulated buildings more than it does poorly insulated structures. (See Lee, A.D. et al., *Cost-effectiveness of Conservation Upgrades in Manufactured Homes*, PNL-6519, September 1988.)

18./ Bonneville has revised its Long-Term Weatherization Program financial assistance levels to encourage consumers to select measures that are more closely aligned with the idealized supply curve.

These results appear to indicate that in more energy-efficient houses, occupants operate their houses more like the Council's assumed standard operating conditions, while in less well-insulated houses they operate the home at reduced amenity levels (i.e., lower thermostat settings). Indeed, it is known that both the average measured temperature and occupant reported thermostat settings in the RSDP/MCS houses were higher than those of the control houses. This is consistent with economic theory and suggests that after weatherization, consumers could be expected to raise their thermostat settings, and thus reduce the savings. Moreover, economic theory would also predict that even without weatherization, thermostat settings will tend to rise over time as electricity prices stabilize and individual incomes rise.

Space Heating Use

Figure 7-8
SUNDAY Predicted and Actual Use in Washington RSDP Houses Superimposed on Various Alternative Operating Conditions



Step 4. Estimate Realizable Conservation Potential

The final step in the Council's assessment of retrofit potential was to develop an estimate of the share of the 190 average megawatt potential that could realistically be achieved over the next 20 years, if there were a need to develop energy resources. In prior plans, the Council used 85 percent, due to the extensive mechanisms to secure conservation under the Northwest Power Act. This value is used again in this analysis.

Space Heating Conservation in New Residential Buildings

Figures 7-9, 7-10 and 7-11 show the technical space heating savings available under the Council's high forecast from new single-family and multifamily residences and from new manufactured houses at various costs. When compared to the prevailing codes and building practices in the region in 1983, new single-family homes represented approximately 960 average megawatts of technical potential if savings costing less than 10 cents per kilowatt-hour could be achieved. Since 1983, the states of Oregon and Washington have revised their energy codes, and other jurisdictions in Idaho and Montana have adopted the Council's model conservation standards. These code changes are anticipated to secure about 405 average megawatts of this technical potential, if they are completely enforced.[19] This leaves 555 average megawatts of technical potential yet to be secured through further code improvements and programs. Approximately 70 percent (380 average megawatts) of these savings are from regionally cost-effective measures that are incorporated into the Council's model conservation standards.[20] An additional 175 average megawatts of conservation is available from measures costing less than 10 cents per kilowatt-hour which have yet to be incorporated in the Council's standards. There is an estimated 55 average megawatts of commercially available space heating conservation in new single-family homes at a levelized cost between 10 and 13 cents per kilowatt-hour.

Under the Council's high forecast, savings costing less than 10 cents per kilowatt hour in multifamily dwellings represented approximately 130 average megawatts of technical potential beyond 1983 codes and building practices. Just over 40 percent (55 average megawatts) of this technical potential has been secured through the code improvements occurring between 1983 and 1989. Of the remaining 75 megawatts of technical potential, 55 average megawatts of savings are from regionally cost-effective measures that are incorporated into the Council's model conservation standards.[21] An additional 20 average megawatts of conservation is available from measures costing less than 10 cents per kilowatt-hour which have yet to be incorporated into the Council's standards. About 10 average megawatts of commercially available space heating conservation savings are available in new multifamily dwellings at a levelized cost of between 10 and 13 cents per kilowatt-hour.

Savings costing less than 10 cents a kilowatt-hour from new manufactured housing represented about 225 average megawatts of technical potential beyond the prevailing building practices of 1983. Although the federal thermal efficiency standards for manufactured homes have not changed since 1974, market demand for more efficient units has resulted in improved efficiency.[22] As a consequence, an

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19./ The state of Washington will begin enforcing an energy code equivalent to the Council's model conservation standards in July 1991. Savings attributable to this code change are not included in this figure.

20./ This is the amount of conservation included in the resource portfolio. For comparison purposes, this is 150 average megawatts in the medium forecast.

21./ This value is 50 average megawatts in the medium forecast.

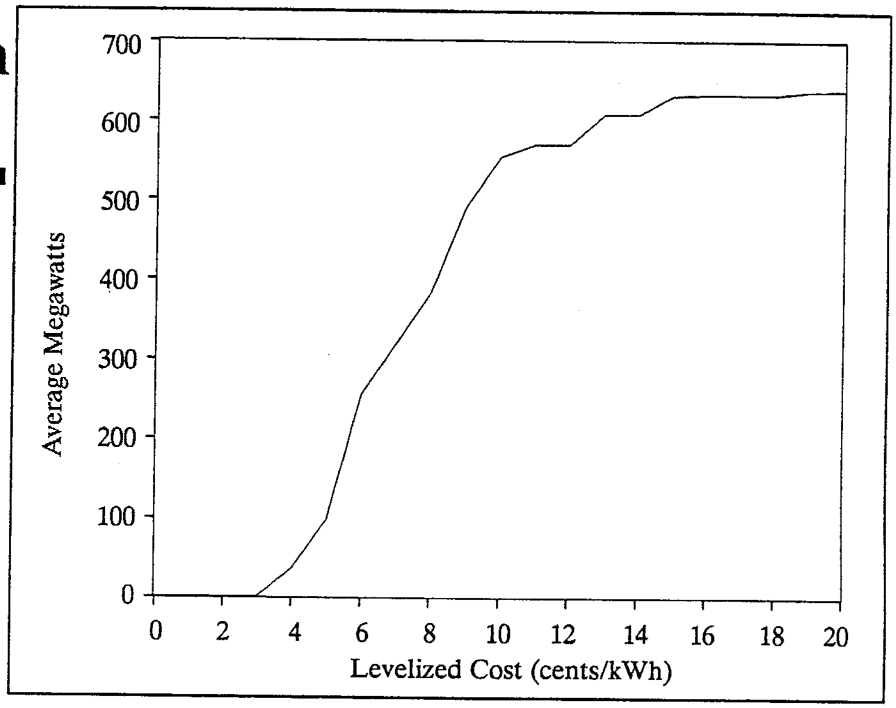
22./ The U.S. Department of Housing and Urban Development (HUD) was directed by Congress to update its thermal standards for manufactured housing in 1987. HUD has yet to comply with this legislation.

estimated 140 average megawatts of savings are now available at a cost below 10 cents per kilowatt-hour from measures beyond current (1990) construction practice in the Council's high and medium forecasts.

The average cost of improving the thermal efficiency of new buildings beyond current codes is about 6 cents per kilowatt-hour even if administrative costs and transmission and distribution adjustments are included. Figure 7-12 illustrates the savings secured through code improvements adopted in 1986. The difference in the heights of the bars represents the savings that will be secured through the improved codes if they are enforced. The remaining potential beyond 1986 codes is what requires further action.

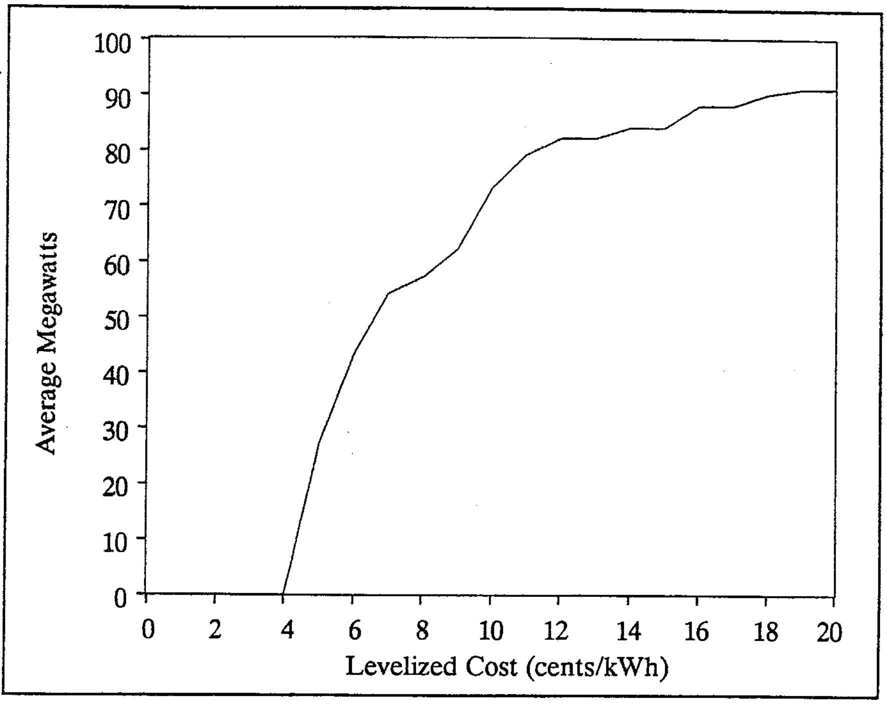
Conservation Potential

Figure 7–9
Technical Conservation from Space Heating Measures Beyond 1986 Codes/Practice in New Single–Family Residences



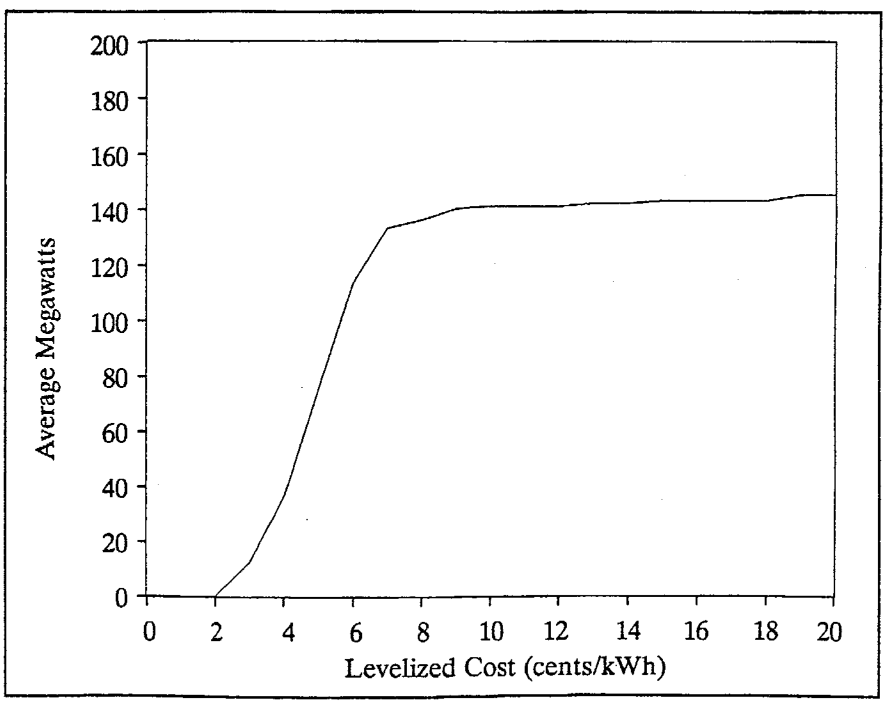
Conservation Potential

Figure 7-10
Technical Conservation from Space Heating Measures Beyond 1986 Codes/Practice in New Multifamily Residences



Conservation Potential

Figure 7-11
Technical Conservation from Space Heating Measures Beyond 1986 Codes/Practice in New Manufactured Houses



Conservation Potential

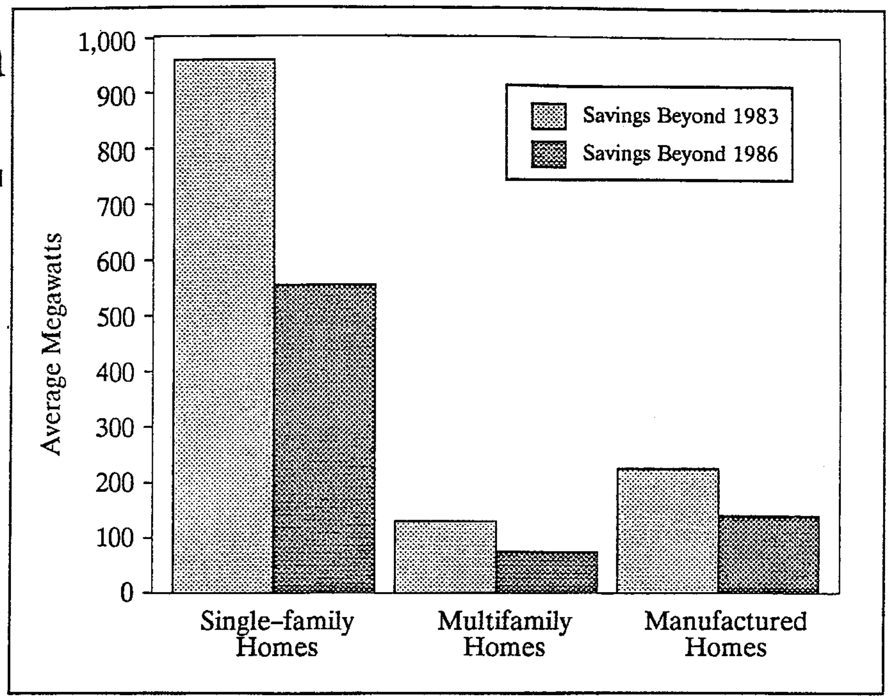


Figure 7-12
Technical Conservation from Space Heating Measures Beyond 1983 and 1986 Codes/Practice

Making new houses more efficient is a high priority for securing a least-cost energy future for the region. It is important to insulate houses fully at the time they are built or cost-effective savings can be lost. In addition, while the number of houses eligible for retrofitting will diminish over time, the number of houses that conservation can reach continues to grow as every new house is built.

The conservation potential available through improvements in the energy efficiency of 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 7-24 summarizes these data sources.

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.

Table 7-24
Key Data Sources for New Space Heating Measures

Residential Characteristics

- Pacific Northwest Residential Energy Survey - Insulation characteristics of new construction. House size and climate zone.
- Housing Industries Dynamics Survey - Insulation characteristics of new construction. House size and climate zone.
- Residential Standards Demonstration Project - Air change rates.
- Residential Construction Demonstration Project - Manufacture housing current construction practice.
- Northwest Residential Infiltration Study - Air change rates.
- Pacific Northwest Labs/Bonneville Power Administration - Current construction practice. Pacific Northwest manufactured housing and conservation upgrade possibilities.

Costs

- Residential Standards Demonstration Project - Measure cost for single-family and multifamily homes.
- Residential Construction Demonstration Project - Measure cost for highly insulated walls (site built) and measure cost for manufactured homes.
- University of Washington Study - Measure cost (site built).
- Manufactured Housing Institute Study - Costs of manufactured home measures.
- U.S. Department of Housing and Urban Development - Costs of manufactured home measures.

Consumption and Savings

- Residential Standards Demonstration Project - Test of simulation model, energy consumption.
- Evaluation reports from weatherization programs - Simulation model comparison.

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.

Tables 7-25 and 7-26 show by climate zone and building type the 1983 "base case" insulation levels assumed by the Council in its assessment of space heating conservation potential in new dwellings. The information on new single-family and multifamily housing characteristics shown in Table 7-25 is derived from three sources. The first is a regional residential energy survey conducted for Bonneville in 1983 (Pacific Northwest Residential Energy Survey 1983, "PNRES '83"). This survey was used to estimate the average size of new dwellings. The second data source was the 1977 through 1983 annual survey of new home characteristics prepared by Housing Industry Dynamics (HID) for Bonneville. The HID survey data was used to determine the typical glass area and foundation types, and the most prevalent level of insulation found in new dwellings.

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. Table 7-26 shows the efficiency levels required by the 1986 revisions to the Oregon and Washington state codes.[23] This table also shows the expected annual space heating use for new residences built to the 1986 Oregon and Washington codes.

Information on the air tightness of new dwellings was obtained from the Residential Standards Demonstration Program (RSDP) sponsored by Bonneville. Data obtained in RSDP appeared to indicate that a house built between 1980 and 1983 experienced between 0.35 and 0.55 air changes per hour, depending on the test method used. Results of air tightness testing conducted through the Northwest Residential Infiltration Study (NORIS) sponsored by Bonneville indicate 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. The NORIS also found that, depending upon the criteria used, from 20 to 50 percent of the homes tested failed to meet the most current American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) standard for acceptable ventilation rates (ASHRAE Standard 62-89). Given this finding and ongoing research being conducted to refine the methods used to measure infiltration and ventilation rates, the Council will continue to assume the ASHRAE rate of 0.35 air changes per hour for current practice homes.

23./ The 1990 session of the Washington State legislature enacted legislation that will require new electrically heated homes constructed after July 1, 1991 to meet a thermal efficiency standard that is expected to be equivalent to the Council's model conservation standards. When the codified version of these thermal standards has been adopted the Council will include these savings in its demand forecast.

Table 7-25
New Residential Construction Base Case Efficiency Levels and Annual Space Heating Use Assumptions

Building Type	Climate Zone 1 Insulation Level	Climate Zone 1 Annual Use (kWh/sq ft)	Climate Zone 2 Insulation Level	Climate Zone 2 Annual Use (kWh/sq ft)	Climate Zone 3 Insulation Level	Climate Zone 3 Annual Use (kWh/sq ft)	Weighted Average Use (kWh/sq ft)
Single-family		6.8		9.7		8.2	7.3
Roof (Attic)	R-30		R-30		R-38		
Vaulted Ceiling	R-19/30		R-19/30		R-30		
Walls	R-11		R-11		R-19		
Under Floor	R-11/19		R-19		R-19		
Windows	Double glazed (U-.90)		Double glazed (U-.90)		Double glazed (U-.65)		
Air Tightness	0.35 ACH		0.35 ACH		0.35 ACH		
Multifamily		3.6		6.0		7.1	4.1
Ceiling/Roof	R-30		R-30		R-30		
Walls	R-11		R-11		R-11		
Under Floor	R-11/19		R-19		R-19		
Windows	Double glazed (U-.90)		Double glazed (U-.90)		Double glazed (U-.65)		
Air Tightness	0.35 ACH		0.35 ACH		0.35 ACH		
Manufactured Homes		6.5		10.0		11.8	8.1
Ceiling/Roof	R-11		R-11		R-11		
Walls	R-11		R-11		R-11		
Under Floor	R-11		R-11		R-11		
Windows	Double glazed (U-.90)		Double glazed (U-.90)		Double glazed (U-.90)		
Air Tightness	0.35 ACH		0.35 ACH		0.35 ACH		

The base-case characteristics for new manufactured housing, shown in Table 7-25, were derived from information obtained from a Bonneville-sponsored study of current construction practices in the Northwest's manufacturing housing industry. The insulation levels assumed were also obtained from the same Bonneville study. These levels exceed the requirements of the U.S. Department of Housing and Urban Development's current rules concerning the eligibility of manufactured homes for mortgage insurance under Title II of the National Housing Act.

Table 7-26
New Residential Construction 1986 Energy Code Requirements and Annual Space Heating Use

	Insulation Level Zone 1		Annual Use (kWh/sq. ft.)		Insulation Level Zone 2		Annual Use (kWh/sq. ft.)	
	OR	WA	OR	WA	OR	WA	OR	WA
Single-family			4.7	4.6			7.5	6.3
Roof	38	38			38	38		
Vaulted	19	30			19	30		
Walls	19	19			19	19		
Underfloors	19	19			19	25		
Windows	R-1.5	R-1.6			R-1.5	R-1.6		
Multifamily			2.4	2.3			4.2	4.0
Roof	38	38			38	38		
Walls	19	19			19	19		
Underfloors	19	19			19	25		
Windows	R-1.5	R-1.6			R-1.5	R-1.6		

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 7-27 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 7-27
Typical New Dwelling Characteristics

Characteristic	Single-Family Detached			Multifamily	Manufactured Home	
Prototype Label Size-Gross Floor Area (sq ft) Foundation Type	A 1,344 Crawl space	B 1,848 Crawl space	C 2,356 Slab-on-grad Partial Basement	12-Units @ 840 sq ft/unit Crawl space	A 924 Skirted	B 1,568 Crawl space
Number of Stories	1	2-Split Level	1 w/partial basement	3 - 4/w garage	1	1
Window Area (sq ft) Glass Area as a % of Floor Area	174 13%	220 12%	310 13% (of unit's floor area)	1,140 11.9%		
Gross Wall Area						
Above Grade	1,395	2,151	1,842	6,422	1,200	1,260
Below Grade	----	----	584	----	----	----
Total Exterior Envelope Area (sq ft)	4,104	4,753	5,264	14,070	3,048	4,396

C:MG/DFT90.AA7 Tables 7-25 and 7-27

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

In the development of the 1983 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 two sources of conservation measure cost in addition to the RSDP cost data. Cost data on highly insulated walls (beyond R-19) was obtained from builders who participated in Bonneville's Residential Construction Demonstration Program. The estimated cost for several conservation measures was also obtained from a report prepared by researchers at the University of Washington who were charged with evaluating the cost effectiveness of measures in the 1986 Washington State Energy Code and the Council's model conservation standards. All costs used in this analysis were adjusted to 1990 dollars using the GNP Implicit Price Deflator for fixed investment in residential construction and include a 36-percent markup for builder overhead, profits and fees.

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. All the windows and 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 costs of improvements in the space heating efficiency of new manufactured housing used in this analysis are based on the results of the cost reported by manufacturers who participated in Bonneville's Residential Construction Demonstration Program (RCDP). In RCDP, 150 manufactured homes were built to the Council's model conservation standards. Three other studies were used to corroborate the preliminary cost information obtained through RCDP. Two studies, one prepared for the Manufactured Housing Institute (MHI), and the second prepared for the U.S. Department of Housing and Urban Development (HUD) reported costs for conservation measures based on national construction costs. The third study, conducted for Bonneville, obtained conservation measure cost data from manufacturers in the region using a survey. Tables 7-28 through 7-36 show the retail costs assumed by the Council for potential cost effective space heating conservation measures for new single- and multifamily dwellings and manufactured housing.

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). As discussed in Step 3 in the residential weatherization section above, this model accurately predicts sub-metered space heating consumption in houses with a wide range of insulation levels.

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 all of the measures' interaction. 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.

Figure 7-13 illustrates how the heating requirements of an average current practice house and a model conservation standards house might be met. Heating requirements are met by solar heat, internal gains (the amount of heat released indoors by people and appliances), and the furnace, which can be supplemented by heat from wood burning stoves or other sources. The current practice house reflects average conditions for a house that is primarily heated with electricity. If the house were primarily heated with wood, the contribution from wood would be much larger, but electrical savings would still be significant as long as electricity was the marginal fuel.

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.[24] The Council assumed no wood heating when evaluating measure savings in new residential buildings. The Council used a constant thermostat setting of 65°F 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 the majority 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

24./ 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.

contribute more usable heat to the house, and thus cut space heating loads. This is reflected in Figure 7-13, where internal gains are larger in the current practice house.

Heating Sources

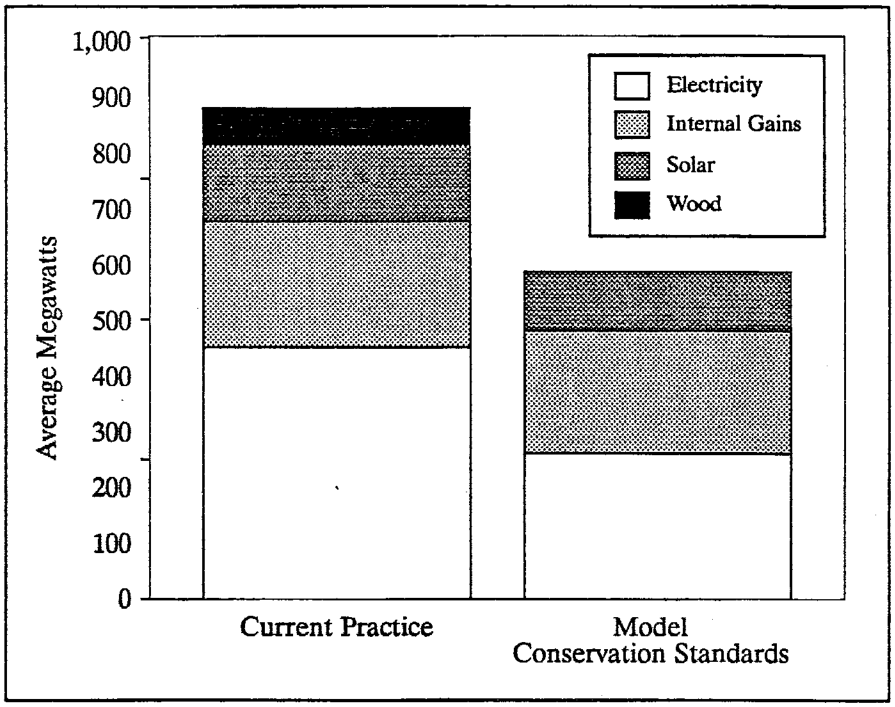


Figure 7-13
Residential Heating Sources

The Council reassessed the planning assumptions described above and feels that these assumptions should be maintained based on 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, especially in new houses, in the next decade. 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 than 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 7-28 through 7-36 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 7-Missoula). The levelized costs shown for single-family and multifamily buildings are based on a 70-year physical life and a financing cost of approximately 9 percent nominal.[25] Levelization was done using a 8.15 percent nominal (3 percent real, with 5 percent inflation) discount rate. The levelized cost shown for manufactured housing is based on a 45-year economic life and levelization at the same nominal financing and discount rate used for single-family and multifamily housing. For planning purposes, it has been assumed that the efficiency improvements in single-family and multifamily houses and manufactured housing will be obtained via a combination of codes, marketing and incentive programs financed through Bonneville, public utilities and the region's investor-owned utilities.

The Council has established model conservation standards for new single-family and multifamily houses heated with electricity. The standards are required to achieve all regionally cost-effective conservation savings. As discussed in Volume II, Chapter 4 of the 1986 plan, the Council has found that power savings that can be achieved by the model conservation standards represent regionally cost-effective resources. "The Model Conservation Standards for New Electrically Heated Residential Buildings, New Commercial Buildings, Residential and Commercial Buildings Converting to Electric Space Conditioning, Utility Residential and Commercial Conservation Programs, and Surcharge Methodology," adopted January 14, 1987, set forth an illustrative prescriptive path for each climate zone that, if installed in a typical new house, would satisfy the standards. The levels of efficiency achieved by the standards that are above those presently required in codes or accepted as current practice are all regionally cost-effective for the average 1,650 square foot single-family house (one- and two-family dwelling) currently being constructed in the region. In selecting the levels of efficiency required in the model conservation standards, the Council chose a typical structure in a typical location in each climate zone and assumed the building was operated in a typical way. Actual buildings will vary from these typical assumptions.

As shown in Tables 7-29 and 7-32, the installation of some measures not presently included in the model conservation standards could be regionally cost-effective. These measures include the use of R-26 advanced-framed walls in climate zone 1, and the use of R-49 advanced-framed attic insulation, R-40 wall insulation and R-15 slab edge insulation in Zones 2 and 3. While the Council has not included these measures in its standards for these climate zones, utility programs should be initiated to secure these savings. These measures presently represent commercially available promising resources, and are not included in the Council's resource portfolio.

25./ As noted in the introduction, finance costs are taken from the system models and reflect a sponsorship mixed among Bonneville and investor-owned utilities.

Table 7-28
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 1 - Portland
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 1,344 SQUARE FEET									
Base Case UA	471	$0	$0	$0.00	8,896	6.6	0	0.0	$0
Insulated Door	460	$50	$50	$0.04	8,557	6.4	338	17.1	$85
Floors R11 to R19	441	$296	$346	$0.26	7,993	5.9	564	39.6	$416
Windows R1.2 to R2.5	363	$849	$1,195	$0.89	5,709	4.2	2,283	42.6	$1,855
Walls R11 to R19	329	$732	$1,927	$1.43	4,742	3.5	966	57.3	$2,674
Walls R19 to R22	323	$165	$2,093	$1.56	4,578	3.4	164	76.0	$2,859
Vault R19 to R30	317	$186	$2,279	$1.70	4,411	3.3	166	84.4	$3,067
Floors R19 to R30	300	$497	$2,776	$2.07	3,968	3.0	443	84.9	$3,624
Attic R30 to R38 STD	296	$163	$2,940	$2.19	3,840	2.9	127	96.6	$3,806
Wall R22 to R26 ADV	272	$827	$3,766	$2.80	3,217	2.4	622	100.5	$4,731
Attic R38 STD to R49 ADV	261	$432	$4,198	$3.12	2,921	2.2	296	110.4	$5,215
Walls R26 ADV to R40 DBW	244	$803	$5,001	$3.72	2,501	1.9	419	144.7	$6,113
Vault R30 to R38	241	$227	$5,228	$3.89	2,431	1.8	70	244.3	$6,367
Floor R30 to R38	236	$538	$5,766	$4.29	2,298	1.7	133	305.4	$6,969
Attic R49 ADV to R60 ADV	233	$346	$6,111	$4.55	2,227	1.7	71	366.5	$7,355
TOTAL							6,669	74.6	$7,355

Table 7-28 (cont.)
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 1 - Portland
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 1,848 SQUARE FEET									
Base Case UA	628	$0	$0	$0.00	12,981	7.0	0	0.0	$0
Insulated Door	617	$50	$50	$0.03	12,635	6.8	346	16.7	$85
Floor R11 to R19	606	$160	$211	$0.11	12,320	6.7	314	38.5	$265
Window R1.2 to R2.5	507	$1,074	$1,284	$0.69	9,319	5.0	3,001	41.0	$2,083
Wall R11 to R19	453	$1,172	$2,457	$1.33	7,705	4.2	1,614	55.0	$3,395
Wall R19 to R22	443	$265	$2,721	$1.47	7,431	4.0	273	73.2	$3,691
Slab R5 to R10	439	$108	$2,830	$1.53	7,321	4.0	110	74.2	$3,813
Vault R19 to R30	436	$108	$2,937	$1.59	7,220	3.9	101	80.6	$3,933
Floor R19 to R30	427	$269	$3,207	$1.74	6,968	3.8	251	81.0	$4,234
Attic R30 to R38 STD	422	$184	$3,390	$1.83	6,813	3.7	154	89.7	$4,440
Wall R22 to R26 ADV	384	$1,324	$4,714	$2.55	5,740	3.1	1,073	93.3	$5,921
Attic R38 STD to R49 ADV	371	$486	$5,200	$2.81	5,378	2.9	362	101.5	$6,465
Wall R26 ADV to R40 DBW	344	$1,286	$6,486	$3.51	4,655	2.5	723	134.6	$7,904
Slab R10 to R15	342	$101	$6,587	$3.56	4,604	2.5	50	149.6	$8,016
Vault R30 to R38	341	$131	$6,718	$3.64	4,560	2.5	43	228.0	$8,163
Floor R30 to R38	338	$291	$7,009	$3.79	4,483	2.4	77	284.9	$8,489
Attic R49 ADV to R60 ADV	335	$389	$7,398	$4.00	4,397	2.4	86	341.9	$8,924
TOTAL							8,583	70.3	$8,924

Table 7-28 (cont.)
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 1 - Portland
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 2,352 SQUARE FEET									
Base Case UA	721	$0	$0	$0.00	14,107	6.0	0	0.0	$0
Insulated Door	715	$25	$25	$0.01	13,939	5.9	167	17.2	$43
Bsmt Wall R11 to R19 W/TB	695	$144	$170	$0.07	13,345	5.7	594	18.4	$204
Floor R11 to R19	689	$103	$273	$0.12	13,149	5.6	195	39.9	$320
Window R1.2 to R2.5	549	$1,513	$1,785	$0.76	9,052	3.8	4,097	42.3	$2,882
Wall R11 to R19	505	$937	$2,723	$1.16	7,818	3.3	1,234	57.5	$3,931
Wall R19 to R22	498	$212	$2,935	$1.25	7,609	3.2	209	76.6	$4,168
Slab R5 to R10	497	$34	$2,968	$1.26	7,576	3.2	32	78.2	$4,206
Vault R19 to R30	492	$126	$3,094	$1.31	7,464	3.2	112	84.9	$4,347
Floor R19 to R30	487	$173	$3,268	$1.39	7,310	3.1	153	85.4	$4,541
Attic R30 to R38 STD	481	$197	$3,464	$1.47	7,152	3.0	157	94.1	$4,760
Wall R22 to R26 ADV	451	$1,058	$4,523	$1.92	6,335	2.7	817	98.0	$5,945
Attic R38 STD to R49 ADV	437	$520	$5,043	$2.14	5,967	2.5	368	106.7	$6,527
Wall R26 ADV to R40 DBW	416	$1,028	$6,071	$2.58	5,406	2.3	560	138.7	$7,677
Slab R10 to R15	415	$31	$6,102	$2.59	5,390	2.3	15	150.5	$7,712
Vault R30 to R38	413	$153	$6,256	$2.66	5,339	2.3	50	229.3	$7,884
Floor R30 to R38	411	$187	$6,443	$2.73	5,290	2.2	49	286.6	$8,094
Attic R49 ADV to R60 ADV	408	$416	$6,859	$2.91	5,198	2.2	91	343.9	$8,559
TOTAL							6,954	65.0	$8,559

NOTE:
UA: measure of resistance to heat loss
Btu/F: British thermal units per degree of Fahrenheit
ACH air changes per hour
ADV advanced framing
STD standard framing
DBW double wall construction

Table 7-29
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 1 - Seattle
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 1,344 SQUARE FEET									
Base Case UA	471	$0	$0	$0.00	10,176	7.6	0	0.0	$0
Insulated Door	460	$50	$50	$0.04	9,791	7.3	385	15.0	$85
Floor R11 to R19	441	$296	$346	$0.26	9,147	6.8	644	34.7	$416
Window R1.2 to R2.5	363	$849	$1,195	$0.89	6,539	4.9	2,608	37.3	$1,855
Wall R11 to R19	329	$732	$1,927	$1.43	5,439	4.0	1,099	50.4	$2,674
Wall R19 to R22	323	$165	$2,093	$1.56	5,253	3.9	186	67.2	$2,859
Vault R19 to R30	317	$186	$2,279	$1.70	5,065	3.8	187	75.1	$3,067
Floor R19 to R30	300	$497	$2,776	$2.07	4,567	3.4	498	75.5	$3,624
Attic R30 to R38 STD	296	$163	$2,940	$2.19	4,422	3.3	144	85.3	$3,806
Wall R22 to R26 ADV	272	$827	$3,766	$2.80	3,717	2.8	705	88.7	$4,731
Attic R38 STD to R49 ADV	261	$432	$4,198	$3.12	3,383	2.5	333	97.9	$5,215
Wall R26 ADV to R40 DBW	244	$803	$5,001	$3.72	2,909	2.2	474	128.2	$6,113
Vault R30 to R38	241	$227	$5,228	$3.89	2,829	2.1	79	215.7	$6,367
Floor R30 to R38	236	$538	$5,766	$4.29	2,679	2.0	150	269.6	$6,969
Attic R49 ADV to R60 ADV	233	$346	$6,111	$4.55	2,598	1.9	80	323.5	$7,355
TOTAL							7,578	65.6	$7,355

Table 7-29 (cont.)
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 1 - Seattle
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 1,848 SQUARE FEET									
Base Case UA	628	$0	$0	$0.00	14,853	8.0	0	0.0	$0
Insulated Door	617	$50	$50	$0.03	14,457	7.8	396	14.6	$85
Floor R11 to R19	606	$160	$211	$0.11	14,096	7.6	360	33.6	$265
Window R1.2 to R2.5	507	$1,074	$1,284	$0.69	10,660	5.8	3,435	35.8	$2,083
Wall R11 to R19	453	$1,172	$2,457	$1.33	8,822	4.8	1,838	48.2	$3,395
Wall R19 to R22	443	$265	$2,721	$1.47	8,509	4.6	312	64.1	$3,691
Slab R5 to R10	439	$108	$2,830	$1.53	8,383	4.5	126	64.9	$3,813
Vault R19 to R30	436	$108	$2,937	$1.59	8,267	4.5	115	70.5	$3,933
Floor R19 to R30	427	$269	$3,207	$1.74	7,980	4.3	287	70.9	$4,234
Attic R30 to R38 STD	422	$184	$3,390	$1.83	7,803	4.2	176	78.7	$4,440
Wall R22 to R26 ADV	384	$1,324	$4,714	$2.55	6,585	3.6	1,217	82.3	$5,921
Attic R38 STD to R49 ADV	371	$486	$5,200	$2.81	6,177	3.3	408	90.0	$6,465
Wall R26 ADV to R40 DBW	344	$1,286	$6,486	$3.51	5,363	2.9	813	119.6	$7,904
Slab R10 to R15	342	$101	$6,587	$3.56	5,305	2.9	58	131.1	$8,016
Vault R30 to R38	341	$131	$6,718	$3.64	5,255	2.8	49	199.7	$8,163
Floor R30 to R38	338	$291	$7,009	$3.79	5,167	2.8	88	249.7	$8,489
Attic R49 ADV to R60 ADV	335	$389	$7,398	$4.00	5,069	2.7	98	299.6	$8,924
TOTAL							9,784	61.7	$8,924

Table 7-29 (cont.)
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 1 - Seattle
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 2,356 SQUARE FEET									
Base Case UA	721	$0	$0	$0.00	16,136	6.8	0	0.0	$0
Insulated Door	715	$25	$25	$0.01	15,944	6.8	191	15.1	$43
Bsmt Wall R11 to R19 w/TB	695	$144	$170	$0.07	15,265	6.5	679	16.1	$204
Floor R11 to R19	689	$103	$273	$0.12	15,042	6.4	223	34.9	$320
Window R1.2 to R2.5	549	$1,513	$1,785	$0.76	10,391	4.4	4,650	37.3	$2,882
Wall R11 to R19	505	$937	$2,723	$1.16	8,997	3.8	1,394	50.9	$3,931
Wall R19 to R22	498	$212	$2,935	$1.25	8,759	3.7	238	67.2	$4,168
Slab R5 to R10	497	$34	$2,968	$1.26	8,721	3.7	37	68.4	$4,206
Vault R19 to R30	492	$126	$3,094	$1.31	8,593	3.6	128	74.2	$4,347
Floor R19 to R30	487	$173	$3,268	$1.39	8,417	3.6	175	74.6	$4,541
Attic R30 to R38 STD	481	$197	$3,464	$1.47	8,236	3.5	180	82.3	$4,760
Wall R22 to R26 ADV	451	$1,058	$4,523	$1.92	7,305	3.1	931	86.0	$5,945
Attic R38 STD to R49 ADV	437	$520	$5,043	$2.14	6,886	2.9	418	94.0	$6,527
Wall R26 ADV to R40 DBW	416	$1,028	$6,071	$2.58	6,255	2.7	631	123.2	$7,677
Slab R10 to R15	415	$31	$6,102	$2.59	6,237	2.6	17	135.2	$7,712
Vault R30 to R38	413	$153	$6,256	$2.66	6,181	2.6	56	206.0	$7,884
Floor R30 to R38	411	$187	$6,443	$2.73	6,126	2.6	55	257.4	$8,094
Attic R49 ADV to R60 ADV	408	$416	$6,859	$2.91	6,024	2.6	101	308.9	$8,559
TOTAL							7,899	57.2	$8,559

NOTE:
UA: measure of resistance to heat loss
Btu/F: British thermal units per degree of Fahrenheit
ACH air changes per hour
ADV advanced framing
STD standard framing
DBW double wall construction

Table 7-30
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 2 - Spokane
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 1,344 SQUARE FEET									
Base Case UA	471	$0	$0	$0.00	14,699	10.9	0	0.0	$0
Insulated Door	460	$50	$50	$0.04	14,200	10.6	498	11.6	$85
Floor R11 to R19	441	$296	$346	$0.26	13,364	9.9	835	26.8	$416
Window R1.2 to R2.5	363	$849	$1,195	$0.89	9,926	7.4	3,438	28.3	$1,855
Wall R11 to R19	329	$732	$1,927	$1.43	8,457	6.3	1,469	37.7	$2,674
Wall R19 to R22	323	$165	$2,093	$1.56	8,207	6.1	250	50.0	$2,859
Vault R19 to R30	317	$186	$2,279	$1.70	7,953	5.9	253	55.5	$3,067
Floor R19 to R30	300	$497	$2,776	$2.07	7,279	5.4	674	55.8	$3,624
Attic R30 to R38 STD	296	$163	$2,940	$2.19	7,081	5.3	197	62.4	$3,806
Wall R22 to R26 ADV	272	$827	$3,766	$2.80	6,112	4.5	968	64.6	$4,731
Attic R38 STD to R49 ADV	261	$432	$4,198	$3.12	5,647	4.2	464	70.3	$5,215
Wall R26 ADV to R40 DBW	244	$803	$5,001	$3.72	4,988	3.7	659	92.2	$6,113
Vault R30 to R38	241	$227	$5,228	$3.89	4,878	3.6	110	155.5	$6,367
Floor R30 to R38	236	$538	$5,766	$4.29	4,668	3.5	209	194.4	$6,969
Attic R49 ADV to R60 ADV	233	$346	$6,111	$4.55	4,556	3.4	112	233.2	$7,355
TOTAL							10,142	49.0	$7,355

Table 7-30 (cont.)
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 2 - Spokane
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 1,848 SQUARE FEET									
Base Case UA	628	$0	$0	$0.00	20,807	11.3	0	0.0	$0
Insulated Door	617	$50	$50	$0.03	20,302	11.0	504	11.4	$85
Floor R11 to R19	606	$160	$211	$0.11	19,843	10.7	458	26.4	$265
Window R1.2 to R2.5	507	$1,074	$1,284	$0.69	15,418	8.3	4,424	27.8	$2,083
Wall R11 to R19	453	$1,172	$2,457	$1.33	12,999	7.0	2,419	36.7	$3,395
Wall R19 to R22	443	$265	$2,721	$1.47	12,586	6.8	413	48.5	$3,691
Slab R5 to R10	439	$108	$2,830	$1.53	12,418	6.7	167	49.0	$3,813
Vault R19 to R30	436	$108	$2,937	$1.59	12,265	6.6	153	53.2	$3,933
Floor R19 to R30	427	$269	$3,207	$1.74	11,884	6.4	380	53.5	$4,234
Attic R30 to R38 STD	422	$184	$3,390	$1.83	11,651	6.3	233	59.4	$4,440
Wall R22 to R26 ADV	384	$1,324	$4,714	$2.55	10,033	5.4	1,617	61.9	$5,921
Attic R38 STD to R49 ADV	371	$486	$5,200	$2.81	9,486	5.1	547	67.2	$6,465
Wall R26 ADV to R40 DBW	344	$1,286	$6,486	$3.51	8,384	4.5	1,101	88.3	$7,904
Slab R10 to R15	342	$101	$6,587	$3.56	8,305	4.5	79	96.5	$8,016
Vault R30 to R38	341	$131	$6,718	$3.64	8,238	4.5	67	147.1	$8,163
Floor R30 to R38	338	$291	$7,009	$3.79	8,118	4.4	119	183.8	$8,489
Attic R49 ADV to R60 ADV	335	$389	$7,398	$4.00	7,985	4.3	133	220.6	$8,924
TOTAL							12,822	47.1	$8,924

Table 7-30 (cont.)
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 2 - Spokane
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 2,356 SQUARE FEET									
Base Case UA	721	$0	$0	$0.00	22,780	9.7	0	0.0	$0
Insulated Door	715	$25	$25	$0.01	22,530	9.6	249	11.5	$43
Bsmt Wall R11 to R19 w/TB	695	$144	$170	$0.07	21,643	9.2	886	12.3	$204
Floor R11 to R19	689	$103	$273	$0.12	21,351	9.1	292	26.7	$320
Window R1.2 to R2.5	549	$1,513	$1,785	$0.76	15,245	6.5	6,106	28.4	$2,882
Wall R11 to R19	505	$937	$2,723	$1.16	13,383	5.7	1,861	38.1	$3,931
Wall R19 to R22	498	$212	$2,935	$1.25	13,065	5.5	317	50.4	$4,168
Slab R5 to R10	497	$34	$2,968	$1.26	13,015	5.5	50	51.0	$4,206
Vault R19 to R30	492	$126	$3,094	$1.31	12,843	5.5	172	55.4	$4,347
Floor R19 to R30	487	$173	$3,268	$1.39	12,607	5.4	235	55.7	$4,541
Attic R30 to R38 STD	481	$197	$3,464	$1.47	12,365	5.2	242	61.4	$4,760
Wall R22 to R26 ADV	451	$1,058	$4,523	$1.92	11,102	4.7	1,262	63.4	$5,945
Attic R38 STD to R49 ADV	437	$520	$5,043	$2.14	10,531	4.5	571	68.9	$6,527
Wall R26 ADV to R40 DBW	416	$1,028	$6,071	$2.58	9,666	4.1	864	90.0	$7,677
Slab R10 to R15	415	$31	$6,102	$2.59	9,642	4.1	24	98.1	$7,712
Vault R30 to R38	413	$153	$6,256	$2.66	9,564	4.1	77	149.5	$7,884
Floor R30 to R38	411	$187	$6,443	$2.73	9,489	4.0	75	186.9	$8,094
Attic R49 ADV to R60 ADV	408	$416	$6,859	$2.91	9,348	4.0	140	224.3	$8,559
TOTAL							10,414	43.1	$8,559

NOTE:
UA: measure of resistance to heat loss
Btu/F: British thermal units per degree of Fahrenheit
ACH air changes per hour
ADV advanced framing
STD standard framing
DBW double wall construction

Table 7-31
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 3 - Missoula
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 1,344 SQUARE FEET									
Base Case UA	471	$0	$0	$0.00	17,269	12.8	0	0.0	$0
Insulated Door	460	$50	$50	$0.04	16,691	12.4	577	10.0	$85
Floor R11 to R19	441	$296	$346	$0.26	15,724	11.7	967	23.1	$416
Window R1.2 to R2.5	363	$849	$1,195	$0.89	11,762	8.8	3,961	24.6	$1,855
Wall R11 to R19	329	$732	$1,927	$1.43	10,063	7.5	1,699	32.6	$2,674
Wall R19 to R22	323	$165	$2,093	$1.56	9,773	7.3	289	43.2	$2,859
Vault R19 to R30	317	$186	$2,279	$1.70	9,478	7.1	294	47.9	$3,067
Floor R19 to R30	300	$497	$2,776	$2.07	8,696	6.5	781	48.1	$3,624
Attic R30 to R38 STD	296	$163	$2,940	$2.19	8,467	6.3	229	53.9	$3,806
Wall R22 to R26 ADV	272	$827	$3,766	$2.80	7,346	5.5	1,121	55.8	$4,731
Attic R38 STD to R49 ADV	261	$432	$4,198	$3.12	6,809	5.1	536	60.9	$5,215
Wall R26 ADV to R40 DBW	244	$803	$5,001	$3.72	6,047	4.5	762	79.7	$6,113
Vault R30 to R38	241	$227	$5,228	$3.89	5,918	4.4	128	133.8	$6,367
Floor R30 to R38	236	$538	$5,766	$4.29	5,675	4.2	243	167.3	$6,969
Attic R49 ADV to R60 ADV	233	$346	$6,111	$4.55	5,545	4.1	130	200.7	$7,355
TOTAL							11,724	42.4	$7,355

Table 7-31 (cont.)
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 3 - Missoula
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 1,848 SQUARE FEET									
Base Case UA	628	$0	$0	$0.00	24,388	13.2	0	0.0	$0
Insulated Door	617	$50	$50	$0.03	23,800	12.9	588	9.8	$85
Floor R11 to R19	606	$160	$211	$0.11	23,265	12.6	534	22.7	$265
Window R1.2 to R2.5	507	$1,074	$1,284	$0.69	18,141	9.8	5,124	24.0	$2,083
Wall R11 to R19	453	$1,172	$2,457	$1.33	15,355	8.3	2,786	31.8	$3,395
Wall R19 to R22	443	$265	$2,721	$1.47	14,879	8.1	475	42.1	$3,691
Slab R5 to R10	439	$108	$2,830	$1.53	14,686	7.9	192	42.5	$3,813
Vault R19 to R30	436	$108	$2,937	$1.59	14,509	7.9	176	46.2	$3,933
Floor R19 to R30	427	$269	$3,207	$1.74	14,070	7.6	438	46.4	$4,234
Attic R30 to R38 STD	422	$184	$3,390	$1.83	13,801	7.5	269	51.5	$4,440
Wall R22 to R26 ADV	384	$1,324	$4,714	$2.55	11,930	6.5	1,870	53.6	$5,921
Attic R38 STD to R49 ADV	371	$486	$5,200	$2.81	11,298	6.1	632	58.1	$6,465
Wall R26 ADV to R40 DBW	344	$1,286	$6,486	$3.51	10,024	5.4	1,274	76.4	$7,904
Slab R10 to R15	342	$101	$6,587	$3.56	9,932	5.4	91	83.3	$8,016
Vault R30 to R38	341	$131	$6,718	$3.64	9,854	5.3	78	127.0	$8,163
Floor R30 to R38	338	$291	$7,009	$3.79	9,715	5.3	138	158.8	$8,489
Attic R49 ADV to R60 ADV	335	$389	$7,398	$4.00	9,561	5.2	154	190.5	$8,924
TOTAL							14,826	40.7	$8,924

Table 7-31 (cont.)
Costs and Savings from Conservation Measures in New Single-family Houses
Zone 3 - Missoula
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 2,356 SQUARE FEET									
Base Case UA	721	$0	$0	$0.00	26,728	11.3	0	0.0	$0
Insulated Door	715	$25	$25	$0.01	26,439	11.2	288	10.0	$43
Bsmt Wall R11 to R19 w/TB	695	$144	$170	$0.07	25,417	10.8	1,021	10.7	$204
Floor R11 to R19	689	$103	$273	$0.12	25,082	10.6	335	23.2	$320
Window R1.2 to R2.5	549	$1,513	$1,785	$0.76	18,049	7.7	7,033	24.6	$2,882
Wall R11 to R19	505	$937	$2,723	$1.16	15,927	6.8	2,121	33.4	$3,931
Wall R19 to R22	498	$212	$2,935	$1.25	15,564	6.6	363	44.1	$4,168
Slab R5 to R10	497	$34	$2,968	$1.26	15,507	6.6	57	44.8	$4,206
Vault R19 to R30	492	$126	$3,094	$1.31	15,311	6.5	196	48.6	$4,347
Floor R19 to R30	487	$173	$3,268	$1.39	15,042	6.4	268	48.9	$4,541
Attic R30 to R38 STD	481	$197	$3,464	$1.47	14,767	6.3	275	53.9	$4,760
Wall R22 to R26 ADV	451	$1,058	$4,523	$1.92	13,335	5.7	1,431	56.0	$5,945
Attic R38 STD to R49 ADV	437	$520	$5,043	$2.14	12,685	5.4	650	60.5	$6,527
Wall R26 ADV to R40 DBW	416	$1,028	$6,071	$2.58	11,695	5.0	989	78.6	$7,677
Slab R10 to R15	415	$31	$6,102	$2.59	11,667	5.0	27	85.4	$7,712
Vault R30 to R38	413	$153	$6,256	$2.66	11,578	4.9	89	130.1	$7,884
Floor R30 to R38	411	$187	$6,443	$2.73	11,491	4.9	87	162.6	$8,094
Attic R49 ADV to R60 ADV	408	$416	$6,859	$2.91	11,329	4.8	161	195.1	$8,559
TOTAL							11,961	37.6	$8,559

NOTE:
UA: measure of resistance to heat loss
Btu/F: British thermal units per degree of Fahrenheit
ACH air changes per hour
ADV advanced framing
STD standard framing
DBW double wall construction

Table 7-32
Costs and Savings from Conservation Measures in New Multifamily Residences
Dwelling Unit Size 840 Square Feet
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
ZONE 1 - PORTLAND									
Base Case	2,420	$0	$0	$0.00	2,855	3.4	0	0.0	$0
Insulated Door	2,384	$13	$13	$0.02	2,774	3.3	81	18.6	$22
Window R1.2 to R2.5	1,871	$464	$477	$0.57	1,629	1.9	1,144	46.4	$808
Floor R11 to R19	1,818	$70	$547	$0.65	1,525	1.8	104	50.9	$886
Wall R11 to R19	1,668	$266	$813	$0.97	1,222	1.5	302	66.6	$1,184
Wall R19 to R22	1,642	$60	$873	$1.04	1,171	1.4	51	89.2	$1,252
Floor R19 to R30	1,597	$118	$991	$1.18	1,080	1.3	91	97.9	$1,383
Attic R30 to R38	1,577	$54	$1,046	$1.24	1,040	1.2	39	102.9	$1,444
Wall R22 to R26 ADV	1,474	$301	$1,346	$1.60	830	1.0	210	108.3	$1,781
Attic R38 to R49 ADV	1,428	$143	$1,490	$1.77	751	0.9	79	136.8	$1,941
Wall R26 ADV to R40 DBW	1,356	$292	$1,782	$2.12	628	0.7	122	179.9	$2,268
Floor R30 to R38	1,341	$127	$1,909	$2.27	603	0.7	25	382.1	$2,411
Attic R49 ADV to R60 ADV	1,329	$115	$2,024	$2.41	584	0.7	18	458.5	$2,539
TOTAL							2,271	75.6	$2,539
ZONE 1 - SEATTLE									
Base Case	2,420	$0	$0	$0.00	3,276	3.9	0	0.0	$0
Insulated Door	2,384	$13	$13	$0.02	3,184	3.8	92	16.4	$22
Window R1.2 to R2.5	1,871	$464	$477	$0.57	1,893	2.3	1,290	41.1	$808
Floor R11 to R19	1,818	$70	$547	$0.65	1,774	2.1	119	44.6	$886
Wall R11 to R19	1,668	$266	$813	$0.97	1,429	1.7	344	58.5	$1,184
Wall R19 to R22	1,642	$60	$873	$1.04	1,371	1.6	58	77.6	$1,252
Floor R19 to R30	1,597	$118	$991	$1.18	1,266	1.5	104	85.2	$1,383
Attic R30 to R38	1,577	$54	$1,046	$1.24	1,221	1.5	45	90.1	$1,444
Wall R22 to R26 ADV	1,474	$301	$1,346	$1.60	980	1.2	240	94.6	$1,781
Attic R38 to R49 ADV	1,428	$143	$1,490	$1.77	889	1.1	91	118.8	$1,941
Wall R26 ADV to R40 DBW	1,356	$292	$1,782	$2.12	748	0.9	140	157.3	$2,268
Floor R30 to R38	1,341	$127	$1,909	$2.27	719	0.9	29	332.4	$2,411
Attic R49 ADV to R60 ADV	1,329	$115	$2,024	$2.41	697	0.8	21	398.8	$2,539
TOTAL							2,578	66.6	$2,539

Table 7-32 (cont.)
Costs and Savings from Conservation Measures in New Multifamily Residences
Dwelling Unit Size 840 Square Feet
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	Annual Use ($/sq ft)	Annual Use (kWh/yr)	Annual Use (kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
ZONE 2 - SPOKANE									
Base Case	2,420	$0	$0	$0.00	5,157	6.1	0	0.0	$0
Insulated Door	2,384	$13	$13	$0.02	5,032	6.0	124	12.2	$22
Window R1.2 to R2.5	1,871	$464	$477	$0.57	3,254	3.9	1,778	29.9	$808
Floor R11 to R19	1,818	$70	$547	$0.65	3,092	3.7	161	32.8	$886
Wall R11 to R19	1,668	$266	$813	$0.97	2,615	3.1	476	42.3	$1,184
Wall R19 to R22	1,642	$60	$873	$1.04	2,534	3.0	81	56.0	$1,252
Floor R19 to R30	1,597	$118	$991	$1.18	2,389	2.8	145	61.3	$1,383
Attic R30 to R38	1,577	$54	$1,046	$1.24	2,322	2.8	66	61.5	$1,444
Wall R22 to R26 ADV	1,474	$301	$1,346	$1.60	1,970	2.3	352	64.6	$1,781
Attic R38 to R49 ADV	1,428	$143	$1,490	$1.77	1,834	2.2	136	79.7	$1,941
Wall R26 ADV to R40 DBW	1,356	$292	$1,782	$2.12	1,616	1.9	217	101.8	$2,268
Floor R30 to R38	1,341	$127	$1,909	$2.27	1,565	1.9	51	187.4	$2,411
Attic R49 ADV to R60 ADV	1,329	$115	$2,024	$2.41	1,526	1.8	38	224.8	$2,539
TOTAL							3,630	47.3	$2,539
ZONE 3 - MISSOULA									
Base Case	2,420	$0	$0	$0.00	6,145	7.3	0	0.0	$0
Insulated Door	2,384	$13	$13	$0.02	6,000	7.1	144	10.5	$22
Window R1.2 to R2.5	1,871	$464	$477	$0.57	3,935	4.7	2,064	25.7	$808
Floor R11 to R19	1,818	$70	$547	$0.65	3,742	4.5	192	27.6	$886
Wall R11 to R19	1,668	$266	$813	$0.97	3,182	3.8	560	36.0	$1,184
Wall R19 to R22	1,642	$60	$873	$1.04	3,086	3.7	95	47.4	$1,252
Floor R19 to R30	1,597	$118	$991	$1.18	2,914	3.5	171	51.9	$1,383
Attic R30 to R38	1,577	$54	$1,046	$1.24	2,837	3.4	77	52.9	$1,444
Wall R22 to R26 ADV	1,474	$301	$1,346	$1.60	2,427	2.9	410	55.5	$1,781
Attic R38 to R49 ADV	1,428	$143	$1,490	$1.77	2,265	2.7	161	67.1	$1,941
Wall R26 ADV to R40 DBW	1,356	$292	$1,782	$2.12	2,010	2.4	255	86.7	$2,268
Floor R30 to R38	1,341	$127	$1,909	$2.27	1,954	2.3	56	171.2	$2,411
Attic R49 ADV to R60 ADV	1,329	$115	$2,024	$2.41	1,911	2.3	42	205.5	$2,539
TOTAL							4,233	40.6	$2,539

NOTE:
UA: measure of resistance to heat loss
Btu/F: British thermal units per degree of Fahrenheit
ACH air changes per hour
ADV advanced framing
TD [illegible]

Table 7-33

Costs and Savings from Conservation Measures in New Manufactured Homes

Zone 1 - Portland

1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	Annual Use (kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 924 SQUARE FEET									
Base Case	395	$0	$0	$0.00	9,159	9.9	0	0.0	$0
Floor R11 to R22	373	$249	$249	$0.27	8,372	9.1	787	28.5	$279
Floor R22 to R33	357	$249	$499	$0.54	7,818	8.5	554	40.4	$558
Insulated Door	350	$87	$586	$0.63	7,565	8.2	253	40.7	$686
Wall R11 to R19	317	$555	$1,142	$1.24	6,431	7.0	1,133	44.0	$1,308
Attic R14 to R22	313	$83	$1,224	$1.33	6,297	6.8	133	55.6	$1,401
Floor R33 to R44	303	$249	$1,474	$1.60	5,957	6.4	339	66.0	$1,680
Window R1.2 to R2.5	255	$967	$2,441	$2.64	4,378	4.7	1,579	72.4	$3,103
Wall R19 to R22	251	$115	$2,557	$2.77	4,241	4.6	136	75.6	$3,232
Vault R14 to R22	247	$131	$2,688	$2.91	4,087	4.4	153	76.6	$3,379
Vault R22 to R33	242	$160	$2,847	$3.08	3,933	4.3	153	93.5	$3,557
Attic R22 to R38	237	$166	$3,013	$3.26	3,790	4.1	143	104.1	$3,743
Vault R33 to R38	236	$84	$3,097	$3.35	3,756	4.1	34	220.7	$3,837
Attic R38 to R49	235	$130	$3,227	$3.49	3,704	4.0	52	224.2	$3,982
TOTAL							5,455	58.6	$3,982
HOUSE SIZE 1,568 SQUARE FEET									
Base Case	591	$0	$0	$0.00	15,652	10.0	0	0.0	$0
Floor R11 to R22	553	$423	$423	$0.27	14,233	9.1	1,418	26.8	$474
Floor R22 to R33	527	$423	$847	$0.54	13,230	8.4	1,003	37.9	$947
Insulated Door	519	$92	$939	$0.60	12,946	8.3	284	38.2	$1,083
Wall R11 to R19	487	$544	$1,482	$0.95	11,754	7.5	1,192	41.0	$1,691
Attic R14 to R22	478	$188	$1,670	$1.07	11,415	7.3	338	49.9	$1,901
Floor R33 to R44	461	$423	$2,094	$1.34	10,774	6.9	641	59.4	$2,375
Window R1.2 to R2.5	381	$1,635	$3,728	$2.38	7,910	5.0	2,864	67.4	$4,780
Wall R19 to R22	377	$113	$3,841	$2.45	7,768	5.0	142	71.4	$4,906
Vault R14 to R22	371	$165	$4,006	$2.56	7,562	4.8	206	71.9	$5,091
Vault R22 to R33	365	$201	$4,208	$2.68	7,355	4.7	206	87.7	$5,316
Attic R22 to R38	355	$377	$4,584	$2.92	7,008	4.5	347	97.6	$5,738
Vault R33 to R38	353	$106	$4,690	$2.99	6,962	4.4	45	207.0	$5,856
Attic R38 to R49	350	$295	$4,985	$3.18	6,836	4.4	126	210.2	$6,186
TOTAL							7,883	56.4	$6,186

NOTE:

- UA: measure of resistance to heat loss
- Btu/F: British thermal units per degree of Fahrenheit
- ACH air changes per hour
- ADV advanced framing
- STD standard framing
- DBW double wall construction

Table 7-34
Costs and Savings from Conservation Measures in New Manufactured Homes
Zone 1 - Seattle
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 924 SQUARE FEET									
Base Case	395	$0	$0	$0.00	10,483	11.3	0	0.0	$0
Floor R11 to R22	373	$249	$249	$0.27	9,581	10.4	902	24.9	$279
Floor R22 to R33	357	$249	$499	$0.54	8,946	9.7	634	35.3	$558
Insulated Door	350	$87	$586	$0.63	8,657	9.4	289	35.6	$686
Wall R11 to R19	317	$555	$1,142	$1.24	7,364	8.0	1,292	38.6	$1,308
Attic R14 to R22	313	$83	$1,224	$1.33	7,211	7.8	152	48.7	$1,401
Floor R33 to R44	303	$249	$1,474	$1.60	6,823	7.4	388	57.7	$1,680
Window R1.2 to R2.5	255	$967	$2,441	$2.64	5,035	5.5	1,787	64.0	$3,103
Wall R19 to R22	251	$115	$2,557	$2.77	4,882	5.3	153	67.3	$3,232
Vault R14 to R22	247	$131	$2,688	$2.91	4,709	5.1	172	68.2	$3,379
Vault R22 to R33	242	$160	$2,847	$3.08	4,537	4.9	172	83.3	$3,557
Attic R22 to R38	237	$166	$3,013	$3.26	4,376	4.7	160	92.8	$3,743
Vault R33 to R38	236	$84	$3,097	$3.35	4,337	4.7	38	196.7	$3,837
Attic R38 to R49	235	$130	$3,227	$3.49	4,279	4.6	58	199.8	$3,982
TOTAL							6,204	51.6	$3,982
HOUSE SIZE 1,568 SQUARE FEET									
Base Case	591	$0	$0	$0.00	17,908	11.4	0	0.0	$0
Floor R11 to R22	553	$423	$423	$0.27	16,284	10.4	1,623	23.4	$474
Floor R22 to R33	527	$423	$847	$0.54	15,136	9.7	1,148	33.1	$947
Insulated Door	519	$92	$939	$0.60	14,811	9.4	324	33.5	$1,083
Wall R11 to R19	487	$544	$1,482	$0.95	13,449	8.6	1,362	35.9	$1,691
Attic R14 to R22	478	$188	$1,670	$1.07	13,061	8.3	387	43.6	$1,901
Floor R33 to R44	461	$423	$2,094	$1.34	12,328	7.9	732	51.9	$2,375
Window R1.2 to R2.5	381	$1,635	$3,728	$2.38	9,061	5.8	3,267	59.1	$4,780
Wall R19 to R22	377	$113	$3,841	$2.45	8,898	5.7	162	62.5	$4,906
Vault R14 to R22	371	$165	$4,006	$2.56	8,664	5.5	233	63.4	$5,091
Vault R22 to R33	365	$201	$4,208	$2.68	8,431	5.4	233	77.5	$5,316
Attic R22 to R38	355	$377	$4,584	$2.92	8,039	5.1	392	86.3	$5,738
Vault R33 to R38	353	$106	$4,690	$2.99	7,987	5.1	51	183.0	$5,856
Attic R38 to R49	350	$295	$4,985	$3.18	7,844	5.0	142	185.9	$6,186
TOTAL							9,009	49.4	$6,186

NOTE: UA: measure of resistance to heat loss
Btu/F: British thermal units per degree of Fahrenheit
ACH: [illegible]

Table 7-35
Costs and Savings from Conservation Measures in New Manufactured Homes
Zone 2 - Spokane
1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	Annual Use (kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 924 SQUARE FEET									
Base Case	395	$0	$0	$0.00	15,341	16.6	0	0.0	$0
Floor R11 to R22	373	$249	$249	$0.27	14,187	15.4	1,153	19.4	$279
Floor R22 to R33	357	$249	$499	$0.54	13,366	14.5	821	27.3	$558
Insulated Door	350	$87	$586	$0.63	12,991	14.1	374	27.5	$686
Wall R11 to R19	317	$555	$1,142	$1.24	11,304	12.2	1,686	29.6	$1,308
Attic R14 to R22	313	$83	$1,224	$1.33	11,104	12.0	200	37.2	$1,401
Floor R33 to R44	303	$249	$1,474	$1.60	10,595	11.5	508	44.1	$1,680
Window R1.2 to R2.5	255	$967	$2,441	$2.64	8,222	8.9	2,373	48.2	$3,103
Wall R19 to R22	251	$115	$2,557	$2.77	8,018	8.7	204	50.7	$3,232
Vault R14 to R22	247	$131	$2,688	$2.91	7,786	8.4	231	50.8	$3,379
Vault R22 to R33	242	$160	$2,847	$3.08	7,553	8.2	232	61.7	$3,557
Attic R22 to R38	237	$166	$3,013	$3.26	7,335	7.9	217	68.7	$3,743
Vault R33 to R38	236	$84	$3,097	$3.35	7,284	7.9	51	145.6	$3,837
Attic R38 to R49	235	$130	$3,227	$3.49	7,205	7.8	79	147.8	$3,982
TOTAL							8,136	39.3	$3,982
HOUSE SIZE 1,568 SQUARE FEET									
Base Case	591	$0	$0	$0.00	25,134	16.0	0	0.0	$0
Floor R11 to R22	553	$423	$423	$0.27	23,075	14.7	2,058	18.5	$474
Floor R22 to R33	527	$423	$847	$0.54	21,614	13.8	1,461	26.0	$947
Insulated Door	519	$92	$939	$0.60	21,198	13.5	415	26.1	$1,083
Wall R11 to R19	487	$544	$1,482	$0.95	19,446	12.4	1,752	27.9	$1,691
Attic R14 to R22	478	$188	$1,670	$1.07	18,945	12.1	500	33.7	$1,901
Floor R33 to R44	461	$423	$2,094	$1.34	17,994	11.5	951	40.0	$2,375
Window R1.2 to R2.5	381	$1,635	$3,728	$2.38	13,714	8.7	4,279	45.1	$4,780
Wall R19 to R22	377	$113	$3,841	$2.45	13,502	8.6	212	47.7	$4,906
Vault R14 to R22	371	$165	$4,006	$2.56	13,194	8.4	307	48.2	$5,091
Vault R22 to R33	365	$201	$4,208	$2.68	12,886	8.2	307	58.8	$5,316
Attic R22 to R38	355	$377	$4,584	$2.92	12,368	7.9	517	65.4	$5,738
Vault R33 to R38	353	$106	$4,690	$2.99	12,300	7.8	68	138.7	$5,856
Attic R38 to R49	350	$295	$4,985	$3.18	12,111	7.7	188	140.9	$6,186
TOTAL							11,632	38.2	$6,186

NOTE: UA: measure of resistance to heat loss
Btu/F: British thermal units per degree of Fahrenheit
ACH air changes per hour

Table 7-36

Costs and Savings from Conservation Measures in New Manufactured Homes

Zone 3 - Missoula

1990 Dollars, 0.35 ACH Assumed as Current Practice

Conservation Measure	UA Btu/F	Cost Incremental	Cost Cumulative	($/sq ft)	Annual Use (kWh/yr)	(kWh/sq ft)	Annual Savings (kWh/yr)	Levelized Cost (mills/kWh)	Present Value ($)
HOUSE SIZE 924 SQUARE FEET									
Base Case	395	$0	$0	$0.00	18,040	19.5	0	0.0	$0
Floor R11 to R22	373	$249	$249	$0.27	16,696	18.1	1,343	16.7	$279
Floor R22 to R33	357	$249	$499	$0.54	15,740	17.0	955	23.5	$558
Insulated Door	350	$87	$586	$0.63	15,305	16.6	435	23.6	$686
Wall R11 to R19	317	$555	$1,142	$1.24	13,352	14.5	1,952	25.6	$1,308
Attic R14 to R22	313	$83	$1,224	$1.33	13,122	14.2	230	32.3	$1,401
Floor R33 to R44	303	$249	$1,474	$1.60	12,537	13.6	585	38.3	$1,680
Window R1.2 to R2.5	255	$967	$2,441	$2.64	9,801	10.6	2,735	41.8	$3,103
Wall R19 to R22	251	$115	$2,557	$2.77	9,565	10.4	236	43.9	$3,232
Vault R14 to R22	247	$131	$2,688	$2.91	9,298	10.1	267	44.0	$3,379
Vault R22 to R33	242	$160	$2,847	$3.08	9,029	9.8	268	53.4	$3,557
Attic R22 to R38	237	$166	$3,013	$3.26	8,778	9.5	250	59.5	$3,743
Vault R33 to R38	236	$84	$3,097	$3.35	8,718	9.4	59	126.1	$3,837
Attic R38 to R49	235	$130	$3,227	$3.49	8,627	9.3	91	128.1	$3,982
TOTAL							9,412	34.0	$3,982
HOUSE SIZE 1,568 SQUARE FEET									
Base Case	591	$0	$0	$0.00	29,467	18.8	0	0.0	$0
Floor R11 to R22	553	$423	$423	$0.27	27,069	17.3	2,398	15.9	$474
Floor R22 to R33	527	$423	$847	$0.54	25,368	16.2	1,701	22.4	$947
Insulated Door	519	$92	$939	$0.60	24,886	15.9	481	22.6	$1,083
Wall R11 to R19	487	$544	$1,482	$0.95	22,861	14.6	2,024	24.1	$1,691
Attic R14 to R22	478	$188	$1,670	$1.07	22,283	14.2	578	29.2	$1,901
Floor R33 to R44	461	$423	$2,094	$1.34	21,185	13.5	1,097	34.7	$2,375
Window R1.2 to R2.5	381	$1,635	$3,728	$2.38	16,267	10.4	4,918	39.3	$4,780
Wall R19 to R22	377	$113	$3,841	$2.45	16,022	10.2	244	41.4	$4,906
Vault R14 to R22	371	$165	$4,006	$2.56	15,667	10.0	355	41.7	$5,091
Vault R22 to R33	365	$201	$4,208	$2.68	15,311	9.8	355	50.8	$5,316
Attic R22 to R38	355	$377	$4,584	$2.92	14,712	9.4	598	56.6	$5,738
Vault R33 to R38	353	$106	$4,690	$2.99	14,633	9.3	79	120.0	$5,856
Attic R38 to R49	350	$295	$4,985	$3.18	14,415	9.2	217	121.9	$6,186
TOTAL							13,445	33.0	$6,186

NOTE: UA: measure of resistance to heat loss
Btu/F: British thermal units per degree of Fahrenheit
ACH air changes per hour

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 to achieve a much smaller average size for new single-family houses (i.e., 1,400 square feet of floor area) than had they been selected on the basis of the more conventional definition of a single-family home (one- and two-family dwellings) used to establish the model conservation standards. The average size of typical new one- and two-family dwellings recently constructed in the region is between 1,600 and 1,800 square feet of floor area.

Once each building design's weight had been established, the average savings by climate type was calculated for all designs. These savings were then 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 7-37 shows the weight assigned each building design and climate type. Tables 7-38 through 7-40 show the weighted average use, cost and savings available from new single-family, multifamily and manufactured houses at levelized costs less than 20 cents per kilowatt-hour (equivalent to 200 mills per kilowatt-hour).

Table 7-37
Weighting Factors Used to Aggregate
Individual Building and Location Savings to Region

Building Type	Weight	Mean Size
Single-family Homes(less than five-plex)		
1,344 square feet - Single Story	90%	
1,848 square feet - Two Story	9%	
2,356 square feet - One Story w/Basement	1%	
		1,400 square feet
Multifamily Homes (five-plex and larger)		
12-Unit	100%	840 square feet/unit[b]
Manufactured Homes		
924 Single Wide	15%	
1,568 Double Wide	85%	1,445 square feet[b]

Zone	HDD[a]	Weight
Single- and Multifamily Homes		
Zone 1 - Portland	4,786	28%
Zone 1 - Seattle	5,444	52%
Zone 2 - Spokane	6,818	16%
Zone 3 - Missoula	7,773	4%
Region	5,572	
Manufactured Homes		
Zone 1 - Portland	4,786	20%
Zone 1 - Seattle	5,444	44%
Zone 2 - Spokane	6,818	27%
Zone 3 - Missoula	5,372	9%
Region	5,892	

[a] HDD - Heating degree days at 65°F based on Typical Meteorological Year (TMY) weather tape used to estimate savings. TMY weather tapes vary slightly from published long-term averages.

[b] Table 7-42 shows the mean size of new units used in the forecast model. The unit sizes shown here were scaled to match those assumed in the forecast model.

Table 7-38
Regionally Weighted Savings and Costs in New Single-family Dwellings

Levelized Cost (mills/kWh)	Capital Cost Total	Capital Cost ($/sq ft)	Annual Use (kWh/yr)	Annual Use (kWh/sq ft)	Relative Use (% of base)	Annual Savings (kWh/yr)	Present Value	Average R-Value
0	$0	0	11,326	8.1	100	0	$0	8.49
10	$2	$0.00	11,303	8.1	99	23	$17	8.53
20	$50	$0.04	10,929	7.8	96	396	$97	8.70
30	$278	$0.20	10,045	7.2	90	1,280	$491	9.20
40	$1,107	$0.80	7,860	5.6	70	3,466	$1,717	10.78
50	$1,410	$1.02	7,111	5.0	63	4,214	$2,232	11.44
60	$2,174	$1.56	5,996	4.3	53	5,329	$2,975	12.41
70	$2,520	$1.81	5,592	4.0	50	5,733	$3,393	12.91
80	$2,934	$2.11	5,175	3.7	46	6,150	$3,848	13.45
90	$3,723	$2.69	4,489	3.2	39	6,836	$4,727	14.52
100	$4,248	$3.07	4,076	2.9	35	7,249	$5,297	15.22
110	$4,390	$3.17	3,975	2.8	34	7,350	$5,455	15.41
120	$4,390	$3.17	3,975	2.8	34	7,350	$5,532	15.50
130	$4,808	$3.47	3,719	2.6	32	7,606	$6,077	16.11
140	$4,808	$3.47	3,719	2.6	32	7,606	$6,154	16.20
150	$5,078	$3.66	3,569	2.5	30	7,756	$6,225	16.25
160	$5,098	$3.68	3,559	2.5	30	7,766	$6,259	16.28
170	$5,098	$3.68	3,559	2.5	30	7,766	$6,270	16.28
180	$5,098	$3.68	3,559	2.5	30	7,766	$6,281	16.29
190	$5,179	$3.74	3,526	2.5	30	7,799	$6,382	16.36
200	$5,194	$3.75	3,520	2.5	30	7,805	$6,410	16.38

Table 7-39

Regionally Weighted Savings and Costs in New Multifamily Dwellings

Levelized Cost (mills/kWh)	Capital Cost Total	Capital Cost ($/sq ft)	Annual Use (kWh/yr)	Annual Use (kWh/sq ft)	Relative Use (% of base)	Annual Savings (kWh/yr)	Present Value	Average R-Value
0	$0	$0.00	3,574	4.3	100	0	$0	5.81
10	$0	$0.00	3,574	4.3	100	0	$0	5.81
20	$13	$0.02	3,477	4.1	97	96	$22	5.90
30	$109	$0.13	3,102	3.7	90	471	$183	6.23
40	$131	$0.16	3,054	3.6	89	519	$207	6.30
50	$583	$0.69	1,920	2.3	54	1,653	$926	7.82
60	$770	$0.92	1,673	2.0	47	1,900	$1,135	8.30
70	$926	$1.10	1,491	1.8	42	2,082	$1,310	8.67
80	$980	$1.17	1,439	1.7	40	2,134	$1,371	8.78
90	$1,070	$1.27	1,360	1.6	38	2,213	$1,471	8.97
100	$1,287	$1.53	1,186	1.4	33	2,387	$1,715	9.42
110	$1,433	$1.71	1,081	1.3	30	2,492	$1,878	9.71
120	$1,508	$1.80	1,034	1.2	28	2,540	$1,962	9.87
130	$1,508	$1.80	1,034	1.2	28	2,540	$1,962	9.87
140	$1,548	$1.84	1,011	1.2	27	2,562	$2,006	9.95
150	$1,548	$1.84	1,011	1.2	27	2,562	$2,006	9.95
160	$1,700	$2.02	938	1.1	25	2,635	$2,176	10.22
170	$1,700	$2.02	938	1.1	25	2,635	$2,176	10.22
180	$1,787	$2.13	902	1.1	24	2,672	$2,274	10.38
190	$1,807	$2.15	893	1.1	24	2,680	$2,296	10.39
200	$1,807	$2.15	893	1.1	24	2,680	$2,296	10.39

Table 7-40

Regionally Weighted Savings and Costs in New Manufactured Dwellings

Levelized Cost	Capital Cost		Annual Use		Relative Use	Annual Savings	Present	Average
(mills/kWh)	Total	($/sq ft)	(kWh/yr)	(kWh/sq ft)	(% of base)	(kWh/yr)	Value	R-Value
0	$0	$0.00	12,328	8.4	100.0	0	$0	7.47
10	$0	$0.00	12,328	8.4	100.0	0	$0	7.47
20	$143	$0.10	11,866	8.0	96.2	462	$161	7.65
30	$787	$0.54	10,394	7.0	84.3	1,934	$892	8.39
40	$1,561	$1.07	9,061	6.1	73.5	3,267	$1,828	9.24
50	$2,368	$1.62	7,843	5.3	63.6	4,485	$2,877	10.18
60	$3,357	$2.29	6,648	4.5	53.9	5,680	$4,222	11.34
70	$3,958	$2.70	6,038	4.1	49.0	6,290	$5,003	12.04
80	$4,099	$2.80	5,931	4.0	48.1	6,397	$5,160	12.19
90	$4,290	$2.93	5,804	3.9	47.1	6,524	$5,375	12.37
100	$4,360	$2.97	5,764	3.9	46.8	6,564	$5,452	12.44
110	$4,360	$2.97	5,764	3.9	46.8	6,564	$5,452	12.44
120	$4,360	$2.97	5,764	3.9	46.8	6,564	$5,452	12.44
130	$4,393	$2.99	5,748	3.9	46.6	6,580	$5,490	12.45
140	$4,421	$3.01	5,736	3.9	46.5	6,592	$5,521	12.46
150	$4,494	$3.06	5,706	3.9	46.3	6,621	$5,603	12.50
160	$4,494	$3.06	5,706	3.9	46.3	6,621	$5,603	12.50
170	$4,494	$3.06	5,706	3.9	46.3	6,621	$5,603	12.50
180	$4,494	$3.06	5,706	3.9	46.3	6,621	$5,603	12.50
190	$4,659	$3.17	5,656	3.8	45.9	6,672	$5,787	12.57
200	$4,659	$3.17	5,656	3.8	45.9	6,672	$5,787	12.57

C:MG/DFT90.AA9 Tables 7-38, 7-39 and 7-40

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 can realistically be achieved, two adjustments must be made to the engineering savings estimates. First, to ensure consistency with the Council's load forecast, the conservation resource based on engineering estimates of current space heating energy use must be adjusted or scaled to account for the forecasting model's estimate of current space heating use. The forecast model estimates shown here assume higher consumer amenity levels in the year 2010 than are present today. This is consistent with the Council's forecast, which projects that consumers will increase their amenity levels by the year 2010. This results in higher space heating use than would otherwise be shown in Table 7-41.

Table 7-41 compares the average space heating energy use by dwelling type for houses built to 1990 practice, as estimated by the Council's forecasting model for the year 2010 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 7-41
Forecast Model vs. Engineering Estimate for Space Heating in New Dwellings, Regional Average Use in 2010

Building Type	Forecasting Model (kWh/yr.)	(kWh/sq. ft./yr.)	Engineering Estimate (kWh/yr.)	(kWh/sq. ft./yr.)
Single-family Home	7,646	5.5	7,491	5.3
Multifamily Home	2,915	2.8	2,806	2.7
Manufactured Home	10,224	6.9	10,570	7.2

The Council's forecasting model does not explicitly assume a specific average dwelling unit size. However, the forecasting model's present implicit assumptions regarding average size for existing dwellings are shown in Table 7-42. Based on survey data, it appears that average new multifamily dwellings (five-plex and larger) and manufactured houses being built today typically are larger than the forecasting model assumes for all existing multifamily dwellings and manufactured houses. However, new single-family housing (less than five-plexes) appears to be the same size as the existing single-family stock. To account for this fact, the forecasting model's projected use for new multifamily units and manufactured homes shown in Table 7-41 has been scaled by the ratio of the size of new stock to existing stock. Similarly, the engineering model's estimates of cost and energy savings from conservation actions in new multifamily dwellings and manufactured homes shown in Table 7-41 also were scaled to match the forecast model's assumptions regarding new unit size. This was done by multiplying the engineering estimates of use, cost and savings by the ratio of average unit size implicitly assumed in the forecast model to the average floor area of new dwelling units. No size adjustment was made for new single-family dwellings, because their size appears to be consistent with the existing stock.

Table 7-42
Forecasting Model Dwelling Size vs. Average New Dwellings
(Square Feet)

Building Type	Model Existing Stock	New Stock	Ratio of New Stock to Model
Single-family Home	1,400	1,400	1.00
Multifamily Home	840	1,030	1.23
Manufactured Home	985	1,475	1.50

The Council's engineering estimates of space heating energy use in new dwellings and the forecasting model now contain similar underlying assumptions regarding appliance efficiency and family size. In order to match current (1990) consumption, the forecasting model must use current (1990) appliance efficiencies. However, because the Council anticipates substantial 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 2010 assumes the presence of more efficient appliances.

Table 7-43 shows the difference in waste heat (i.e., internal gains) released inside typical single-family dwellings from people and appliances assumed by the forecasting model in the late 1980s and in 2010. At current efficiencies and persons per household, approximately 6,800 kilowatt-hours of heat are released each year inside the house by people, lights and appliances. However, with anticipated improvements in appliance efficiency and a reduction in the average number of people per household, this will drop to approximately 5,450 kilowatt-hours per year by 2010.

Because this 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 2010 would fall about 1.2 kilowatt-hours per square foot. This reduction amounts to about 1,600 kilowatt-hours per year in the average new single-family house. However, 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 0.9 kilowatt-hours per square foot, per year.

Table 7-44 shows the technical conservation potential in the Council's high forecast from improvements in space heating efficiency in new single-family and multifamily dwellings and manufactured houses from a 1983 code/construction practice base. Table 7-45 shows the potential in the Council's medium forecast. Tables 7-46 and 7-47 show the technical potential in the Council's high and medium forecast from a base that incorporates the more efficient 1986 codes as the base. Table 7-48 shows the number of new electrically heated residences for all Council forecasts by dwelling type.

Table 7-43
Internal Gain Changes from More Efficient Appliances

Appliance/Source	Energy Use Per Unit (kWh/yr) Saturation (Units/Household)	At Current Efficiencies	At Forecast Efficiencies	Percent Indoors	Internal Gains Provided At Current Efficiencies (kWh/yr)	At Forecast Efficiencies Indoors (kWh/yr)
Lighting	1.00	740	725	90	665	650
Refrigerator[a]	1.083	910[b]	670	100	985	725
Range/Cooking	1.00	960	950	100	980	880
Freezer	.53	640[b]	500	50	170	125
Water Heater[c]	1.00	1,300	980	50	650	490
Television	2,000 set-hr/yr	200	200	100	200	200
Clothesdryer	.7	530	430	10	35	30
Dishwashers, Clotheswashers, & Misc. Appliances	--	1,750	1,500	50	875	750
People[d]	2.6/2.2	1,920	1,810	100	1,930	1,720
TOTAL					6,490	5,570

[a] Assumes one refrigerator is located inside the house and 50 percent of .165 refrigerators are located outside the house.

[b] For these appliances, current efficiencies are the level of the 1990 Federal Appliance Standards.

[c] Waste heat from water use is included with contribution from people.

[d] Contribution from people includes 290 kilowatt-hours per year, per occupant as sensible heat and 230 kilowatt-hours per year, per occupant as latent heat. Also included is about 565 kilowatt-hours per year of latent heat provided to the house from the use of warm water for cooking and bathing.

C:MG/DFT90.AA6 Table 7-43

Table 7-44
Potential Savings above 1983 Practice from Space Heating in New Residential Buildings Average Megawatts in High Forecast

Levelized Cost (cents/kWh) Nominal	Real	Single-Family Houses	Multifamily Houses	Manufactured Houses	Total
0	0	0	0	0	0
1.0	0.5	0	0	20	20
2.0	1.0	10	5	30	45
3.0	1.5	85	10	80	180
4.0	2.0	375	10	120	505
5.0	2.5	490	80	160	730
6.0	3.1	660	100	200	960
7.0	3.6	725	110	215	1,050
8.0	4.1	790	110	220	1,120
9.0	4.6	890	120	225	1,235
10.0	5.1	960	130	225	1,315

Table 7-45
Potential Savings above 1983 Practice from Space Heating in New Residential Buildings Average Megawatts in Medium Forecast

Levelized Cost (cents/kWh) Nominal	Real	Single-Family Houses	Multifamily Houses	Manufactured Houses	Total
0	0	0	0	0	0
1.0	0.5	0	0	20	20
2.0	1.0	5	5	30	40
3.0	1.5	30	10	75	115
4.0	2.0	150	10	120	290
5.0	2.5	195	75	160	430
6.0	3.1	265	90	195	550
7.0	3.6	290	100	215	605
8.0	4.1	320	100	215	635
9.0	4.6	360	105	220	685
10.0	5.1	385	115	220	720

Table 7-46
Potential Savings above 1990 Practice from Space Heating in New Residential Buildings
Average Megawatts in High Forecast

Levelized Cost (cents/kWh) Nominal	Real	Single-Family Houses	Multifamily Houses	Manufactured Houses	Total
0	0	0	0	0	0
1.0	0.5	0	0	0	0
2.0	1.0	0	0	0	0
3.0	1.5	0	0	10	10
4.0	2.0	35	0	35	70
5.0	2.5	95	30	75	200
6.0	3.1	255	45	115	415
7.0	3.6	320	55	135	510
8.0	4.1	385	55	135	575
9.0	4.6	490	60	140	690
10.0	5.1	555	75	140	770

Table 7-47
Potential Savings above 1986 Practice from Space Heating in New Residential Buildings
Average Megawatts in Medium Forecast

Levelized Cost (cents/kWh) Nominal	Real	Single-Family Houses	Multifamily Houses	Manufactured Houses	Total
0	0	0	0	0	0
1.0	0.5	0	0	0	0
2.0	1.0	0	0	0	0
3.0	1.5	0	0	10	10
4.0	2.0	15	0	35	50
5.0	2.5	35	25	75	135
6.0	3.1	100	40	110	250
7.0	3.6	125	50	130	305
8.0	4.1	150	55	135	340
9.0	4.6	195	55	140	390
10.0	5.1	220	65	140	425

Table 7-48
Number of New Electrically Heated Dwellings
1990 to 2010

Dwelling Type	High	Medium-High	Medium	Medium-Low	Low
Single-family Home	1,357,875	781,544	551,777	393,323	162,767
Multifamily Home	440,517	398,396	382,236	358,133	600,032
Manufactured Home	278,349	306,841	273,516	239,115	136,998

Electric Water Heating Conservation

The energy used to heat water represents the second largest end use of electricity in the residential sector. Figure 7-15 shows the technical potential for improving the efficiency of residential water heating at various costs of electricity. These savings represent better insulated water heaters, pipe wraps and more efficient appliances that use hot water (e.g., clotheswashers, dishwashers and showerheads).

Conservation Potential

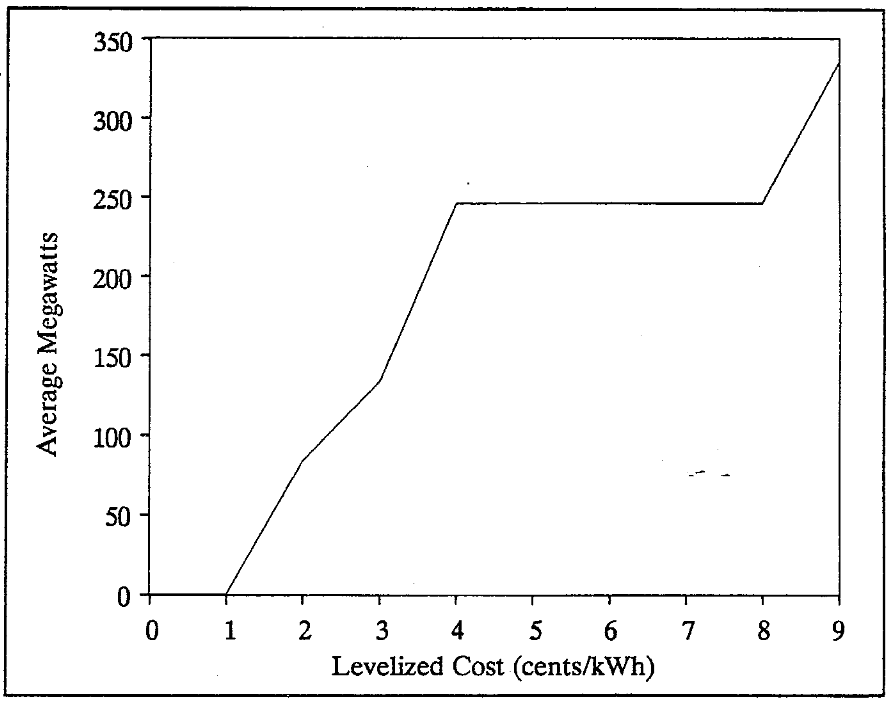


Figure 7-14
Technical Conservation Potential from Residential Water Heating Measures

The cost-effective technical potential identified by the Council for electric water heaters and water consuming appliances is about 335 average megawatts in the high-demand forecast and 187 average megawatts in the medium forecast. The average cost of improving the efficiency of electric water heaters is 4 cents per kilowatt-hour, which escalates to 5 cents per kilowatt-hour if administrative costs and transmission and distribution adjustments are incorporated.

The Council's assessment of the conservation potential available from improved residential water heating efficiency involved three steps. These were to:

1. Estimate the cost and savings potential available from improved water heating efficiency beyond the new 1990 federal standard.

2. Develop conservation supply functions for the total potential.

3. Calibrate savings to the Council's forecast.

The key data for this information comes from research and programs operated in the region. These are summarized in Table 7-49.

Table 7-49
Key Data Sources for Water Heating Measures

Costs	
U.S. Department of Energy	- Costs of efficient dish and clothes washers
Oregon Department of Energy	- Costs of efficient showerheads
Bonneville Power Administration's Water Heating Program	- Costs of wraps
Pacific Power and Light's Appliance Advisory Group	- Costs of bottom boards, thermal traps and pipe wraps
Bonneville Power Administration Study	- Costs of thermal traps and pipe wraps
Consumption and Savings	
Hood River Project	- Household water heater consumption
Residential Standards Demonstration Program	- Household water heater consumption
End-Use Load and Conservation Assessment Program	- Household water heater consumption
Seattle City Light Evaluations	- Savings for bottom boards, thermal traps/ pipe wraps and efficient tanks
Bonneville Power Administration Studies	- Savings for bottom boards, thermal traps/ pipe wraps and efficient tanks

Step 1. Estimate the Cost and Savings Potential Available from Improved Water Heating Efficiency

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. Variable use is the amount of hot water actually used in the household. Variable use differs substantially among households, depending upon such factors as the habits and number of occupants, and the stock of appliances that use hot water (such as clotheswashers and dishwashers), as well as the temperature of the hot water and the cold water that enters the tank.

In 1987, a national appliance standards act was passed that regulates the maximum energy consumption of a variety of household appliances, including electric water heaters, refrigerators and freezers. For electric water heaters, the appliance standards regulate the standby losses from the water heater tank. The level of the national standard is about the level or slightly more efficient than the level set by Oregon and Washington for water heaters sold in their states. The federal standard becomes effective in 1990, and a review of the standard by the secretary of the U.S. Department of Energy to see if it should be strengthened is required by 1992. The estimates of conservation potential for water heater tanks developed here are based on going beyond the current federal standard and setting a more stringent standard equivalent to the level of some of the most efficient tanks produced today. It is envisioned that a revision to the federal standard as well as other acquisition efforts, such as programs to get showerheads and other measures will be able to secure savings beginning in 1995.

The base use of water heaters from which conservation potential could be estimated was derived by reviewing research. Table 7-50 summarizes available data on standby losses from conventional (typically R-5) tanks. Water heat was directly submetered in all field studies. Laboratory tests on individual units had lower standby losses than those found in field tests. The average value of the full sample is 1,610 kilowatt-hours per year, identical to the Seattle City Light number of 1,610 kilowatt-hours per year. This value was compared to an estimate of standby losses from the federal standard, which was derived from work done for Bonneville. This indicated that standby losses from the federal standard are on the order of 1,290 kilowatt-hours per year. This lower base was used as the estimate of base case use in both the forecast of electricity demand and the estimate of conservation savings when the federal standard becomes effective in 1990. It is not clear how this estimate relates to an efficient tank that was tested in the laboratory by Bonneville. The laboratory testing showed standby losses for this efficient tank at a much lower level, about 800 kilowatt-hours per year. While it is not known how this tank relates to the federal standard, it is presumably more efficient. Further research needs to be done in this area to better establish the estimated standby loss of a tank that meets the federal appliance standard.

Table 7-50
Data on Standby Losses from Conventional Water Heater Tanks

Source	Standby (kWh/yr.)	N	Notes
Seattle City Light	1,610	26	All unwrapped, submetered
Biemer/Auburg '84	1,375	1	Laboratory tests
Goldstein/Clear	1,468		Calculated for 1960-1980 vintage tanks
Ek '82 (#36)	1,483	1	Laboratory test
Ecotope '82	1,995	91	Some wrapped, many different locations
Ecotope Heat Pump Study	1,731	39	Median standby losses in three cities are weighted by climate zone's contribution to regional population
Average	1,610		

Variable use for the pre-conservation situation was estimated from studies that reported the gallons of hot water used per person or per household. Table 7-51 summarizes the empirical data. Hot water demand was actually measured in some cases, while in others it was calculated. If the figures are converted to kilowatt-hours per person,[26] the average kilowatt-hour use per occupant is approximately 1,400 kilowatt-hours per year. Given the tremendous variation inherent in hot water variable use, this number is reasonably close to the value used in the 1983 and 1986 plans, which is 1,310 kilowatt-hours per occupant for an 80°F temperature differential. The Council continued using the 1,310 kilowatt-hours per occupant for base year use, since available data did not dictate a change.

26./ This assumes a 90°F temperature differential between the incoming water and the tank setting.

Table 7-51
Variable Demand Use for Hot Water

Source	Gallons per year per Person	N	Notes
Lawrence Berkeley Laboratories	5,582		
Natural Resources Defense Council	5,411		Calculated
Seattle City Light	6,019	26	Calculated
Ecotope Heat Pump Study	7,680	38	Submetered participants selected on basis of family size and high water use
Bavir	7,094		Regression results from submetered sample
Long Island Light Co.	6,788	257	Submetered
Average	6,429	gallons/person/year	

At 90°F temperature differential this translates to: 1,399 kWh/person/year

In recent years, considerable end-use monitored data has been collected on total electricity consumption for water heating in the Northwest. Table 7-52 summarizes such data collected through the Hood River Conservation Project, which monitored existing houses in Hood River, Oregon, and the Residential Standards Demonstration Project, which monitored new water heaters in new houses. The new houses are more representative of use with the federal standards in place, since the new houses were primarily built in Washington and Oregon, which have standards already that approximate the federal standard. In addition, Table 7-52 shows the average consumption of end-use monitored houses in the End-Use Loads and Conservation Assessment Program (ELCAP). This information was not available as a function of household size. ELCAP water heating data is currently being analyzed further to add information to the estimates.

Table 7-52
Measured Consumption of Electric Water Heaters

Occupants per Household	Hood River Conservation Project Consumption (kWh/yr.)	Hood River Conservation Project Sample Size	Residential Standards Demonstration Project Consumption (kWh/yr.)	Residential Standards Demonstration Project Sample Size
1	2,843	25	2,764	30
2	4,173	78	3,812	109
3	5,756	26	4,817	93
4	6,253	35	5,541	133
5	7,582	9	5,688	34
6	9,504	6	6,730	18
7	--	--	8,143	8

End-Use Load and Conservation Assessment Program (ELCAP) Consumption (kWh/yr.)
5,098

The number of occupants per house according to the forecast is about 2.7 occupants per household in the early years. Using 1,310 kilowatt-hours per occupant and 1,290 kilowatt-hours for standby losses puts consumption at about 4,800 kilowatt-hours per household. This is in the range of monitored use in both the Hood River and RSDP samples for this household size, and seems to be an appropriate estimate of base case electric water heating consumption.

The two primary sources for estimating the savings available from various standby conservation measures were a Seattle City Light study, which served as the basis for the 1983 plan figures, and a laboratory study conducted by Bonneville in 1984 (Biemer, Auburg, Ek).

The Seattle City Light and Bonneville studies primarily tested R-5 tanks, but they also looked at more efficient tanks and savings from measures after a more efficient tank was installed. These studies started with different standby losses for an efficient tank (910 kilowatt-hours per year for Seattle City Light compared to 725 kilowatt-hours per year for the Bonneville study) and found different absolute savings estimates. The results for each study are shown in Table 7-53. Water heater wraps and thermal traps are the individual measures with the greatest difference. The Council used an average of the savings reported in both studies for savings from R-11 wraps, bottom boards and thermal traps.

Thermal traps are assumed to achieve the same savings as pipe wraps at a similar cost. These measures are interchangeable. Similarly, the R-11 wrap is used to represent savings and costs that could accrue from either a wrap or more insulation installed during the manufacturer of the tank, both of which result in a more efficient tank. Barriers currently exist to securing more efficient tanks--either through wrapping with an exterior blanket or by manufacturing and distributing tanks manufactured with more insulation inside. The problem with wrapping a new tank is that the warranty is voided for some manufacturers. More efficient tanks currently are not manufactured in large numbers or distributed throughout the region. It is expected that either or both of these barriers can be removed by 1995, and so savings are represented from accomplishing one of these measures by 1995.

Table 7-53
Savings from Water Heating Measures
(kWh/yr. at 70° Temperature Differential)

Measures	Seattle City Light[a] Savings (kWh)	Ek/Auburg '84[b] Savings (kWh)
R-11 Wrap	88	168
Bottom Board	35	32
Thermal Trap	156	68
Total Savings	279	268

[a] Based on standby losses for an efficient tank of 910 kilowatt-hours per year.

[b] Based on standby losses for an efficient tank of 725 kilowatt-hours per year.

Conservation measures for variable use include clotheswashers and dishwashers that use hot water more efficiently, and energy-saving showerheads. The costs and savings available from efficient clotheswashers and dishwashers were taken from work done for the U.S. Department of Energy in support of a rulemaking to investigate whether more efficient standards should be set for these appliances. The DOE study showed that using measures that were cost-effective to this region, more efficient clotheswashers would save about 190 kilowatt-hours per year, and more efficient dishwashers would save 118 kilowatt-hours per year.

Costs and savings from energy-saving showerheads are based primarily on work done in Oregon and on research into hot water use during showers. An Oregon survey found that new showerheads had an average flow rate of about 3.2 gallons per minute. Oregon has a standard that requires 3.0 gallons per minute, and Washington recently adopted legislation limiting maximum flow levels. More energy saving units are available on the market, and a reasonable range would be about 2.3 gallons per minute. Savings are based on installing 2.3 gallons per minute showerheads in new houses with electric water heat instead of 3.0 gallons per minute showerheads. It was assumed that showers last for an average of 10 minutes, and that half the water consumed is hot. Costs were also taken from the Oregon survey and doubled to reflect the fact that many new homes would need two showerheads. No incremental installation costs were attached to the more efficient showerhead, since savings are attributed to new houses only which would have had installation costs for a standard showerhead.

Costs for water heater wraps are from Bonneville. Costs for bottom boards are from Pacific Power and Light, and costs for thermal traps or pipe wraps are adapted from Pacific Power and Light and Cal Ek's work at Bonneville.

The lifetimes of the measures discussed above are 10 years, except for showerheads, which are 20 years.

Solar water heaters are used in this analysis to represent either solar water heaters or heat pump water heaters. Either technology significantly reduces the electricity used to heat water. The costs and percent savings for solar water heaters is taken from the Council's staff issue paper entitled "Assessment of the Potential for the Direct Application of Renewable Resources" (publication #89-39). It appears that solar water heaters would be cost-effective in households with large hot water demand, such as those represented by greater than four people per household. Savings from solar water heaters in houses with greater than three or four people represent about 50 to 80 average megawatts and are considered a promising resource.

The above assumptions led to the cost-effectiveness calculation for each measure shown in Table 7-54. This table assumes an average household with 2.4 occupants, which is the forecast value for out-years of the forecast. Savings for standby loss conservation measures have been reduced to reflect the interaction between internal gains from water heaters and space heating electricity consumption. This is described in the section that follows the analysis of refrigerator and freezer conservation potential. The table shows the marginal cost of each water heating conservation measure, starting with a tank that meets the federal appliance standard for 1990. Except for solar water heaters, none of the measures exceeds 10 cents per kilowatt-hour, even after taking into account the interactive effect with space heating.

Table 7-54
Measure Costs and Savings for Water Heaters

Measure	Measure Capital Cost	Measure Present Value Cost	Savings with Interaction[a] (kWh/yr.)	Levelized Cost (cents/kWh)
Base Use = 4,434 kWh/year (EF = .88)				
Base Case	$0	0	0	0
Efficient Showerhead (7-2.3 gpm)	$15	$29	380	1.0
Thermal Trap or Pipe Wrap	$10	$20	91	2.8
Efficient Clotheswasher	$28	$55	190	3.8
Efficient Dishwasher	$18	$35	118	3.9
R-11 Wrap or Efficient Tank	$10	$88	133	8.7
Bottom Board	$45	$20	29	8.9
Solar Water Heater	$2,000	$2,410	1,440	16

[a] This reflects the reduced savings from standby loss measures due to the interaction with electric space heating.

Step 2. Develop Conservation Supply Functions for Technical and Achievable Potential

The savings for each measure were multiplied by the number of units existing in 2010 to which that measure applied. The number of electric water heaters was taken as the number of units existing in 2010. The number of electric water heaters that appears in the forecast between 1995 and 2010 would overcount the number of water heaters in 2010, since the average lifetime of water heaters is shorter than the 15 years between 1995 and 2010, and consequently some replacements would be occurring. The savings from showerheads are assumed to be limited by the number of new houses likely to be built between 1995 and 2010 with electric water heaters. However, if every existing house that has an electric water heater also used an energy saving showerhead, 100 additional average megawatts of technical potential could be included. Assuming an achievable potential of 50 percent, this is another 50 average megawatts. As a conservatism, this is not currently included in the technical potential but is considered a promising resources. The number of clotheswashers and dishwashers is assumed to track the number of electric water heaters in 2010 with saturations of 78 percent and 50 percent respectively.

Table 7-55
Number of Eligible Units by 2010 for Water Heating Measures

Measure	High Forecast	Medium Forecast
Efficient Showerheads	1,955,000	1,203,000
Efficient Clotheswashers	3,710,000	2,997,000
Efficient Dishwashers	2,379,000	1,921,000
Efficient Tanks or R-11 Wraps	4,757,000	3,842,000
Thermal Trap or Pipe Wrap	4,757,000	3,842,000
Bottom Board	4,757,000	3,842,000

Step 3. Calibrate the Supply Curve to the Council's Forecast and Incorporate Behavioral Impacts on the Savings Estimates

The engineering and field measurements described above predict a base water heater use of between 4,434 and 4,827 kilowatt-hours per year, depending on the number of occupants in the average household. As mentioned above, these figures represent standby losses at the level of the federal standard. Since the consumption of the average water heater at the avoided cost cut-off is 3,826 kilowatt-hours per year, the cost-effective relative efficiency improvement holding behavior constant is 0.86. In the medium demand forecast, base-case use in 2010 at the frozen efficiency level of the federal standard is about 4,400 kilowatt-hours per year. For purposes of the supply curve, the difference between the forecast base-case use and the engineering base-case use is so small that no calibration was necessary. In prior analyses, it was assumed that the difference was due to variations in the operation of hot water consuming appliances. Previously, such differences reduced the supply curve somewhat for each of these appliances to account for the different base-case uses.

This relative efficiency change was incorporated in the forecast, and energy consumption after all measures were installed was estimated. Savings for the average water heater are the difference between base use of 4,401 kilowatt-hours and use after the conservation measures are installed. Because there are different penetration rates on each measure, and measures can only be applied if the appliance is present (e.g., a dishwasher), the savings-weighted penetration rate is 0.74.

The amount of conservation available in the high demand forecast can then be estimated as the number of new water heaters, times the weighted penetration rate, times the estimate of cost-effective savings. The megawatts available in the medium- and high-demand forecast at various costs is presented in Table 7-56.

Table 7-56
Conservation Available from Water Heaters

Levelized Cost (cents/kWh)		Cumulative Technical Potential (average megawatts)	
Nominal	Real	High Forecast	Medium Forecast
0	0	0	0
1	.5	0	0
2	1	84	48
3	1.5	134	80
4	2	246	126
5	2.5	246	126
6	3	246	126
7	3.5	246	126
8	4	246	126
9-15	4.5-7.5	335	187

Conservation in Other Residential Appliances

Approximately one-quarter of the electricity currently consumed in the residential sector is used to operate refrigerators, freezers, stoves and lights. This section describes the conservation assessment for refrigerators that contain freezers (hereafter called refrigerators), freezers, clothesdryers and residential lighting.

Refrigerators and Freezers

The Council estimates 175 average megawatts of technical savings are available from conservation in refrigerators and freezers in the high-demand forecast and 132 in the medium forecast. These are available at an average cost of about 6 cents per kilowatt-hour for refrigerators and about 2 cents per kilowatt-hour for freezers, including administrative costs and transmission and distribution adjustments.

The average megawatts currently identified for refrigerators and freezers represent significantly less than the available conservation presented in the 1986 Power Plan. Most of this reduction results from a new federal appliance efficiency act, discussed below, which regulates the minimum efficiency of new appliances.

Some of the savings estimated in the 1986 plan have essentially been incorporated in the forecast of electricity demand as reduced use. This change illustrates the effectiveness of appliance standards at acquiring conservation resources.

The savings identified by the Council are based on cost-effective efficiency improvements that go beyond recent federal legislation. The National Appliance Energy Conservation Act was passed by Congress and signed by President Reagan in early 1987. It sets an initial maximum energy consumption level for refrigerators and freezers (as well as other home appliances) that becomes effective for any unit sold in or after 1990. The federal law also requires a review of these initial standards for refrigerators and freezers by 1990. The Department of Energy reviewed the standards and adopted more stringent levels to become effective in 1993. Currently, the Council's forecast of electricity demand incorporates the use implied by the federal 1990 standard, which has become the base case against which further efficiency improvements are measured.

The current analysis shows that cost-effective efficiency improvements beyond the 1990 federal standard are achievable. The conservation resource is modeled as revised appliance standards that could become effective in 1995. The level of efficiency represented as the conservation potential is the level recommended by the Council to the U.S. Department of Energy.

Refrigerators and freezers that significantly exceed the recommended standard level are not yet commercially available, although engineering estimates indicate that technologies able to beat the recommended level are attainable. A promising conservation measure for further advancements is the application of evacuated panels. This technology is under development. In addition, an alternative design refrigerator that exceeds the energy requirement of the recommended level by about 50 percent can be purchased today, but only at a high price. This refrigerator corroborates the fact that more efficient refrigerators can be made. Savings from this advanced refrigerator are about 160 average megawatts in a high-demand forecast. However, the refrigerators are expensive, because they are handmade. Most likely they would have to be mass-manufactured before they would become cost-effective. Savings from evacuated panels in freezers are about 20 average megawatts. Since these technologies are not yet available, their total savings of 180 average megawatts are simply used here to represent a "promising" resource, but one which is not yet commercially available.

The Council used two steps to evaluate the savings available from refrigerator and freezer efficiency improvements. These were to:

1. Estimate the cost and savings potential available from improved refrigerator and freezer efficiency.

2. Develop technical and achievable conservation potential and calibrate the conservation potential to the Council's forecast.

The key data used in this analysis are from the U.S. Department of Energy proceedings on refrigerator and freezer efficiency improvements.

Step 1. Estimate the Costs and Savings Potential Available from Improved Refrigerator and Freezer Efficiency

The potential for saving energy from improved refrigerator and freezer operating efficiencies is well documented. The U.S. Department of Energy and the California Energy Commission have reviewed the option of appliance efficiency standards over the last decade. The Department of Energy has done a very recent study on efficiency improvements to refrigerators and freezers. The savings and cost information from the current review are used here. The measures represent options that could be manufactured into appliances by the early 1990s.

In this analysis, an 18-cubic-foot automatic defrost refrigerator with a top-mounted freezer was used as the prototype to represent refrigerators. Both a 15-cubic-foot manual defrost upright freezer and a 17-cubic-foot chest freezer were used to represent freezers. About 61 percent of the refrigerators sold in the region have top-mounted (as opposed to side-by-side) freezers. Automatic defrost units represent approximately 70 to 80 percent of the refrigerators sold today. About 50 percent of freezers sold are uprights, and about 50 percent are chest styles.

To get a feel for how the various standards affect consumption, take the example of the typical refrigerator. The Association of Home Appliance Manufacturers estimates that the average unit of this sort sold in 1983 consumed about 1,156 kilowatt-hours per year. The 1990 federal standard requires that this same refrigerator consume no more than about 950 kilowatt-hours per year. Furthermore, the cost-effective level of consumption used in this analysis would reduce consumption further to only 640 kilowatt-hours, nearly half the consumption in 1983.

This analysis evaluates cost-effectiveness from the perspective of the region. Table 7-57 presents cost and savings information for the prototype 18-cubic-foot refrigerator. Savings and levelized costs include the interaction of appliance efficiency improvements with space heating requirements, described more fully in the following section.

Table 7-57
Measure Cost and Savings for Prototype Refrigerator[a]

	Use (kWh/yr.)	Measure Cost	Cumulative Cost	Cost of Savings (cents/kWh)[b]
Current Federal Code for 1990	947	$0	$0	0
Foam Insulation in Door Compressor EER[c] 5.0	787	$11.24	$11.24	1.3
Improved Foam Insulation, (k=0.11)	745	$7.27	$18.51	3.2
Compressor EER 5.3	714	$13.12	$31.63	7.9
Efficient fans, 2" Door Insulation with Improved Foam (k=0.10)	637	$50.74	$82.38	12.2
Adaptive Defrost, Evacuated Panels (k=0.05)	515	$102.97	$185.35	156.3

[a] Analysis is for an 18-cubic-foot automatic defrost refrigerator with a top-mounted freezer.

[b] Adjusted for space heat interaction.

[c] EER - Energy-Efficiency Ratio.

The costs and savings for measures that can be applied to the prototype upright and chest freezers appear in Table 7-58. As with refrigerators, this information is taken from the U.S. Department of Energy technical documentation.

Table 7-58
Measure Cost and Savings for Prototype Freezers

	Use (kWh/yr.)	Measure Capital Cost	Levelized Cost (cents/kWh)[a]
Upright[b]			
Base Case	777	$0	0
Compressor EER 5.0[c]	606	$15.19	1.2
Improved Foam Insulation	544	$7.63	1.6
Compressor EER 5.3	511	$13.07	5.2
Door Insulation 2" and Better Foam	453	$28.12	6.4
Evacuated Panel	343	$51.40	6.2
Chest[d]			
Base Case	600	0	0
Compressor EER 5.0, Foam Insulation in Lid	475	$11.25	1.2
Improved Foam Insulation	442	$4.68	1.9
Compressor EER 5.3	415	$13.01	6.4
2.5" Lid, Better Foam Insulation	370	$25.55	7.5
Evacuated Panel, 2.5" Sides	315	$52.07	12.5

[a] Adjusted for space heat interaction.

[b] Analysis is for a 15-cubic-foot upright freezer with manual defrost.

[c] EER - Energy-Efficiency Ratio.

[d] Analysis for a 17-cubic-foot chest freezer with manual defrost.

Step 2. Develop Conservation Supply Functions for Technical and Achievable Potential Consistent with the Council's Forecast

The savings resulting from improvement to the cost-effective level for refrigerators and freezers were multiplied by the number of refrigerators and freezers purchased between 1995 and 2010, as predicted in the Council's high forecast. Since the energy load that has to be met by thermal plants after conservation actions are taken is determined by the forecast, the savings from conservation measures in refrigerators and freezers has to be evaluated consistently with the values carried in the forecasting model.

The Council's forecasting model, which now includes the 1990 federal appliance standards, was used to estimate the base case use of refrigerators and freezers in the year 2010 with efficiencies frozen at the 1990 federal standards. In the medium-demand forecast, new refrigerators use 906 kilowatt-hours per year and freezers use 636 kilowatt-hours per year for the average refrigerator and freezer purchased in the region.

For refrigerators, a base use of 906 kilowatt-hours per year and a conservation cut-off of 637 kilowatt-hours per year resulted in a total technical potential:

$$TS = N \times S \times I \div C$$

$$= 5{,}232{,}000 \times (906-637) \times 0.8 \div 8{,}760{,}000$$

$$= 128 \text{ average megawatts}$$

Where:

TS = Total savings from refrigerators, expressed in average megawatts

N = Number of refrigerators purchased 1995 to 2010

S = Savings from each refrigerator, in kilowatt-hours per refrigerator (pre-conservation use minus-post conservation use)

I = Loss of savings due to interaction with the space heating system

C = Conversion from kilowatt-hours to average megawatts (8,760,000 kilowatt-hours per average megawatt)

For freezers, a base case use of 636 kilowatt-hours per year and a conservation cut-off of 411 kilowatt-hours per year, resulted in a total technical potential:

$$TS = N \times S \times I \div C$$

$$= 2{,}143{,}000 \times (636-411) \times 0.87 \div 8{,}760{,}000$$

$$= 48 \text{ average megawatts}$$

Where:

TS = Total savings from freezers, expressed in average megawatts

N = Number of freezers purchased 1995 to 2010

S = Savings from each freezer in kilowatt-hours per refrigerator (pre-conservation use minus-post conservation use)

I = Loss of savings due to interaction with the space heating system

C = Conversion from kilowatt-hours to average megawatts (8,760,000 kilowatt-hours per average megawatt)

The achievable portion is considered to be 90 percent of technical potential.

Clothesdryers

In support of efficiency standards for residential appliances, the U.S. Department of Energy investigated improvements that could be made to residential clothesdryers. The analysis shown below is taken from the draft technical documentation used by the Department of Energy.

Table 7-59 displays the information collected by the department. Annual usage has been scaled to reflect the number of dryer loads done per year in the Northwest, compared to the national testing procedure. Using this scaled savings, it appears only one measure, automatic termination based on moisture or temperature, is cost-effective. If this level is adopted, about 20 average megawatts could be secured. However, this assumes that the measure is not already widely used in currently sold clothesdryers. The resource would be smaller, if the base case were already more efficient.

Table 7-59
Measure Cost and Savings for Clothesdryers

Measure	Measure Capital Cost	kWh/Year Use	Levelized Cost (cents/kWh)
Base Case	0	532	0
Automatic Termination	$8	469	5
1" Cabinet Insulation	$11	459	19
Recycle Exhaust	$52	432	31
Heat Pump Clothesdryer (off base)	$300	170	13

In addition, there are two advanced technologies that could save significant amounts of electricity, if they became commercially available. These are heat pump clothesdryers and microwave clothesdryers. Heat pump clothesdryers were described in the Department of Energy documentation, and are used here to represent the size and cost of the savings that would accrue from either technology. Both heat pump and microwave clothesdryers are in the prototype stage. The key disadvantages of each unit are that the heat pump dryer requires longer to dry than the conventional unit, and the microwave dryer cannot dry materials with metal threads, although it can dry clothes with metal buttons and zippers. On the other hand, the microwave unit dries clothes more quickly than a conventional dryer, and appears to be less tough on fabric. If heat pump clothesdryers were used instead of the conservation measures listed in Table 7-59, they would save about 110 average megawatts at about 13 cents per kilowatt-hour. Since this resource is not yet commercially available in the United States, it is considered promising and should be targeted for development, if possible.

Residential Lighting

Great strides have been made in developing lighting technologies to replace traditional incandescent bulbs in a residential setting. The typical replacement is to put a compact fluorescent (bulb and ballast) into the existing incandescent socket. Compact fluorescents now exist that are similar to incandescent bulbs in color, but that use significantly less energy. For example, a 75-watt incandescent bulb is typically replaced with an 18-watt fluorescent bulb and ballast to achieve similar light levels. This means a significant savings every time the light is turned on.

Compact fluorescents are currently commercially available, but there is an emerging lighting technology that might prove more efficient and inexpensive in the future. This technology is essentially an electronic signal that excites gasses common in all bulbs to create light. The first prototype versions have succeeded in producing as much light as a 150-watt incandescent, with similar color, in a similar sized and shaped bulb. These are projected to be about half the cost of the compact fluorescents. Since these are not yet commercially available, this section focuses on the compact fluorescent.

There are some problems with the new compact fluorescents. First, they have a high first cost, about $20 instead of the $0.66 cost of incandescent bulbs. Even though they last much longer, there is sticker price shock when the consumer sees them in the market place. Second, they are not yet widely available in stores that sell light bulbs. Probably because of the high first cost, a large market has not developed for these bulbs, even though they save energy. Third, the compact fluorescent, which is larger than the incandescent, may not fit in the existing socket because of the configuration of many lamp shades and lamp harps. Finally, there currently are no compact fluorescents that have the light output of a 100-watt incandescent or greater and will easily fit into existing fixtures. In order to achieve more light output, the fluorescent bulb must get larger, which will further limit its application in existing fixtures and sockets.

In terms of program design, there are slightly different problems. For example, administrative costs could overwhelm cost-effective savings, if fluorescent bulbs were the only reason for a visit to a house. However, if the bulbs were installed while the utility was also doing other things in the house, they would remain cost-effective. In addition, there are questions about the longevity of savings. A fluorescent bulb may last 10,000 hours, but at the end of this life, how can the electric system be assured that the fluorescent will be replaced in kind, instead of with a low-first-cost incandescent that fits the same socket?

These problems can be resolved. The program questions can be resolved during program design, but they must be kept in mind. The prior set of technical questions essentially mean that the resource size may not be as large as once thought, since there are households where no incandescents will be able to be replaced and others where very few will be accommodated.

On the other hand, there also are some benefits to the compact fluorescents. They do not need replacement nearly as often, and consequently maintenance is minimal. This is especially important in hard-to-reach places, such as stairwells, and in areas where the lights burn long hours.

There were two steps used to estimate the savings available from efficient residential lighting:

1. Estimate the levelized cost of improving the efficiency of residential lighting.

2. Develop technical and achievable conservation potential.

Step 1. Estimate the Levelized Cost of Improving the Efficiency of Residential Lighting

In this analysis, an 18-watt compact fluorescent replacing a 75-watt incandescent is used to represent a typical levelized cost for the generic installation of compact fluorescents for incandescents in existing housing. The general question is whether this measure has a low enough levelized cost to warrant further evaluation of the total conservation potential. As seen below, since it passes this test in existing housing and is considered promising in new housing, the average wattage reductions expected per house are used to estimate regional potential. A retrofit situation is evaluated first.

Energy savings are based on some data collected for Pacific Power and Light Company. In a study examining the potential for retrofitting compact fluorescents into existing houses, they collected information on the number of lamps that could be converted, the number of hours the lights were on, and other information on occupant attitudes. While not regionally representative, this data is the only monitored source of information available. It is used to estimate the cost-effectiveness and size of the conservation resource.

Pacific Power and Light found that an average of three bulbs could be replaced per house. Only two of these bulbs were monitored for their hours of usage, but these were on an average of two hours per day. In the example used here of an 18-watt fluorescent replacing a 75-watt incandescent, the savings are then 42 kilowatt-hours per year, per bulb. However, as described in the next section, some of the savings from making the lighting more efficient are lost, because the space heater has to operate more frequently. In an electrically heated house, about 50 percent of the savings are lost, but only about 45 percent of the houses in the region are electrically heated. This results in a total net loss of about 22 percent. Instead of 42 kilowatt-hours per year being saved, only 33 kilowatt-hours are saved. This lower figure is used in the cost-effectiveness evaluation and in the estimate of total regional megawatts.

The lifetime of a compact fluorescent is about 10,000 hours, but this is tested assuming longer on-times than two hours per day. Consequently, the 10,000 hours is assumed to be shortened to 9,000 hours. This implies a lifetime of 12 years if the lamp is on only two hours per day.

The cost of compact fluorescents has dropped significantly over the years. Currently, the retail cost of an 18-watt compact fluorescent, including the ballast, is about $18, according to information from the Rocky Mountain Institute and various discussions with lighting professionals. This price can be reduced, if the unit is purchased in bulk. For example, distributor costs are closer to $10 to $15. There may be some incremental installation cost, since the first one that is installed may be installed by the utility. For initial purposes, assume that the installation cost is $1 per bulb, assuming installation occurs when the utility is conducting other business at the house; for example, the utility might be conducting weatherization audits, replacing a water heater or installing a showerhead. The net cost of the compact fluorescent must be reduced to reflect the cost of replacing the incandescents because they last only 850 to 1,000 hours, while the florescent lasts 9,000 to 10,000 hours. This means not incurring a $0.66 cost for an incandescent bulb 10 times over the life of the compact fluorescent.

Using these assumptions, the levelized cost of the compact fluorescent is about 8 cents per kilowatt-hour and, therefore, cost-effective if administrative costs are kept fairly low.

Very little data is available to estimate the costs and savings of compact fluorescents in new houses. The benefit of putting compact fluorescents in new housing is that the fixtures can guarantee that the replacement bulb is also fluorescent. New fixtures that are specifically designed for compact fluorescents will generally not accept the shape of an incandescent bulb. In addition, the fluorescents can be placed in rooms with high usage, such as kitchens and apartment hallways, where they result in a quicker payback.

Unfortunately, the incremental cost of the compact fluorescent fixtures appears to be quite high at this time. A quick investigation of the cost of incandescent versus fluorescent recessed fixtures indicates that the incremental cost may be about $60 on average for recessed fixtures at the retail level. This represents a fixture with two 17-watt compact fluorescents replacing a fixture with a 100-watt incandescent. This incremental cost is higher than in the commercial sector, for at least two reasons. First, the incandescent fixtures used in commercial applications are often of higher quality, thus costing more and lowering the incremental step to fluorescents. Second, the commercial sector can buy in large quantities, thus lowering the costs of both fixtures. However, it seems likely that the costs even to the residential market will become lower as purchases increase and the technology becomes more widespread. In the meantime, this analysis will continue to use an estimated $60 cost.

If it is assumed that the lights would be on about four hours per day, and the total lifetime is about 9,000 hours, as discussed above, then the compact fluorescent would last about six years. Using these assumptions, the levelized cost of compact fluorescents in new houses with the appropriate fixtures is about 25 cents per kilowatt-hour or about two and a half times the avoided cost cutoff. This is primarily due to the high incremental cost of the fixture. As mentioned above, it is reasonable to assume that this cost could decline as the market matures. As in existing housing, some traditional incandescent fixtures and bulbs could be replaced with compact fluorescents. However, because fixtures made specifically for compact fluorescents prevent the use of incandescents, this assures that the resource would be perpetuated. For this reason it is a much more reliable resource, and would be the preferred alternative in new housing. At this time, however, it is probably best to consider the resource in new houses as promising.

Step 2. Estimate Technical and Achievable Conservation Potential

In order to estimate the impact on the region, if a full effort were made to install compact fluorescents in existing houses, two more data points are needed. First, what is the average wattage reduction when a compact fluorescent replaces an incandescent? Second, to how many households does the retrofit apply?

Pacific Power and Light's experience indicates that an average 50 watts were saved for each incandescent bulb replaced. The Council's forecast shows 2.95 million pre-1990 households (includes single-family, multifamily and manufactured houses) surviving until 2010. This information, combined with an average on-time of two hours per day, three applicable fixtures per house, and the average interaction with space heating of about 22 percent loss in savings, represents a technical potential of 30 average megawatts in existing housing.

There are approximately 3.28 million new households built between 1990 and 2010 in the high-demand forecast and 1.92 million in the medium forecast. Currently there is no known source of data for how many fixtures can be fluorescent in a new house or how many hours they are on. The following are simply some rough estimates to make a first cut at the regional costs and savings. Since there are more opportunities for putting compact fluorescents into new houses than existing houses, we'll assume that four fixtures can be replaced (averaged over single-family, multifamily and manufactured houses). These are assumed to result in an average 50-watt reduction, and are assumed to operate about four hours per day. Using these assumptions for new houses, this indicates a promising resource on the order of 85 average megawatts in the high forecast and 50 average megawatts in the medium forecast.

These savings from residential lighting are not currently included in the portfolio analysis, but the savings from existing houses are proposed to be included in the final plan.

The Interaction Between Internal Gains and Electric Space Heat

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.[27]

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 is, the less useful the waste heat from the appliance. For example, the space 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 does not contribute to internal gains. Consequently, any efficiency improvements in appliances located outside the house would be fully realized as 100-percent energy savings and would not require that additional heat be provided by the furnace.

27./ Solar gains are considered constant in this discussion.

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.[28] 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 and 13 percent of the savings from standby losses on water heaters, refrigerators and freezers, respectively. These figures were used to devalue the savings obtainable from these appliances in the preceding cost-effectiveness evaluations.

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Commercial Sector

Of the estimated conservation resource, the commercial sector accounts for roughly half of the total. At the same time, the commercial sector represents the most diverse and perhaps the least understood of all the sectors. It includes buildings ranging from 1,000 square foot convenience stores to 50-story office towers and energy uses ranging from computers to supermarket refrigerators. These two facts make the commercial sector a particularly difficult, yet critically important, part of estimating the conservation resource in the region.

Because of the complexity of the sector, much less precision is possible for estimating the conservation potential, when compared to the residential sector. For example, while three prototype residential buildings may encompass a majority of the energy-consuming characteristics in residential buildings, the 10 prototypes in the commercial analysis, each modeled twice as new and existing buildings, only start to reflect the wide range of energy-consuming characteristics found in commercial buildings.

This section describes the current energy uses in the sector, the process used to evaluate the conservation potential, and a comparison with conservation program experience.

Summary

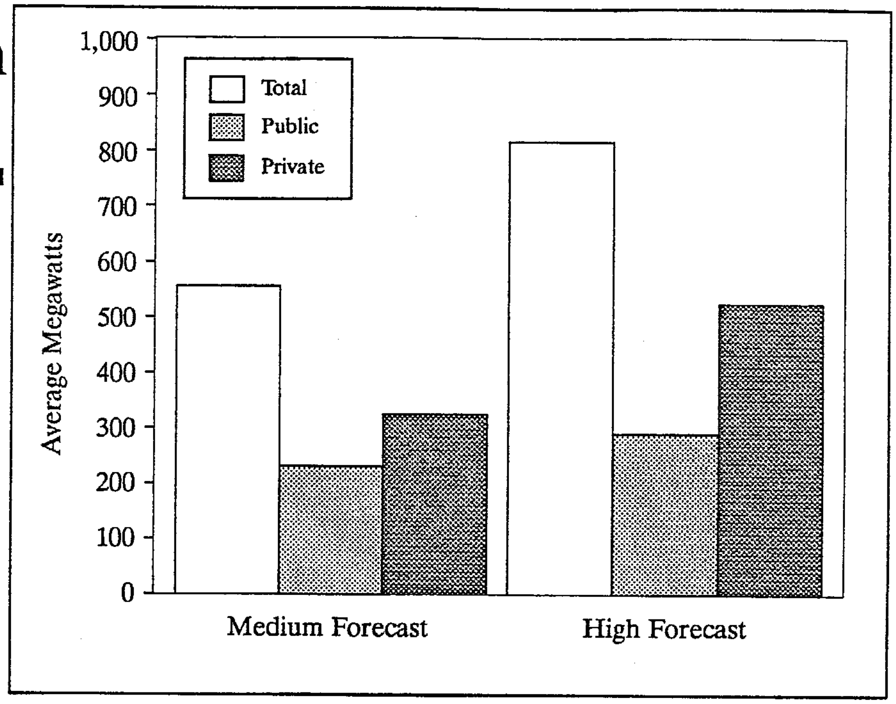
In 1989, the commercial sector consumed approximately 22 percent of the region's total energy sales or about 3,761 weather adjusted average megawatts. This sector's energy consumption is dominated by lighting (33 percent), space heating (27 percent), ventilation (15 percent) and cooling (8 percent). Further detail on the current estimates by end use are provided in Volume II, Chapter 6.

The Council's current assessment of cost-effective efficiency improvements for existing and new commercial buildings starts with engineering estimates from 10 prototype commercial buildings. These estimates of savings are translated into relative efficiency improvements, which are then installed in the forecasting model to estimate realized savings that are consistent with the load forecast. The engineering estimates of relative savings also were compared to experience from a regional program. The savings presented here from new commercial buildings reflect the conservation potential beyond the savings secured by the 1986 Oregon and Washington energy codes. Figures 7-15 and 7-16 show the amount of existing and new commercial sector conservation available under medium- and high-load forecasts for public and private utility service territories.

In the high forecast, the combined total of technical conservation potential for the sector is over 1,550 average megawatts. This makes the commercial sector conservation resource one of the largest resources in the portfolio and over half of the entire conservation resource. However, this amounts to only 20 percent of the projected commercial electric energy demand in the year 2010. Figures 7-15 and 7-16 also show that the largest share of this resource resides in private utility service territory. The resource is split fairly evenly between existing and new commercial buildings.

Conservation Potential

Figure 7-15
Technical Potential for Existing Commercial Buildings



Conservation Potential

Figure 7-16
Technical Potential for New Commercial Buildings

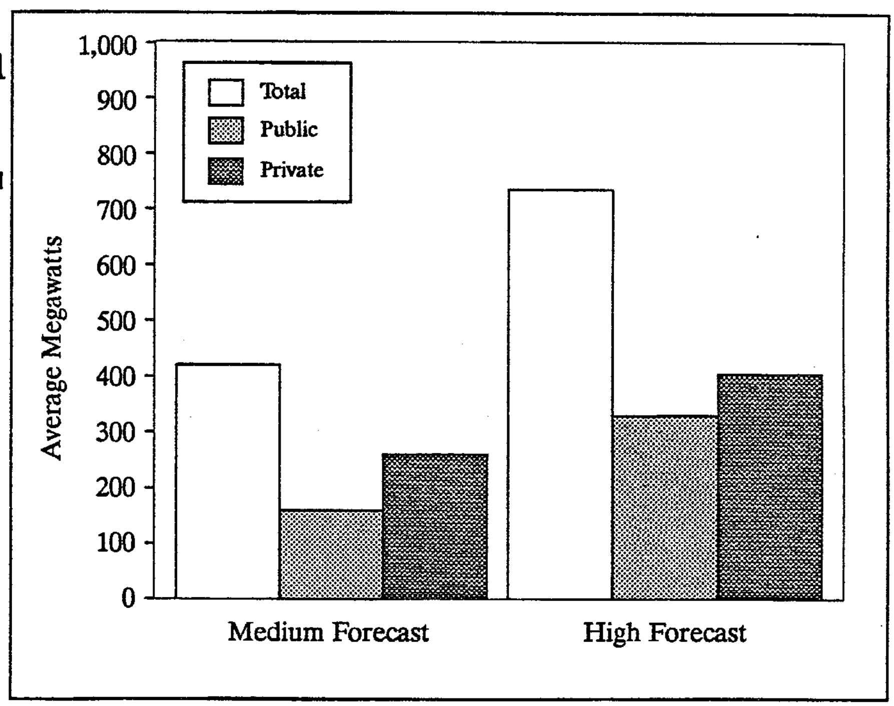


Figure 7-17 shows the amount of commercial sector conservation available at various costs in existing and new buildings.

Savings from existing commercial buildings are available at an average cost of 5 cents per kilowatt-hour. Savings from new commercial buildings are available at an average cost of about 2 cents per kilowatt-hour. These levelized costs escalate to 6 and 3 cents per kilowatt-hour, respectively, if administrative costs and transmission and distribution adjustments are included. Like new residences, it is important to build new commercial structures efficiently, in order to avoid losing a cost-effective conservation resource.

In addition to the resources described above, there are an estimated 150 additional average megawatts available from commercially available measures that cost between 10 and 13 cents per kilowatt-hour. While many of these technologies are available but expensive today, with the rapid change in technology in this sector, it is likely that many will become less expensive in the near future. This is especially true in the lighting end use where solid state electronics are revolutionizing the powering and control of electric lighting equipment.

Conservation Potential

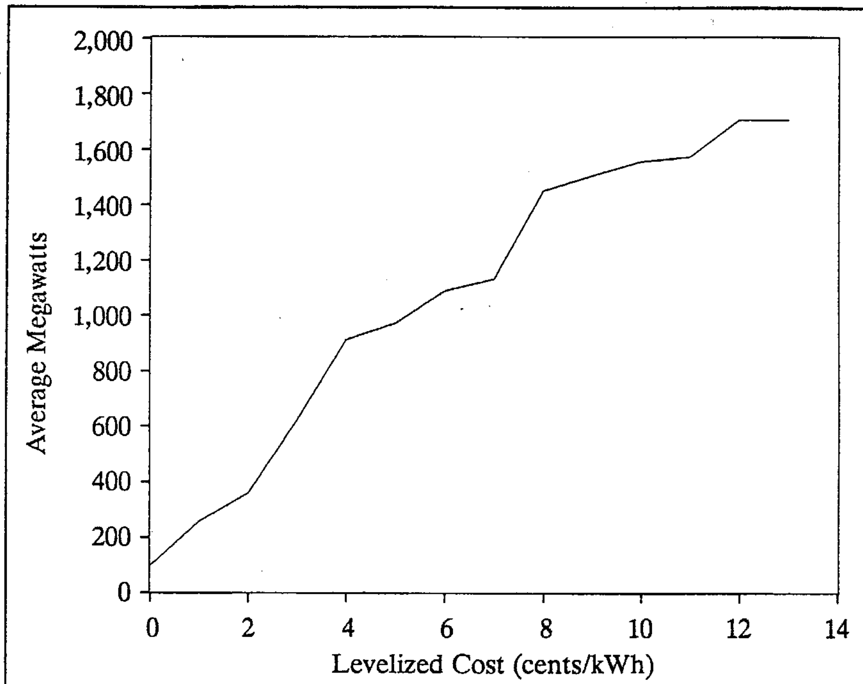


Figure 7–17
Technical Conservation Potential from the Commercial Sector

The Council's estimate of conservation savings from the commercial sector involved the following three steps:

1. Identify the current regional average consumption for typical existing and new commercial buildings.

2. Evaluate cost-effective efficiency improvements in existing and new commercial buildings.

3. Develop estimates of conservation potential in new and existing commercial buildings that are consistent with the Council's load forecasts.

Step 1. Identify the Current Regional Average Consumption for Typical Existing and New Commercial Buildings

The Council's commercial sector forecasting model contains representations of 10 building categories. Table 7-60 shows the annual energy use for all-electric[29] commercial buildings that comprised the stock in 1979, as estimated by the Council's forecast. This table also presents billing data information collected by Energuard and billing data information collected by the Commercial Audit Program (CAP). These two programs combined have large sample sizes for many of the building types. There is quite good agreement between the forecast estimates and data from billing records. For the forecast's restaurant category, there is a large discrepancy, because the forecast includes all types of restaurants, including sit-down and fast-food, while the billing data is from fast-food restaurants only. Fast-food restaurants have very high energy use per square foot, because they usually are quite small and serve a large number of meals per day. The warehouse category also has a large variance between one of the billing data samples and the forecast. This could be due to small sample size. It should be remembered that, while there is reasonable agreement between the forecast and billing data for average values, for most of these building categories, a tremendous variation exists in use in any given building.

To convey the relative importance of each building type in the analysis, the last column of Table 7-60 shows the percent of total electricity consumption for existing buildings in 2010, by building type. These percentages account for the fact that not all end uses require electricity as their fuel. Office and retail buildings are far and above the most crucial building types for determining electricity consumption in existing commercial buildings. These two building types alone represent almost 50 percent of projected electricity consumption in the year 2010 in currently existing commercial buildings.

29./ The term all-electric means that every end use in the building uses electricity as the fuel. The electricity consumption of the average building will be lower, since some end uses, for example, space heating, water heating or cooking, can be fueled by gas.

Table 7-60
Summary of Annual Energy Use for Existing Commercial Buildings Located in the Region (All-electric Buildings)

Building Type (Sample size = N)	Commercial Audit Program (kWh/sq. ft./yr.)	Energuard Data (kWh/sq. ft./yr.)	ELCAP[a] (kWh/sq. ft./yr)	Council's Forecast (1979 Stock) (kWh/sq ft/yr)	Building Type's Percent of Total Electricity Consumption in 2010
Office	28[b] (N=579)	27 (N=157)	21 (N=14)	25	30%
Retail	21 (N=681)	22 (N=581)	13 (N=17)	18	19%
Grocery	57[b] (N=198)	61 (N=336)	76 (N=6)	70	7%
Restaurant			43 (N=6)	38	5%
Fast-Food	133 (N=47)	116 (N=20)			
Hotel/Motel	26 (N=61)	23 (N=6)	--	19	2%
Health		29 (N=30)	--	19	6%
Hospital	81[c] (N=22)				
School	24[c] (N=61)	20 (N=146)	9 (N=2)	22	9%
College		inc. in "Schools"	7 (N=1)	20	4%
Warehouse	12 (N=43)	20 (N=77)	8 (N=12)	23	3%
Other		22 (N=41)	7 (N=3)	18	16%
					100%

[a] Consumption data from End-use Load and Conservation Assessment Project commercial summaries.

[b] Consumption data for this building type was augmented by information from the Public Utility Regulatory Policies Act of 1978.

[c] Consumption data for this building type was augmented by information from the Institutional Buildings Program (IBP) and the Institutional Conservation Program (ICP).

In comparing the billing data shown in Table 7-60 and the forecast model assumptions, three factors should be kept in mind. First, the buildings with billing data from the Commercial Audit Program and Energuard shown in Table 7-60 were not selected to be statistically representative of the average. Second, the annual use data from these sources represent each building's total energy use, regardless of the fuel source. Total energy use is then converted to kilowatt-hours per square foot. Since many of these buildings use natural gas or fuel oil for some end uses, the conversion efficiencies of these fuels are included in the figures. In contrast, the figures from ELCAP and the Council's forecast shown here assume that all energy requirements of the building are supplied by electricity. Third, the year of operation for the buildings in the sample is mostly prior to 1985, and the forecast figures use 1979 as the operating year. Finally, the ELCAP numbers include some new buildings in these summaries, although the majority of the buildings are pre-1980 stock.

The ELCAP data present some unique opportunities for further comparisons, because of the detailed end-use monitored data available. Unfortunately, the sample sizes monitored for most of the building types are so small that it is difficult to draw any conclusions from the group. However, the sample sizes for office and retail are large enough to permit some aggregation and draw some conclusions. Due to the sample selection procedure and limited size of even these groups. it would be careless to generalize these conclusions to the rest of the regional stock, but it is useful to compare the monitored data with both the forecast output and the engineering prototype analysis used to generate the supply curves.

Table 7-61 presents a comparison of the ELCAP data, prototype engineering analysis and the forecast estimates for a number of end uses in new and existing office and retail buildings. Since the ELCAP offices average less than 50,000 square feet, the ELCAP buildings must be compared more with the Uniform Industrial Code small prototypes than with the large prototype. Interestingly enough, the agreement between the forecast and the ELCAP data is fairly good for almost all end uses. However, neither Uniform Industrial Code prototype seems to agree very well with the forecast or the ELCAP data by end-use, even though the Uniform Industrial Code prototypes were calibrated to other samples of commercial buildings. Probably one of the more significant differences between the prototypes and the monitored data is the significantly higher cooling energy consumption and lower heating energy consumption in the ELCAP/forecast group, compared to the Uniform Industrial Code prototypes. Given that lighting impacts both heating and cooling, this difference has significant implications on the HVAC interactions of lighting measures. This observed difference was the primary reason for revising the interactions predicted by the engineering analysis.

Table 7-61
EUI Summary Table - Existing Office Buildings
kWh/sq. ft.

Building Type	Small Office	ComBase Offices	Pub Util Offices	Medium Office	Large Office
Developer	UIC	ELCAP N=7	NPPC/For	ASHRAE	UIC
Prototype	Baseline	Mean Pre-1980	1980 all Electric	Average all Cases	Base line
Floor Area (sq. ft.)	4,880	9,150	N/A	48,664	408,000
Space Heat	10.33	7.19	6.69	2.62	14.16
Space Cool	1.98	2.13	5.50	4.07	1.70
HVAC Auxiliary	1.20	2.69	4.23	2.77	5.34
Hot Water	0.54	1.40	0.25	0.27	0.20
Internal Lighting	5.76	9.37	8.37	6.36	10.11
External Lighting	1.26	2.17		0.00	0.39
Vertical Transport	0.30	0.05		1.39	0.90
Misc. Equipment	2.28	2.51	3.52	1.95	2.22
Total	23.66	27.51	28.55	19.42	35.02

Table 7-61 (cont.)
New Office Buildings
kWh/sq. ft.

Building Type	Small Office	ComBase Offices	Pub Util Offices	Medium Office	Large Office
Developer	UIC	ELCAP	NPPC/For	ASHRAE	UIC
Prototype	Base line	Mean Post-1979	1990 all Electric	Average all Cases	Base line
Floor Area (sq. ft.)	4,880	11,915	N/A	48,664	408,000
Space Heat	8.54	3.18	6.14	2.61	6.29
Space Cool	1.79	1.68	3.09	3.62	1.30
HVAC Auxiliary	2.01	4.43	4.00	2.78	2.96
Hot Water	0.52	0.60	0.26	0.27	0.20
Internal Lighting	5.46	6.13	8.20	6.39	8.52
External Lighting	1.36	1.39	--	0.00	0.38
Vertical Transport	0.29	0.05	--	1.39	0.60
Misc. Equipment	2.53	2.96	3.63	1.95	2.40
Total	22.50	20.42	25.21	19.00	22.65

Table 7-61 (cont.)
Existing Retail Buildings
kWh/sq. ft.

Building Type	Small Retails	ComBase Retails	Pub Util Retails	Large Retails
Developer	UIC	ELCAP	NPPC/For	UIC
Prototype	Base line	Mean Pre-1980	1980 all Electric	Base line
Floor Area (sq. ft.)	13,125	26.565	N/A	120,000
Space Heat	4.78	2.74	7.67	2.53
Space Cool	0.85	0.86	2.77	0.48
HVAC Auxiliary	1.00	0.64	3.84	3.25
Hot Water	0.42	0.52	0.20	0.21
Internal Lighting	7.75	6.28	6.02	13.77
External Lighting	0.87	0.69	--	0.26
Vertical Transport	0.00	0.02	--	0.64
Misc. Equipment	1.14	1.8	2.11	1.24
Total	16.81	13.55	22.69	22.38

Table 7-61 (cont.)
New Retail Buildings
kWh/sq. ft.

Building Type	Small Retails	ComBase Retails	Pub Util Retails	Large Retails
Developer	UIC	ELCAP	NPPC/For	UIC
Prototype	Base line	Mean Post-1979	1980 all Electric	Base line
Floor Area (sq. ft.)	13,125	2,867	N/A	120,000
Space Heat	3.50	3.11	7.01	0.39
Space Cool	0.74	0.55	1.44	0.63
HVAC Auxiliary	1.60	1.02	2.47	5.06
Hot Water	0.42	0.42	0.21	0.21
Internal Lighting	8.43	3.80	6.07	12.51
External Lighting	0.75	2.33	--	0.25
Vertical Transport	0.00	0.00	--	0.64
Misc. Equipment	0.87	1.08	2.17	0.60
Total	16.31	12.31	19.37	20.29

Less data is available on the actual energy use of newly built commercial buildings in the region. Table 7-62 shows energy use data that is available from new commercial buildings. The Council's forecast assumptions on new commercial buildings built to 1980 practice appear first in Table 7-62. These buildings are assumed to meet the level of ASHRAE 90-80A,[30] that represents the level of Oregon and Washington state building codes in 1980. The second column shows available data from work done by a Bonneville contractor and from work at the Oregon Department of Energy on billing information in recently built commercial buildings. This can be compared to billing data collected primarily through the Commercial Audit Program, which is shown in the third column. The final column in Table 7-62 shows the percent of electricity consumption in the year 2010 represented by each building type. Again, offices and retail stores are the most important building types, in terms of expected electricity consumption in 2010, if buildings continued to be constructed to 1986 codes. These building types are followed in importance by restaurants and groceries.

30./ ASHRAE stands for the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. This organization sets various standards for building practices based on consensus.

Table 7-62
Summary of Annual Energy Use for New Commercial Buildings Located in the Region (All-electric Buildings)

	1980 Practice From Forecast (kWh/sq. ft./yr.)	Sample of Current Practice (Approximately 1980 Construction) (Sample Size = N) (kWh/sq. ft./yr.)		Building Type's Percent of Total Electricity Consumption in 2010
		Oregon Survey	Commercial Audit Program	
Office	27	19 (N = 14)	21 (N = 159)	20%
Restaurant	30	--		12%
Fast-Food	N/A		141 (N = 16)	
Retail	20	22 (N = 8)	20 (N = 135)	17%
Grocery	58	44 (N = 1)	70 (N = 46)	11%
Warehouse	34	18 (N = 1)	15 (N = 5)	5%
School	22	16 (N = 3)	12 (N = 2)	9%
College	20	22 (N = 1)	--	3%
Health	16	--	--	9%
Hotel/Motel	13	--	23 (N = 12)	7%
Miscellaneous	14	28 (N = 2)	--	7%
				100%

The comparison of values in Table 7-62 needs to be qualified. First, the forecast figures for both 1980 practice and estimated 1988 practice assume an all-electric building; consequently, fuel conversion efficiencies are not incorporated. In contrast, the average use figures for current practice buildings are for total energy and include fuel conversion efficiencies. Second, the sample size of energy consumption in new buildings is very small, except for offices and retail, and buildings were not selected to represent the region.

In comparing data for new commercial buildings, it is important to understand that there have been significant changes in this portion of the sector that make it difficult to model. Changes in energy-use patterns in areas like Seattle that have recently experienced strong economic growth can greatly influence the total energy consumption of a building. In addition, increased use of computers, both desktop and central, have increased the total consumption and shifted a great deal of heating into a cooling requirement. Both of these trends, as well as other effects, have altered the way that the buildings behave, making it difficult to model from either a forecasting or engineering perspective.

Figure 7-18 compares predicted or modeled energy use with metered use, for offices from several different data sets, including the Seattle Major Projects Evaluation and Energy Edge. With this small a sample, it is very difficult to predict the absolute usage of a small sample of buildings. Further work needs to be completed to refine both the models and our understanding of the factors that drive the buildings energy use.

New Office Buildings Energy Use

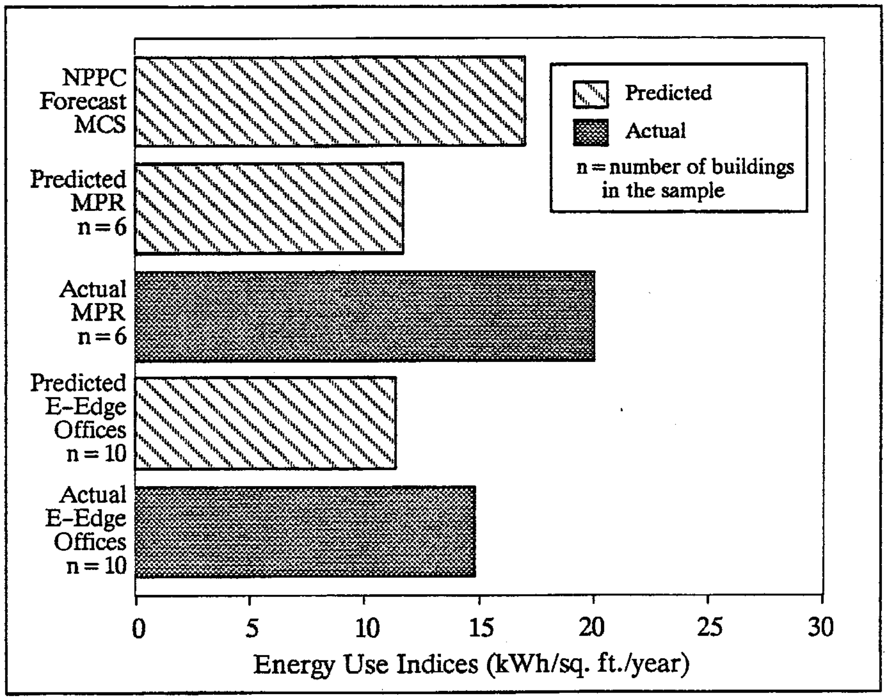


Figure 7-18
Preliminary Comparison of Energy Use Indices for New Office Buildings

Step 2. Evaluate the Efficiency Improvement Available in Existing and New Commercial Buildings

For both new and existing buildings, the estimates of cost-effective efficiency changes, and costs to achieve these changes are based primarily on work done for Bonneville by United Industries Corporation. This work develops base-case energy, use savings and costs from adding conservation measures for 12 prototype buildings. For existing commercial buildings, each prototype is modeled to reflect existing stock in 1979. To represent new commercial buildings, each prototype was modified to reflect how a new building of this prototype would have been built in 1980. The base-case use of each building prototype was calibrated to billing data available for that building type. These values primarily came from the Commercial Audit Program.

Initial costs and savings from installing conservation measures were estimated using an engineering model, which was calibrated to billing data. Because commercial conservation measures can have significant interaction with one another, it is necessary to use an engineering model to determine the net savings from an individual measure. For example, making lighting more efficient can save electricity both from the lights and from the cooling load of the building. But if the building has a greater heating load than cooling load, then more heating will be required when the more efficient lights are installed. Because of these and other interactions, savings that are evaluated from installing one individual measure can be under- or overestimated compared to the savings that can be achieved when a package of conservation measures is installed.

To the extent possible, the savings estimates take into account the interaction of the package of measures installed in the building. The Uniform Industrial Code work was used to determine the interaction terms for all of the prototypes except office and retail. Interaction terms for these two prototypes were taken from a study of lost-opportunity resources in renovations and remodels in the commercial sector. The primary reason for using the different set of interaction terms lies specifically in the large building prototypes in these sectors. The Uniform Industrial Code work predicted interaction terms that appeared to be too large for these types of buildings and the renovation/remodel study was thought to provide a more realistic assessment of these terms.

Measures analyzed for all prototype buildings fall primarily into the following end uses: lighting; heating, ventilation and air conditioning; and domestic hot water. Where appropriate, the prototypes included an analysis of refrigeration conservation measures as well. Lighting measures include efficient lamps and ballasts, more efficient fixtures and advanced control systems. Heating, ventilating and cooling improvements included such measures as economizers to use outside air to cool, variable air volume controls and radiant heaters, where applicable. Building structure measures, such as roof and wall insulation, and more efficient windows also were modelled as HVAC measures. Refrigeration improvements were taken from a study done for Bonneville by ADM Associates. Refrigeration savings applied only to grocery stores and restaurants.

As with any prototype work, some of the measures applied to the prototype building would not apply to a particular building, if an audit were done on it. Conversely, there may be measures that are not included in the prototype analysis that can be applied to the audited building. Essentially, the measures used in the prototype analysis are simply a proxy for the costs and savings that one could expect to achieve in the great variety of buildings the prototype represents. However, the actual measures that are installed to secure the savings may vary significantly from those in the prototype analysis.

Since the Uniform Industrial Code work was completed in 1987, there have been a number of technological improvements that allow greater levels of efficiency to be achieved, particularly in the lighting sector. A detailed look at lighting in the office and retail sectors was performed for this plan. Tables 7-63 through 7-70 list the individual measures for lighting, HVAC and domestic hot water for large and small offices and retail prototypes for both existing and new buildings. HVAC and domestic hot water measures were taken directly from the Uniform Industrial Code work, since there has been less innovation in these areas, since the Uniform Industrial Code work was completed.

Table 7-63
New Large Office

Measure Description	Energy Savings (kWh/yr.)	Energy Use (kWh/yr.)	Use (kWh/ sq. ft.)	Lighting Power Density (watts/sq. ft.)	Percent of Base	First Cost		
						Initial Cost (1982$)	Measure Life (years)	Levelized Cost (m./kWh)
Lights								
Base: 4x40W Fluor & 100w Inc		3,455,760	8.47	2.0	100%			
100W Incand. to 34W Fluor.	230,817	3,224,943	7.90	1.9	93%	21,476	30	19.9
T-8 Electronic Ballast	1,259,002	1,965,940	4.82	1.1	57%	110,735	30	12.0
Daylight Dimming Photocells	166,685	1,799,256	4.41	1.0	52%	28,273	30	27.9
3 Tube Parabolic Fixtures	366,745	1,432,511	3.51	0.8	41%	156,371	30	75.3

Measure Description	O&M			Measure		Program		
	O&M Cost (1982$)	O&M Life (years)	Levelized Cost (m./kWh)	Levelized Cost (mills/kWh)	Present Value Cost ($)	Cumulative Savings (kWh/yr.)	Cumulative Present Value ($)	Cumulative Cost (m./kWh)
Lights (cont.)								
Base: 4x40W Fluor & 100w Inc								
100W Incand. to 34W Fluor.	-6,400	1	-87.7	-67.8	-186,403	230,817	-186,403	-67.8
T-8 Electronic Ballast	18,791	6	8.5	20.5	307,453	1,489,820	121,050	6.8
Daylight Dimming Photocells	0	0	0.0	27.9	55,444	1,656,504	176,494	8.9
3 Tube Parabolic Fixtures	-11,409	6	-17.7	57.7	251,823	2,023,249	428,317	17.8

Table 7-63 (cont.)
New Large Office

Measure Description	Energy Savings (kWh/yr.)	Energy Use (kWh/yr.)	Use (kWh/ sq. ft.)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m./kWh)
HVAC							
Base Case		3,858,482	9.46	100%			
R-19 Wall Insulation	728,584	3,129,898	7.67	81%	43,517	45	7.5
Temp Reset, Multizone	314,119	2,815,779	6.90	73%	31,891	45	12.7
Low-E Windows	421,094	2,394,685	5.87	62%	71,878	30	28.1
Roof Insulation R-16 to R-30	13,527	2,381,158	5.84	62%	10,692	45	99.0

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m./kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr.)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m./kWh)
HVAC (cont.)								
R-19 Wall Insulation	0	0	0	7.5	64,906	72,8584	64,906	7.5
Temp Reset, Multizone	0	0	0	12.7	47,566	104,2703	112,471	9.1
Low-E Windows	0	0	0	28.1	140,955	146,3797	253,426	14.5
Roof Insulation R-16 to R-30	0	0	0	99.0	15,947	147,7324	269,373	15.3

Table 7-63 (Cont.)
New Large Office

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
Hot Water							
Base Case		79,988	0.20	100%			

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
Hot Water (cont.)								

Table 7-64
New Large Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Lighting Power Density (Watts/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
Lights								
Base Case		1,486,392	12.39	2.5	100%			
Efficient Incandescent	198,482	1,287,910	10.73	2.2	87%	5491	15	8.7
T-8 Elec & 3T Para (Sales)	615,168	672,742	5.61	1.1	45%	75014	15	31.1
2T T-8 Electronic (storage)	46,866	625,877	5.22	1.1	42%	6914	15	35.0

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
Lights (cont.)								
Efficient Incandescent	-1,232	1	-19.6	-10.9	-25,826	198,482	-25,826	-10.9
T-8 Elec & 3T Para (Sales)	598	4	0.8	31.9	233,847	813,650	20,8021	21.5
2T T-8 Electronic (storage)	541	4	9.6	44.5	24,852	860,515	232,873	22.7

Table 7-64 (cont.)
New Large Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
HVAC							
Base Case		638,734	5.32	100%			
Efficient Fan Motors	16,083	622,651	5.19	97%	14,883	18	210.7
Roof Insulation	8,778	613,873	5.12	96%	55,278	45	788.7

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
HVAC (cont.)								
Efficient Fan Motors	0	0	0	210.7	40,364	16,083	40,364	210.7
Roof Insulation	0	0	0	788.7	82,447	24,861	122,811	1174.8

Table 7-64 (cont.)
New Large Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Percent of Base	First Cost		
					Initial Cost (1982$)	Measure Life (years)	Levelized Cost (m/kWh)
Hot Water							
Base Case		25,198	0.21	100%			
DHW Tank Insulation	1,452	23,746	0.20	94%	285	15	50.5
DHW Cock Timer	160	23,586	0.20	94%	206	10	466.4

Measure Description	O&M			Measure		Program		
	O&M Cost (1982$)	O&M Life (years)	Levelized Cost (m/kWh)	Levelized Cost (mills/kWh)	Present Value Cost ($)	Cumulative Savings (kWh/yr)	Cumulative Present Value ($)	Cumulative Cost (m/kWh)
Hot Water (cont.)								
DHW Tank Insulation	0	0	0	50.5	873	1,452	873	50.5
DHW Cock Timer	0	0	0	466.4	889	1,612	1,762	924.6

Table 7-65
New Small Office

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Lighting Power Density (Watts/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
Lights								
Base Case		28,128	5.76	2.2	100%			
Incand. to 34W Fluorscent	1,774	26,354	5.40	2.1	94%	372	15	70.6
T-8 Electronic Ballast	5,857	20,496	4.20	1.6	73%	1,465	25	38.7
Daylight Dimming Photocells	1,179	19,317	3.96	1.5	69%	361	25	55.3
3 Tube Parabolic Fixtures	1,640	17,677	3.62	1.4	63%	1,075	25	131.7

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
Lights (cont.)								
Incand. to 34W Fluorscent	-115.0	1	******	-134.6	-2,843	1,774	-2,843	-134.6
T-8 Electronic Ballast	207	6	20.1	58.8	4,102	7,632	1,259	13.8
Daylight Dimming Photocells	0	0	0	55.3	776	8,811	2,034	19.4
3 Tube Parabolic Fixtures	-123	6	-42.6	89.1	1,741	10,451	3,775	30.3

Table 7-65 (cont.)
New Small Office

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
<u>HVAC</u>							
Base Case		49,809	10.21	100%			
Reduce Minimum Outside Air	4,585	45,224	9.27	91%	47	15	2.6
Wall Insulation	8,898	36,326	7.44	73%	1,547	45	21.8
Roof Insulation	3,659	32,667	6.69	66%	951	45	32.6
Optimum Start Timer	3,092	29,575	6.06	59%	1,107	15	92.1
Low-E Windows	2,706	26,869	5.51	54%	1,207	30	73.5
Economizer	4,706	22,163	4.54	44%	2,020	15	110.4
Heat Pump 1.9	8,198	13,965	2.86	28%	4,429	15	139.0

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
<u>HVAC</u> (cont.)								
Reduce Minimum Outside Air	0	0	0	2.6	144	4,585	144	2.6
Wall Insulation	0	0	0	21.8	2,307	13,483	2,451	23.1
Roof Insulation	0	0	0	32.6	1,418	17,142	3,870	88.8
Optimum Start Timer	0	0	0	92.1	3,391	20,234	7,261	197.2
Low-E Windows	0	0	0	73.5	2,367	22,940	9,628	298.8
Economizer	0	0	0	110.4	6,188	27,646	15,816	282.2
Heat Pump 1.9	0	0	0	139.0	13,567	35,844	29,383	301.0

Table 7-65 (cont.)
New Small Office

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Percent of Base	First Cost		
					Initial Cost (1982$)	Measure Life (years)	Levelized Cost (m/kWh)
Hot Water							
Base Case		2,637	0.54	100%			
DHW Tank Insulation	363	2,274	0.47	86%	71	15	50.3
DHW Cock Timer	65	2,209	0.45	84%	51	15	201.8

Measure Description	O&M			Measure		Program		
	O&M Cost (1982$)	O&M Life (years)	Levelized Cost (m/kWh)	Levelized Cost (mills/kWh)	Present Value Cost ($)	Cumulative Savings (kWh/yr)	Cumulative Present Value ($)	Cumulative Cost (m/kWh)
Hot Water (cont.)								
DHW Tank Insulation	0	0	0	50.3	217	363	217	50.3
DHW Cock Timer	0	0	0	201.8	156	428	374	482.8

Table 7-66
New Small Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Lighting Power Density (Watts/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
Lights								
Base Case		104,030	7.93	1.9	100%			
Efficient Incand.	10,379	93,651	7.14	1.7	90%	2,158	15	54.5
T-8 Electronic (Sales)	24,615	69,035	5.26	1.3	66%	5,547	15	57.5
2T T-8 Electronic (storage)	3,815	65,220	4.97	1.2	63%	306	15	15.6

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
Lights (cont.)								
Efficient Incandescent	-42.25	1	-12.9	41.6	5,147	10,379	5,147	41.6
T-8 Electronic (Sales)	48	4	1.6	59.1	17,319	34,995	22,466	53.9
2T T-8 Electronic (storage)	75	4	16.2	31.8	1,443	38,810	23,909	51.7

Table 7-66 (cont.)
New Small Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
HVAC							
Base Case		66,217	5.05	100%			
Wall Insulation (sales)	12,896	53,321	4.06	81%	1,229	45	11.9
Wall Insulation (storage)	1,869	51,452	3.92	78%	751	45	50.3
Roof Insulation (sales)	25,082	26,370	2.01	40%	4,645	45	23.2
Roof Insulation (storage)	1,672	24,698	1.88	37%	819	45	61.3
Low-e Windows	1,962	22,736	1.73	34%	760	45	48.5
Radiant Heaters	828	21,908	1.67	33%	346	10	151.4
Heat Pump COP 2.0	7,344	14,564	1.11	22%	4,872	10	240.3

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
HVAC (cont.)								
Wall Insulation (sales)	0	0	0	11.9	1,833	12,896	1,833	11.9
Wall Insulation (storage)	0	0	0	50.3	1,120	14,765	2,953	132.7
Roof Insulation (sales)	0	0	0	23.2	6,928	39,847	9,881	33.1
Roof Insulation (storage)	0	0	0	61.3	1,222	41,519	11,103	557.6
Low-e Windows	0	0	0	48.5	1,134	43,481	12,236	523.7
Radiant Heaters	0	0	0	151.4	1,493	44,309	13,729	1392.3
Heat Pump COP 2.0	0	0	0	240.3	21,020	51,653	34,749	397.3

Table 7-66 (cont.)
New Small Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
Hot Water							
Base Case		5,567	0.42	100%			
DHW Tank Insulation	363	5,204	0.40	93%	71	15	50.3
DHW Cock Timer	40	5,164	0.39	93%	51	10	461.9

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
Hot Water (cont.)								
DHW Tank Insulation	0	0	0	50.3	217	363	217	50.3
DHW Cock Timer	0	0	0	461.9	220	403	438	918.5

Table 7-67
Existing Large Office

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Lighting Power Density (Watts/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
Lights								
Base Case 40W Fluor & 100w Inc		3,801,336	9.32	2.2	100%			
100W Incand. to 34W Fluor.	216,950	3,584,386	8.79	2.1	94%	60,848	15	79.7
T-8 EEM Bal & Parab. Fixt	1,696,733	1,887,653	4.63	1.1	50%	410,458	30	37.9
T-8 Add Electronic Ballasts	318,077	1,569,575	3.85	0.9	41%	86,396	30	42.6
Daylight Photocell Dimming	138,317	1,431,259	3.51	0.8	38%	42,692	30	48.4

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
Lights (cont.)								
100W Incand. to 34W Fluor.	-6,400	1	-93.3	-13.6	-32,685	216,949.8	-32,685	-13.6
T-8 EEM Bal & Parab. Fixt	382	6	0.1	38.0	715,562	191,3683.	682,877	32.1
T-8 Add Electronic Ballasts	0	0	0	42.6	150,251	223,1760.	833,129	33.6
Daylight Photocell Dimming	0	0	0	48.4	74,245	237,0077.	907,374	34.5

Table 7-67 (cont.)
Existing Large Office

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
HVAC							
Base Case Term/Reheat		8,649,293	21.20	100%			
Temp Reset, Multizone	599,341	8,049,941	19.73	93%	4,651	11	2.6
Roof Insulation R-6 to R-19	42,543	8,007,398	19.63	93%	8,283	30	30.5
Variable Air Volume	3,331,686	4,675,712	11.46	54%	761,184	11	76.7

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
HVAC (cont.)								
Temp Reset, Multizone	0	0	0	2.6	17,335	599,341	17,335	2.6
Roof Insulation R-6 to R-19	0	0	0	30.5	14,405	641,884	31,740	4.5
Variable Air Volume	0	0	0	76.7	2,837,097	3,973,570	2,868,837	65.0

Table 7-67 (cont.)
Existing Large Office

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Percent of Base	First Cost		
					Initial Cost (1982$)	Measure Life (years)	Levelized Cost (m/kWh)
Hot Water							
Base Case		79,988	0.20	100%			

Measure Description	O&M			Measure		Program		
	O&M Cost (1982$)	O&M Life (years)	Levelized Cost (m/kWh)	Levelized Cost (mills/kWh)	Present Value Cost ($)	Cumulative Savings (kWh/yr)	Cumulative Present Value ($)	Cumulative Cost (m/kWh)
Hot Water (cont.)								

Table 7-68
Existing Large Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Lighting Power Density (Watts/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
Lights								
Base Case		1,636,364	13.64	2.8	100%			
Efficient Incandescent	211,002	1,425,362	11.88	2.4	87%	24,842	15	31.6
2T T-8 Electronic (storage)	45,201	1,380,162	11.50	2.3	84%	11,114	15	60.2
T-8 Elec & 3T Para (Sales)	660,527	719,634	6.00	1.2	44%	179,376	15	69.6

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
Lights (cont.)								
Efficient Incandescent	-1,087	1	-16.3	15.3	35,862	211,002	35,862	15.3
2T T-8 Electronic (storage)	541	4	9.9	70.1	35,162	256,202	71,023	25.0
T-8 Elec & 3T Para (Sales)	665	4	0.8	70.4	516,396	916,729	587,419	57.7

Table 7-68 (cont.)
Existing Large Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/sq ft)	Percent of Base	First Cost		
					Initial Cost (1982$)	Measure Life (years)	Levelized Cost (m/kWh)
HVAC							
Base Case		750,366	6.25	100%			
Reduce Minimum Outside Air	139,585	610,781	5.09	81%	6,219	9	17.7
Roof Insulation	220,617	390,164	3.25	52%	26,576	30	18.9
Caulking & Weatherstripping	1,095	389,069	3.24	52%	280	10	92.1
Wall Insulation	136,024	253,045	2.11	34%	135,750	30	156.4
Radiant Heaters (Storage)	3,803	249,242	2.08	33%	3,366	10	318.6

Measure Description	O&M			Measure		Program		
	O&M Cost (1982$)	O&M Life (years)	Levelized Cost (m/kWh)	Levelized Cost (mills/kWh)	Present Value Cost ($)	Cumulative Savings (kWh/yr)	Cumulative Present Value ($)	Cumulative Cost (m/kWh)
HVAC (cont.)								
Reduce Minimum Outside Air	0	0	0	17.7	27,473	139,585	27,473	17.7
Roof Insulation	0	0	0	18.9	46,218	360,202	73,691	30.1
Caulking & Weatherstripping	0	0	0	92.1	1,119	361,297	74,810	6,154.8
Wall Insulation	0	0	0	156.4	236,082	497,321	310,893	205.9
Radiant Heaters (Storage)	0	0	0	318.6	13,451	501,124	324,343	7,683.2

Table 7-68 (cont.)
Existing Large Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
Hot Water							
Base Case		25,198	0.21	100%			
DHW Tank Insulation	1,734	23,464	0.20	93%	187	10	38.8
DHW Time Clocks	168	23,296	0.19	92%	206	10	441.4

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
Hot Water (cont.)								
DHW Tank Insulation	0	0	0	38.8	747	1,734	747	38.8
DHW Time Clocks	0	0	0	441.4	823	1,902	1,570	842.1

Table 7-69
Existing Small Office

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/sq ft)	Lighting Power Density (Watts/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
<u>Lights</u>								
Base Case 40W Fluor & 100w Inc		25,236	5.17	2.0	100%			
Incand. to 34W Fluorscent	1,774	23,461	4.81	1.8	93%	1,053	15	168.7
T-8 Electronic Ballast	5,857	17,604	3.61	1.4	70%	2,650	25	77.1
Daylight Dimming Photocells	1,179	16,425	3.37	1.3	65%	722	25	113.3
3 Tube Parabolic Fixtures	1,580	14,845	3.04	1.2	59%	3,647	30	374.5

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
<u>Lights</u> (cont.)								
Incand. to 34W Fluorscent	-110.6	1	******	-28.6	-563	1,774	-563	-28.6
T-8 Electronic Ballast	207	6	20	97.2	6318	7,632	5,755	67.9
Daylight Dimming Photocells	0	0	0	113.3	1483	8,811	7,238	74.0
3 Tube Parabolic Fixtures	-128	6	-46.0	328.5	5759	10,390	12,998	112.7

Table 7-69 (cont.)
Existing Small Office

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
HVAC							
Base Case		65,924	13.51	100%			
Reduce Minimum Outside Air	7,315	58,609	12.01	89%	68	15	2.4
Roof Insulation	5,502	53,107	10.88	81%	1,189	30	33.9
Low-E Glass	9,088	44,019	9.02	67%	5,207	30	89.8
Optimum Start timer	3,606	40,413	8.28	61%	1,506	15	107.4
High-Eff Heat Pump @ Repl.	16,836	23,577	4.83	36%	7,796	15	119.1
Economizer	4,296	19,281	3.95	29%	2,215	15	132.6

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
HVAC (cont.)								
Reduce Minimum Outside Air	0	0	0	2.4	194	7,315	194	2.4
Roof Insulation	0	0	0	33.9	2,068	12,817	2,262	37.0
Low-E Glass	0	0	0	89.8	9,055	21,905	11,317	112.2
Optimum Start timer	0	0	0	107.4	4,300	25,511	15,618	390.2
High-Eff Heat Pump @ Repl.	0	0	0	119.1	22,260	42,347	37,878	202.7
Economizer	0	0	0	132.6	6,325	46,643	44,203	926.9

Table 7-69 (cont.)
Existing Small Office

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/sq ft)	Percent of Base	First Cost		
					Initial Cost (1982$)	Measure Life (years)	Levelized Cost (m/kWh)
Hot Water							
Base Case		2,506	0.51	100%			
DHW Tank Insulation	413	2,093	0.43	84%	47	10	41.0
DHW Cock Timer	65	2,028	0.42	81%	51	15	201.8

Measure Description	O&M			Measure		Program		
	O&M Cost (1982$)	O&M Life (years)	Levelized Cost (m/kWh)	Levelized Cost (mills/kWh)	Present Value Cost ($)	Cumulative Savings (kWh/yr)	Cumulative Present Value ($)	Cumulative Cost (m/kWh)
Hot Water (cont.)								
DHW Tank Insulation	0	0	0	41.0	188	413	188	41.0
DHW Cock Timer	0	0	0	201.8	146	478	333	462.1

Table 7-70
Existing Small Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Lighting Power Density (Watts/sq ft)	Percent of Base	First Cost: Initial Cost (1982$)	First Cost: Measure Life (years)	First Cost: Levelized Cost (m/kWh)
Lights								
Base Case		104,030	7.93	1.9	100%			
Efficient Incandescent	9,596	94,434	7.19	1.7	91%	2158	15	59.0
T-8 Electronic (Sales)	22,758	71,675	5.46	1.3	69%	5547	15	62.2
2T T-8 Electronic (storage)	1,568	70,108	5.34	1.3	67%	306	15	37.9

Measure Description	O&M: O&M Cost (1982$)	O&M: O&M Life (years)	O&M: Levelized Cost (m/kWh)	Measure: Levelized Cost (mills/kWh)	Measure: Present Value Cost ($)	Program: Cumulative Savings (kWh/yr)	Program: Cumulative Present Value ($)	Program: Cumulative Cost (m/kWh)
Lights (cont.)								
Efficient Incandescent	-42.25	1	-13.9	45.0	4798	9596	4798	45.0
T-8 Electronic (Sales)	48	4	1.7	63.9	16143	32355	20941	58.3
2T T-8 Electronic (storage)	75	4	39.4	77.4	1346	33922	22287	59.2

Table 7-70 (cont.)
Existing Small Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Percent of Base	First Cost Initial Cost (1982$)	First Cost Measure Life (years)	First Cost Levelized Cost (m/kWh)	
HVAC								
Base Case		87,020	6.63	100%				
Roof Insulation (Sales)	33,258	53,762	4.10	62%		5,436	30	25.6
Roof Insulation (Storage)	2,445	51,317	3.91	59%	959	30	61.5	
COP 2.0 Heat Pumps (Repl)	22,533	28,784	2.19	33%	4,872	15	55.6	
Low-E Windows (Sales)	7,518	21,266	1.62	24%	5,535	30	115.3	
Heat Recovery Exhaust	7,533	13,733	1.05	16%	6,192	14	226.2	

Measure Description	O&M Cost (1982$)	O&M Life (years)	O&M Levelized Cost (m/kWh)	Measure Levelized Cost (mills/kWh)	Measure Present Value Cost ($)	Program Cumulative Savings (kWh/yr)	Program Cumulative Present Value ($)	Program Cumulative Cost (m/kWh)
HVAC (cont.)								
Roof Insulation (Sales)	0	0	0	25.6	9,454	33,258	9,454	25.6
Roof Insulation (Storage)	0	0	0	61.5	1,668	35,703	11,122	409.8
COP 2.0 Heat Pumps (Repl)	0	0	0	55.6	13,911	58,236	25,033	100.1
Low-E Windows (Sales)	0	0	0	115.3	9,626	65,754	34,659	415.3
Heat Recovery Exhaust	0	0	0	226.2	18,913	73,287	53,571	640.7

Table 7-70 (cont.)
Existing Small Retail

Measure Description	Energy Savings (kWh/yr)	Energy Use (kWh/yr)	Use (kWh/ sq ft)	Percent of Base	First Cost		
					Initial Cost (1982$)	Measure Life (years)	Levelized Cost (m/kWh)
Hot Water							
Base Case		5,567	0.42	100%			
DHW Tank Insulation	424	5,143	0.39	92%	47	10	39.9
DHW Cock Timer	40	5,103	0.39	92%	51	10	459.0

Measure Description	O&M			Measure		Program		
	O&M Cost (1982$)	O&M Life (years)	Levelized Cost (m/kWh)	Levelized Cost (mills/kWh)	Present Value Cost ($)	Cumulative Savings (kWh/yr)	Cumulative Present Value ($)	Cumulative Cost (m/kWh)
Hot Water (cont.)								
DHW Tank Insulation	0	0	0	39.9	188	424	188	39.9
DWH Cock Timer	0	0	0	459.0	204	464	392	882.0

C:JPH.M11/GENERAL.BK6 Tables 7-63 through 7-70

The lighting analysis from these two building types indicates that it is possible to achieve approximately 50 percent savings of lighting energy using current high-efficiency lamps, solid state electronic ballasts and daylighting controls. This estimate of efficiency improvements is conservative, relative to estimates from the Rocky Mountain Institute and Lawrence Berkeley Laboratories, but it is more in keeping with the experience of programs in the Northwest. However, the analysis is still limited to some extent by the prototypes. This estimate is 50 percent of 1980 levels of energy consumption. The 1986 codes adopted in Oregon and Washington will reduce these savings to approximately 40 percent still achievable from new construction. It is clear that a significant reduction in lighting consumption in these two building types is possible.

Table 7-71 shows the savings percentages, if all measures costing less than 10 cents per kilowatt-hour are added to the prototypes that represent existing buildings. The table also shows the pre-conservation consumption estimate for each prototype building, which reflects the 1979 stock. These savings can be compared to savings estimates from Puget Power's retrofit program collected for the 1986 Power Plan. Puget's information is shown in Table 7-72. Some of the prototype buildings in Table 7-71 result in estimates of savings and use close to those reported by Puget, while others are quite different. Some of the differences may stem from the representativeness of the prototypes. For example, the hospital prototype does not encompass general health care buildings, such as doctor's offices and laboratories, while Puget's audit program may have included these. The vintage of the buildings in Puget's program also is unknown compared to this analysis. Finally, it is not clear how the cost of measures recommended in Puget's program compares with the 10 cents per kilowatt-hour levelized cost used to cut off the conservation measures in the prototype analysis. It appears that significant savings can be achieved by retrofitting existing buildings, from 12 percent to over 40 percent of the energy used.

Table 7-71
Costs and Percent Savings for Conservation in Existing (1979 Vintage) Commercial Buildings: Prototype Analysis[a]

	Percent Savings	Average Levelized Cost of Measures (mills/kWh)	Base-Case Use (kWh/sq. ft./yr.)
Office	37%	29	29
Retail	40%	39	19
Fast-Food Restaurant	29%	61	123
Warehouse	42%	30	12
Hospital	12%	18	64
Schools	41%	39	21
Grocery	25%	33	58
Hotel	23%	37	28

[a] These values are for an all-electric building.

Table 7-73 shows cost and savings information similar to Table 7-71 for new buildings.

Table 7-72
Retrofit Savings from Existing Commercial Buildings: Puget Power's Program[a]

Building Type (Sample Size = N)	Percent Savings from Average Use	Average Use of Program Buildings (Pre-Retrofit) (kWh/sq. ft./yr.)
Office (N=62)	30%	26
Retail (N=11)	16%	25
Grocery (N=36)	23%	62
Restaurant (N=10)	22%	89
Hotel (N=2)	16%	24
Hospital (N=30)	28%	29
School (N=28)	17%	24
Warehouse (N=4)	26%	16
Other (N=8)	21%	22

Average savings = 22 percent
Average savings weighted by building type = 22 percent

a Program offers measures, such as heating, ventilating and air-conditioning modifications, glazing and insulation, lighting measures and some process modifications.

A significant problem that surfaces from the prototype analysis is that, in some cases, the prototypes used for the conservation analysis poorly represent the building categories used in the load forecast. For example, a fast-food restaurant was modeled as the restaurant prototype, but the restaurant category in the forecast includes fast-food restaurants, cafeterias and leisure dining. Extra care was taken to make the prototypes for offices and retail stores consistent with the categories used in the load forecast, because these are the most important building types. However, limited information prevented this kind of extensive modeling on some of the other building types.

A discussion of how the prototypes were used to represent the forecast building categories follows. For the building categories of offices, retail stores, schools and groceries, the levelized costs and percent savings estimates from the prototypes were used directly to represent savings off the 1979 or 1980 base.[31]

For the restaurant category in the forecast, the fast-food prototype was assumed to represent 14 percent of the restaurant floor space and this portion received all the costs and savings for the fast food prototype. The residual 86 percent of restaurant floor space was assumed to save only the costs and savings

31./ As described in subsequent paragraphs, these base lines also were changed to account for retrofitting since 1979 and new building codes that went into effect after 1980.

that were available on the prototype for lights and heating, ventilating and air conditioning.

For hotels/motels, the hotel prototype was assumed to represent 41 percent of the floor space, and this received all the costs and savings modeled in the prototype. The remaining 59 percent of hotel/motel floor space was given the costs and savings from lighting improvements only modeled on the prototype.

For warehouses, the prototype was assumed to represent 32 percent of the floor space, and all the costs and savings were attributed to this portion. For the remaining 68 percent of floor space, lighting costs and savings only from the prototype were used.

The building categories of health and college were represented as a mix of the other building prototypes. The health sector in the forecasting model includes laboratories, nursing homes, offices and hospitals. The prototype represents only hospitals. The mix of other prototypes that was used to represent the forecast health category was: 49 percent hospital, 34 percent small office and 17 percent hotel. There was no prototype developed for colleges, but the mix of prototypes that was used to represent this forecast category was: 21 percent school, 13 percent small office, 12 percent restaurant, 1 percent hospital, 20 percent hotel and 33 percent miscellaneous.

Finally, the miscellaneous building category was assumed to achieve a 15-percent savings over the 1979 base case for existing buildings and 1980 base case for new buildings.

Table 7-73
Costs and Percent Savings for Conservation in New (1980 Vintage) Commercial Buildings Prototype Analysis[a]

	Percent Savings	Average Levelized Cost of Measures (mills/kWh)	Base-Case Use (kWh/sq. ft.)
Office	36%	39	21
Retail	38%	45	18
Fast-Food Restaurant	26%	57	126
Warehouse	42%	37	9
Hospital	14%	16	62
Schools	7%	65	10
Grocery	28%	24	62
Hotel	13%	37	24

[a] These values are based on an all-electric building.

Table 7-74 shows the actual percent savings and levelized costs that were estimated for each of the forecast building categories at a 10 cents per kilowatt-hour cutoff after all these adjustments were made. The efficiency level achieved after all cost-effective improvements are made in existing buildings built before 1980 is also the efficiency level assumed for buildings constructed between 1980 and

1986. While these buildings are probably more efficient to begin with than the average pre-1979 stock, there are still savings to be secured. The assumption is that they can be taken to a similar post-conservation efficiency level at a similar cost to the pre-1979 stock.

Table 7-74
Percent Savings and Levelized Cost
Estimated for the Forecast Building Categories[a]

	Existing Stock (1979 Base)		New Construction (1980 Base)	
	% Savings	Levelized Cost (mills/kWh)	% Savings	Levelized Cost (mills/kWh)
Office	37%	29	36%	39
Retail	40%	39	38%	45
Grocery	25%	30	28%	25
Restaurant	24%	62	25%	64
Hotel/Motel	12%	44	8%	37
Health	16%	27	22%	31
Elementary/Secondary	41%	35	7%	68
College	22%	28	17%	51
Warehouse	18%	32	19%	43
Miscellaneous	15%	44	15%	51

[a] Based on an all-electric building.

Another problem that is created by the prototype analysis stems from the year used as the base case. Table 7-74 indicates the cost-effective savings available from existing buildings in 1979 and new buildings built in 1980. However, between 1979 and 1988, some retrofit activity has diminished the conservation resource in existing buildings, and new buildings built after 1980 already will be complying with new energy codes that were adopted after 1980. Consequently, the conservation potential in new commercial buildings also is reduced compared to Table 7-74. For existing commercial buildings, the savings that already have occurred through retrofitting are estimated using the forecasting model. The forecast estimates that an average 22 percent of the cost-effective savings available in Table 7-74 already have occurred by 1988 for the existing stock. Since this estimate is derived using the forecasting model, it is consistent with the forecast's estimates of fuel saturations. The fact that 22 percent of the savings already is achieved also means that some of the costs also have been incurred. The simplifying assumption made in this analysis is that the very cheapest measures were used to achieve the 22-percent savings that occurred between 1979 and 1988. The average savings summarized in this chapter incorporate the reduction in savings and increase in cost from retrofit activity that has occurred since 1979.

A similar problem exists for new commercial buildings. Oregon and Washington, which represent a significant portion of expected new commercial growth, adopted more stringent commercial building codes in 1986. Since the savings estimates in Table 7-74 are based on new construction in 1980, the effect of the more stringent codes must be removed to determine the remaining conservation potential that is yet to be secured. For the values in this draft, this was accomplished by estimating the reduction in energy use in new commercial buildings as a consequence of the 1986 codes. This estimate was taken from work done by Battelle Pacific Northwest Laboratories for the Council, combined with some estimates using the prototypes in this conservation analysis.

The amount of savings resulting from the 1986 codes was estimated using the forecasting model. About 47 percent of the total savings represented in Table 7-74 are secured through current building codes, if those codes are fully enforced. These codes (but only with partial compliance) are represented in the load forecasts. The remaining 53 percent is yet to be achieved through both strengthened codes and programs. It is important to note that this estimate of savings from existing codes assumes that the energy related portions of those codes, such as lighting budgets and insulation, are being enforced. If these codes currently are not enforced, much of the conservation that is already counted as secured will be lost.

Step 3. <u>Develop Estimates of Technical Realizable Potential for Conservation in New and Existing Commercial Buildings, Consistent with the Load Forecast</u>

The total regional savings available from conservation potential in new and existing buildings was estimated using the Council's commercial sector forecasting models, as described below.

First, this sector's demand was forecast assuming efficiency improvements were made to existing buildings through 1989 and new buildings are built to existing state building codes. Then the percent improvement represented by the 10 cents per kilowatt-hour conservation cut off was imposed on each building type, and the demand for electricity was re-estimated. The difference between projected demand at current 1989 efficiencies and demand with the technical conservation improvements represented the total technical conservation.

In the Council's high forecast, approximately 810 average megawatts are achievable in existing buildings and 643 average megawatts in new commercial buildings. As mentioned above, the Council is committed to further reviewing measures that can be applied to these prototype buildings, which is likely to increase savings. Table 7-75 shows the total technical conservation that is available at a given cost in the high- and medium-demand forecasts. While the megawatts at 10 cents per kilowatt-hour are based on an aggregation of the prototypes, the shape of the supply curve is based on the distribution of savings from the office and retail prototypes only. Consequently, it simply should be viewed as an approximation of the shape of the curve.

Table 7-75 indicates that there is approximately another 150 average megawatts of savings between 10 cents per kilowatt-hour and 13 cents per kilowatt hour. While the curve is definitely flattened out at this point, it is not clear whether this is a real effect or more a function of the limitations of the Uniform Industrial Code work. As mentioned earlier, technology changes, particularly in lighting, may provide additional savings in this higher cost block. The Council is committed to pursuing this issue in more detail, as more information on the newer technologies becomes available.

Table 7-75
Technical Conservation from Commercial Buildings

Levelized Cost Nominal	Real	Total Cumulative Megawatts High	Medium
1	0.5	281	160
2	1.0	389	222
3	1.5	680	388
4	2.0	998	570
5	2.5	1,061	606
6	3.0	1,190	679
7	3.5	1,238	707
8	4.0	1,588	906
9	4.5	1,649	941
10	5.0	1,704	973
11	5.5	1,724	984
12	6.0	1,871	1,068
13	6.5	1,871	1,068

As a final note, the current analysis assumes that the savings in existing buildings are achieved at the full cost and limited application of a true retrofit situation. Analysis in the renovation/remodel study indicate that a significant quantity of savings are available at a substantially lower cost, if the measures are installed during a normal remodel or renovation cycle of a building. In some building types, these events are fairly frequent and should be pursued as a vehicle for program acquisition. If this program emphasis does take place then the costs for retrofit may well be overestimated in this analysis and the savings possibly underestimated. Offsetting this to some unknown degree may be a shortened lifetime for the conservation measure.

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Industrial Sector

In 1989, firm sales to the industrial sector were 6,900 average megawatts, which is about 40 percent of firm loads. About one-third of total industrial demand for electricity is consumed by the direct service industries, which are mainly the aluminum industry, and some chemical and other primary metal producers. The largest consumers among the non-direct service industries are lumber and wood products, pulp and paper, chemicals, food processing and primary metals.

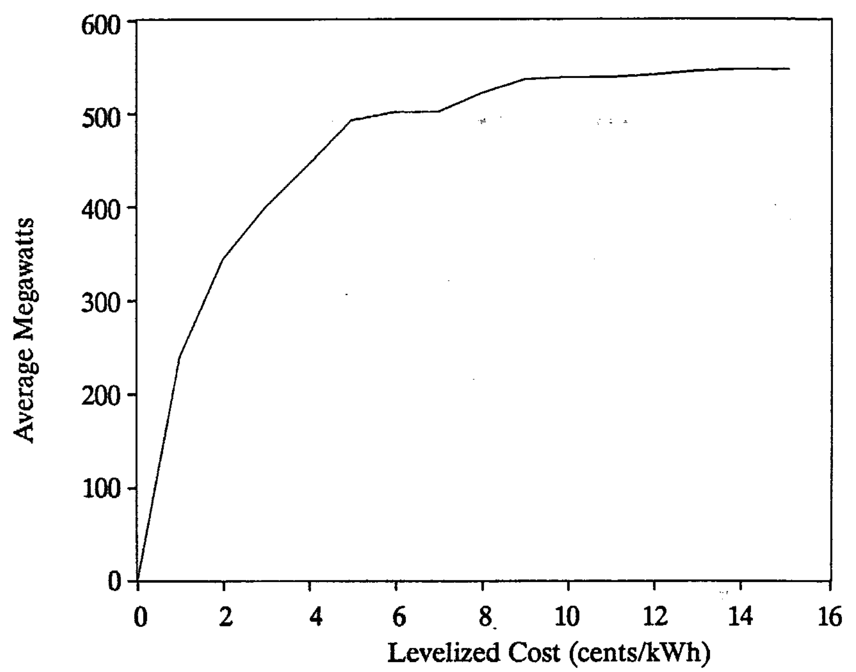
A new model to estimate non-aluminum industrial savings was developed for Bonneville, since the 1989 supplement. The new model simply collected existing data and organized it in a format to produce supply curves. In the high- and medium-demand forecasts, the model derives 265 average megawatts of technical potential from existing industries at a cost of about 2 cents per kilowatt-hour. This still rounds to 2 cents per kilowatt-hour, even if administrative costs and transmission and distribution adjustments are incorporated. Conservation from new and expanding loads in the high-demand forecast are 270 average megawatts at a cost of about 2 cents per kilowatt-hour. This remains about 2 cents per kilowatt-hour, if administrative costs and transmission and distribution adjustments are made. In the medium forecast, about 75 average megawatts are available. Conservation from the direct-service aluminum industries is being secured through the conservation modernization program. Consequently, these savings are not available for further development and are not included in this chapter. Figure 7-19 depicts the amount of conservation available at various costs.

Assessing the technical and economic potential for industrial conservation presents a more difficult problem than in any other sector. Not only are industrial uses of electricity more diverse than in other sectors, but the conservation potential is also more site-specific. Moreover, because energy use frequently plays a major role in industrial processes, many industries consider energy-use data proprietary.

In prior power plans, the conservation estimates primarily were based on a survey asking individual plant managers to estimate conservation potentials in their specific plant. The surveys were coordinated by industry trade associations, such as Northwest Pulp and Paper Association and the Industrial Customers of Northwest Utilities. Data from specific firms were masked to protect proprietary data. However, the current estimates are based on a new model, which incorporated information from the survey, as well as from other data sources. This chapter briefly describes the analysis. The model used to derive the conservation estimates was developed for Bonneville. Significant portions of the material presented in this section are taken from materials presented by Bonneville in summarizing the contractor's work.

Conservation Potential

Figure 7–19
Technical Conservation Potential from the Industrial Sector



The steps used to evaluate conservation are:

1. Evaluate measures that can be applied to the industrial sector, using existing data.

2. Calibrate to the electricity demand forecast for current and expected loads.

3. Compare the results to program information.

   The key data sources for the industrial sector come from programs operated in the region. These are listed in Table 7-76.

Table 7-76
Key Sources for the Industrial Sector

BPA's Industrial Test Program	-	Cost and savings of measures
Dunn and Bradstreet Industrial Survey	-	Consumption broken down by end use
Motors Study	-	Cost and savings of motors
Survey of Industrial Customers	-	Consumption and savings potential

Step 1. Evaluate Applicable Conservation Measures

The model used to derive conservation estimates in the industrial sector investigates conservation measures based on seven specific end-uses, which are called service demands. An energy conservation measure is a specific equipment replacement or operating change that reduces the energy used in a particular service demand.

The seven service demands and corresponding conservation measures are:

Lighting: The lighting measures include the replacement of incandescent bulbs with fluorescent bulbs, replacement of fluorescent ballasts with electronic ballasts and the conversion of mercury vapor lights to high-pressure sodium or metal halide lighting. Lighting controls are included with some measures.

Air-Conditioning: The single air conditioning measure is the installation of an economizer on an air-conditioning system.

Processing heating: The single-process heating measure is insulation on steam pipe. This measure has limited applicability, because the process heat for most firms comes from fossil fuels.

Compressed Air: The available measures include a leak reduction program, a reduction in operating pressure and the use of electronic controllers.

Pumping: Measures considered to reduce the electricity used in pumping include pump downsizing, variable speed drives, flow restricting nozzles and oversized piping.

Refrigeration: The refrigeration measures include the reduction of condensing pressure, options to increase suction pressure, the use of automatic controls and various measures to reduce air infiltration.

Motors: The single type of motor measure is the replacement of a standard-efficiency motor with a high-efficiency motor. Since the cost and percentage savings of motors are a function of the size of the motor and the feasibility of rewinding the incumbent motor, separate measures are identified for five size ranges.

The data used for each measure includes the cost of the measure and the cost of the incumbent equipment replaced by the measure. Annual operating and maintenance costs for each measure also are used. The energy savings for a measure are characterized as a percentage reduction that can be achieved by substituting the measure for the incumbent equipment. The energy savings for each measure depend on the annual operating hours for each industry and the percentage of time during plant operating hours that the measure is actually saving energy.

The data to develop the conservation measures came from several sources. The most important are the reports produced by the Industrial Test Program. This program performed 10 energy audits in each of the food, wood products and pulp and paper industries.

Data in the 1985 supply curve report completed for the Council by Synergic Resources Corporation and used to estimate conservation in the 1989 supplement also was used. Most of the motors data came from the 1987 report by Seton, Johnson & Odell, Inc., which estimated the conservation potential in lost opportunities for the industrial sector in the Pacific Northwest. Many other data sources also were used.

The model does not assume that all measures are available to all industries, not only because the industry may not have the applicable service demand, but because efficient equipment may already be installed. In these cases, there is no further conservation potential.

Step 2. Calibrate to the Demand Forecast

The next step is to apply the conservation measures to the forecast's electricity loads by industry. The load forecast is used to derive current electricity use and predicted load growth by industry. The 10 industries included in this assessment are displayed in Table 7-77.

Table 7-77
Industries in the Industrial Supply Curve Model

Standard Industrial Classification Code (SIC)	Industry
10	Mining Industries (composite of SICs 10-14)
20	Food and Kindred Products
24	Lumber and Wood Products
26	Paper and Allied Products
28	Chemicals and Coal Products
29	Petroleum and Coal Products
32	Stone, Clay and Glass Products
33	Primary Metals Industries
37	Transportation Equipment
50	Minor Industries

In the model, SIC 50 was created to estimate savings from all industrial loads not counted in any of the other nine industries listed above. The aluminum smelters are the only plants served directly by Bonneville, which are excluded from the model.

The forecasted electricity use for each industry is allocated to service and subservice demands, and conservation measures are identified for each demand. The allocations of energy use to service and subservice demands are derived from the Dun & Bradstreet Major Industrial Plant Database (MIPD). This data comes from surveys of larger energy-intensive firms.

For example, motors constitute one service demand, and motors in the 21 to 50 horsepower range constitute a subservice demand within the motors service demand. Measure 702, in the model, replaces standard-efficiency motors with high-efficiency motors in the 21 to 50 horsepower size range. The implementation of measure 702 will reduce electricity use by about 5 percent in the available portion of the subservice demand. It is currently assumed that 25 percent of the energy used by motors in the 21 to 50 horsepower subservice demand cannot be reduced by measure 702, because it is estimated that this percentage of the subservice demand is already served by high-efficiency motors, and no further improvement is possible.

Step 3. Compare Model Results to Programs

There are a number of reasons to expect that the savings and costs generated by this analysis are conservative. First, the measures considered in this model are very specific equipment changeouts. Major process changes are not considered, because the available data sources did not consider major process changes in the energy audits. Major process changes can create significant conservation opportunities.

Second, the data sources used to develop this supply curve had little information on measures in the upper cost brackets, so the lack of costly conservation opportunities in the supply curve is due more to data deficiencies than to a genuine shortage of expensive ways to trim electricity use in the industrial sector.

Third, this supply curve probably underestimates the savings potential and overestimates the costs of savings from new facilities. All measure cost and savings data are based on the cost of substituting the more efficient measures for existing equipment in existing plants. More savings may be available at a lower cost, if they are acquired when a plant is built rather than later as retrofits. However, no data is in hand on this issue.

Finally, measure costs are based on the full cost of the measure, excluding the salvage value of existing equipment. This will create a high levelized cost relative to a cost with salvage values included. In addition, the assumption was used that measures were installed before normal retirement of existing equipment. This means that the full cost of the efficient measure was used instead of the incremental cost between the efficient and inefficient version. If this assumption were changed to reflect only incremental costs, the average cost would fall slightly from 2.3 to 1.9 cents per kilowatt-hour, and an additional 100 average megawatts of technical conservation potential would fall below the 10 cents per kilowatt-hour avoided cost in the medium forecast scenario. The timing of this resource's acquisition would be determined by the schedule of industrial plant renovations and change-outs. These 100 average megawatts are identified as part of the promising resources category.

In addition to these known conservatisms and in comparison to information collected by the Oregon Department of Energy and to audits conducted by the Energy Analysis and Diagnostic Center nationwide, the percent savings from the model are fairly low. The current analysis indicates savings potential at about 6 percent of loads. The Oregon Department of Energy data set includes information from 111 site visits to individual plants, and the Energy Analysis and Diagnostic Center data set includes information from 750 audits. Both of these indicate an average savings from recommended conservation measures that is about 10 percent. These recommended conservation measures did not span the full cost-effectiveness range to 10 cents per kilowatt hour and were based on a lower avoided cost. If audits had tried to identify all measures up to 10 cents per kilowatt hour, more savings would have been identified. For example, the Energy Analysis and Diagnostic Center data base only identified measures with less than a two-year payback.

These program results were discussed in advisory committee meetings. It was decided to retain the current model estimates as a conservative estimator of savings, instead of moving now to an estimate based on these audits. However, it also was agreed that these audit results warranted further investigation, and that future program results and information will prove invaluable in helping refine the size of future conservation estimates. Programs will be the primary source of information for further revisions to the supply curves. If 10 percent savings based on program experience were used instead of the 6 percent savings calculated from the model, an additional 175 average megawatts in existing industries, and 180 average megawatts in new and expanding industries in the high (50 average megawatts in the medium) would be available. These are considered promising resources.

The results of the analysis described above led to the savings in Table 7-78. About 540 average megawatts were identified as cost-effective resources at an average cost of about 2 cents per kilowatt hour, after incorporating adjustments for administrative costs and transmission and distribution credits.

Table 7-78
Industrial Sector Technical Conservation Potential

Levelized Cost (cents/kWh)		New and Expanding Loads (MWa)		Existing (MWa)
Nominal	Real	High Forecast	Medium Forecast	
0	0	0	0	0
1	0.5	121	33	118
2	1	175	48	168
3	1.5	203	57	196
4	2	226	62	219
5	2.5	251	70	241
6	3	256	70	245
7	3.5	256	73	245
8	4	266	73	255
9	4.5	273	75	263
10	5	274	75	264
11	5.5	274	75	264
12	6	276	76	265
13	6.5	278	77	267
14	7	279	77	268
15	7.5	279	77	268

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Andrews, Laurel; Leary, Neal and McDonald, Craig. Synergic Resources Corporation, *Survey of Industrial Conservation and Cogeneration Potential in the Pacific Northwest*, SCR Report No. 7197-R3, prepared for the Northwest Power Planning Council, 1984.

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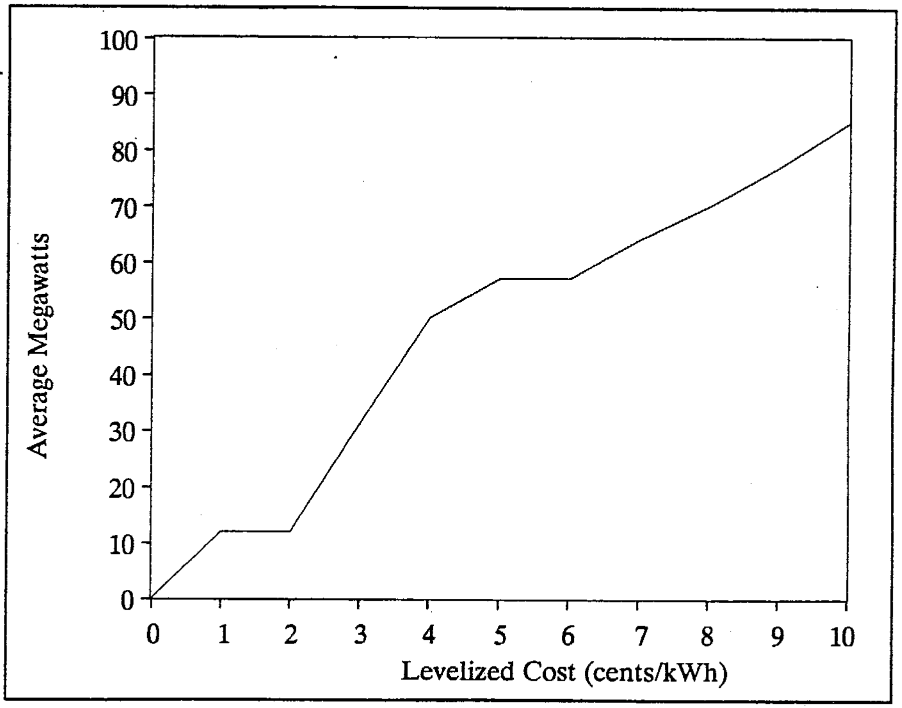
Irrigation Sector

In 1989, the region's irrigated agriculture consumed about 640 average megawatts of electricity, about 4 percent of the region's total consumption. The technical potential for conservation measures, evaluated with a marginal measure not exceeding a cost of 10 cents per kilowatt-hour, ranges between 40 and 85 average megawatts, depending on whether scheduling and energy-efficient motors are included as measures. These savings are available at an average cost of about 5 cents per kilowatt-hour, even if administrative costs and transmission and distribution adjustments are incorporated. Figure 7-20 depicts irrigation sector conservation available at various costs, assuming all measures are included.

Conservation Potential

Figure 7-20
Technical Conservation Potential from the Irrigation Sector



The conservation resource in public utility service areas is estimated to be about 40 percent of the total potential, with about 60 percent in the private utility service areas. This split is based on the proportion of total irrigation loads in the Council forecast, not including Bureau of Reclamation loads.

The Council's assessment of conservation potential for this sector involved the following two steps:

1 Evaluate the end-use conservation measures to be included in the supply curve analysis.

2. Estimate realizable conservation potential, by using the cost and potential savings data available from the Irrigation Sector Energy Planning Model.

Step 1. Evaluate the End-use Conservation Measures to be Included in the Analysis

In the 1986 Power Plan, the Council relied on estimates of conservation potential in irrigated agriculture provided by a Bonneville contractor. At the time, the research represented the most complete picture of energy conservation opportunities in the region's irrigation sector. Since that time, Bonneville's irrigation research contractor has updated its analytical studies in order to better characterize the irrigation sector. This effort has produced improved base line data, which the Council used to prepare its assessment of the conservation potentials in this sector. The primary effect of this updated information is a reduction in the potential savings previously estimated for the 1986 irrigation supply curve. These adjustments were made for the 1989 supplement and are included in the current estimate.

A major reason for this reduction from the 1986 plan is evidence from the Bonneville Irrigation Conservation Program that indicates at this time irrigators are unwilling to adopt use of low-pressure measures on many hand-move and sideroll systems. While Bonneville is sponsoring research on low-pressure nozzles for application in these systems, at this time there is sufficient uncertainty about when significant penetration of this measure would occur.

In addition, based on survey results, irrigators are continuing to take conservation actions at a greater rate than previously assumed, thereby reducing the amount of potential conservation available.

Energy-efficient motors were included as a conservation measure in the 1989 supplement but not the 1986 plan.

The conservation opportunities considered in the irrigation supply curve estimates include:

- low pressure irrigation on center-pivot systems;
- fittings redesign;
- main-line modifications;
- improved scheduling; and
- energy-efficient motors.

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, resulting in decreased energy losses due to friction. This redesign generally can be accomplished most economically by installing a second main line pipe parallel to the existing one.

Improved scheduling involves the improvements in both timing and amount of water applications. 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. Research results indicate that scheduling is easier to implement on center pivot systems than on hand-move and sideroll systems. Recently, the question has been raised whether scheduling really saves electricity. Savings from scheduling are dependent upon farmers overwatering in the base case, which is not well documented. In addition, an evaluation of Bonneville's Irrigated Agriculture Conservation Program indicated 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 was constrained. A further evaluation of scheduling, finished in early 1990, was inconclusive on the question of whether scheduling was an energy saver.

Energy-efficient electric motors are those that are manufactured with materials and designs that reduce the level of energy losses compared to standard electric motors. The electric motors are used to operate water pumps. Recently, implementors of Bonneville's irrigation program have cast doubts on the ability of energy-efficient motors to survive under the type of conditions that exist in the fields. Some have argued that energy-efficient motors are less able than a standard motor to withstand the voltage imbalances that occur in the field, and, therefore, their longevity is significantly shortened. In addition, some argue that when an energy-efficient motor is rewound, it is most commonly not done to energy-efficiency levels, and therefore, the savings are lost over the long term. These questions need to be investigated further to document the extent of the problem and whether some of the new generation of energy-efficient motors might perform better. In the meantime, there remain questions about whether to include this measure in the conservation supply estimates.

The effect of removing scheduling and energy-efficient motors from the supply curve would be to drop the 85 average megawatt resource potential to about 40 average megawatts. Comment is desired on which value to use in the final resource portfolio studies. Currently, the Council has retained both scheduling and energy-efficient motors in the resources used in the portfolio analysis.

Step 2. <u>Estimate Conservation Potential</u>

Conservation supply estimates for the irrigation sector were developed using the Irrigation Sector Energy Planning model. The model combines both engineering and economic principles to derive energy savings and levelized costs per kilowatt-hour for conservation investments. The average megawatts available

CHAPTER 12

MODEL CONSERVATION STANDARDS AND SURCHARGE METHODOLOGY[1]

1./ This amendment to the 1986 Northwest Conservation and Electric Power Plan supersedes the Council's previous model conservation standards and surcharge methodology. These include the model conservation standard for new electrically heated residential buildings; the standard for utility conservation programs for new residential buildings; the standard for all new commercial buildings; the standard for utility conservation programs for new commercial buildings; the standard for electric space-conditioning system conversions; and the standard for conservation activities not covered explicitly by the other model conservation standards.

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Introduction

As directed by the Northwest Power Act, the Council designed the model conservation standards to produce all electricity savings that are cost-effective for the region. The standards also are designed to be economically feasible for consumers, taking into account financial assistance from Bonneville. All cost-effective conservation should be captured at the time the buildings are constructed or, in the case of existing buildings, at the time they undergo major remodeling or renovation.[2] Where such cost-effective measures are not installed at the time of construction, it can be prohibitively expensive, if not impossible, to return to the structure and add the measures later. The result is that a cost-effective resource is lost to the region forever.

The Council is committed to capturing all achievable electricity savings from the standards as soon as possible. The Council's call for the immediate acquisition of the conservation savings available in new buildings is not new. In its first power plan, adopted in 1983, the Council stated that it was vital that the region take actions to secure conservation in new buildings. In light of the fact that the region is now in load/resource balance, the need to implement the actions called for in this rule is even more urgent. The longer the region delays the acquisition of the conservation savings available in new buildings, the sooner the region's utilities will have to develop more expensive and less environmentally desirable resource alternatives.

The Council believes that the task of capturing all regionally cost-effective electricity savings can best be achieved through more stringent state and local building codes and effective Bonneville and utility programs to encourage levels of construction equivalent to the model conservation standards. State and local governments should be charged with the responsibility of securing, through local building codes, those savings that are economically feasible without financial assistance from the region's power system. The region's utilities should secure all efficiency improvements above and beyond those captured by local code that are projected to produce regionally cost-effective electricity savings.

The following goal, objectives and activities are necessary to fulfill these commitments.

2./ For the sake of brevity, the terms "construction," "new construction," "new buildings" and "new structures" are used throughout this rule to include major remodels and renovations of existing buildings where such actions involve lost-opportunity resources.

Goal

To improve the efficiency with which new residential and commercial buildings use electricity and to ensure that buildings converting from other fuels also use electricity efficiently. Bonneville should acquire from new residential and new commercial buildings all electric energy savings that are expected to cost less than 10 cents per kilowatt-hour in nominal 1990 dollars. Through a combination of Bonneville programs, other utility programs and codes, at least 85 percent of these savings should be achieved.

Objectives

In designing and implementing programs to achieve that goal, Bonneville and the region's utilities are to achieve the following objectives:

1. New electrically heated residential buildings that comply with the model conservation standards are to be built to energy-efficiency levels that are at least equal to those in the component performance paths displayed in Table 12-1 on page 12-13. New commercial buildings that comply with the model conservation standards are to be built to energy-efficiency levels that are at least equal to commercial building specifications set forth in this chapter.

2. Conservation measures used to achieve the model conservation standards should provide reliable savings to the power system and be available commercially throughout the region.

3. Conservation measures used to achieve the model conservation standards should maintain or improve indoor air quality that was typical in 1983. The Council is committed, in the design of the model conservation standards, to preserve indoor air quality at levels at least equal to those present in new residences and commercial buildings constructed in the region in 1983. Given the substantial uncertainty that characterizes these public health issues, measures selected to be included in the standards must have a high probability of achieving or exceeding this objective. This continuing commitment to preserve indoor air quality reflects the Council's obligation to account for environmental costs and benefits in framing the model standards.

4. Conservation measures used to achieve the model conservation standards should be economically feasible for consumers, taking into account the financial assistance made available under the Act. Economic feasibility for building owners must be maintained by Bonneville providing financial assistance for any measures that are regionally cost-effective, but beyond the point at which the building owner experiences the lowest costs of owning and operating the building. This level of construction is referred to as the minimum life-cycle cost point. To maintain economic feasibility, financial assistance should be at least equal to the difference between the present value life-cycle cost of a building built to the minimum life-cycle cost, and that of a building that includes all regionally cost-effective measures. Financial assistance from Bonneville and utilities should cover costs above the building

owner's minimum life-cycle cost point, but the financial assistance for energy savings from the entire package of measures in the standards should not be more than the regionally cost-effective limit. Within these limits, the financial assistance should be adjusted from time to time to achieve clearly defined penetration targets in model conservation standards construction practice. The financial assistance should be distributed equitably throughout the region.

5. Conservation measures used to achieve the model conservation standards should maintain or improve amenity levels (e.g., comfort, window area, architectural styles, etc.) typical of buildings constructed in 1983.

6. Bonneville and the region's utilities should provide financial, marketing and technical assistance to achieve the model conservation standards regionwide.

7. Given that building practices change as new materials and information become available, Bonneville should commit to a regular and ongoing program of:

   a. data collection on cost, energy performance and environmental quality of new buildings constructed in the region;

   b. analysis of these data, sharing results with the region, and program changes based firmly on the results of such analysis; and

   c. continued research, development and demonstration designed to lower costs, improve performance, ensure maintenance of indoor air quality, and enhance comfort and safety of buildings constructed to the model conservation standards levels.

8. Model conservation standards programs should not significantly alter the consumer's choice of heating fuel.

9. The programs developed to implement the standards and the levels of efficiency required by the standards should remain relatively stable for a period of three years. The Council will use new information gathered in the intervening years to revise the model conservation standards, if appropriate, and Bonneville should revise related model conservation standards programs.

Activities: Model Conservation Standards

Achieving the improved levels of efficiency with which new buildings use electricity and ensuring that buildings converting from other fuels also use electricity efficiently is the goal of the Council's model conservation standards. Bonneville has a key leadership role in achieving the goal of constructing more efficient buildings in the region.

Even though the benefits of building to the model conservation standards are clear, home buyers, commercial building developers, builders, lenders, state and local governments, and utilities need technical and financial assistance to make the transition to energy-efficient buildings that will be consistent with the standards.

Bonneville should continue activities to assist home buyers, commercial building developers, state and local governments, builders, utilities, realtors, lenders and appraisers to accurately evaluate building techniques that will achieve improved levels of electrical energy efficiency. This training and technical information is needed so that all of the decision-makers involved in constructing and purchasing new buildings can make an informed decision that recognizes the importance of energy-efficient measures in the total cost of owning and heating or cooling the building. Bonneville activities listed below are those that the Council has determined are important in achieving its goal.

Bonneville activities are discussed in four sections below: 1) new electrically heated residences; 2) new commercial buildings; 3) general activities that relate to more than one of the building sectors; and 4) conversions of buildings to electric space conditioning.

New Electrically Heated Residential Buildings

Bonneville should develop and implement a work plan that includes the following actions:

- Assist states, local governments and/or utilities in their efforts to comply with the Council's residential model conservation standards, described in Table 12-1 on page 12-13.

- Maintain an aggressive energy-efficient new home marketing program (e.g., Super Good Cents). The Super Good Cents and Northwest Energy Code programs should include a path that allows the builder/home buyer to choose mechanical ventilation with heat recovery if the house is built with advanced infiltration control. Financial assistance for this path should include payments for the heat recovery ventilator up to the cost-effectiveness level. Bonneville's financial assistance should be sufficient to encourage the further development of this technology.

- Establish a program to offer financial assistance to local utilities for both single-family and multifamily dwellings. Bonneville should establish financial assistance levels that will lead the region in achieving 85 percent of the savings that would be realized if model conservation standards levels of construction were achieved in all electrically heated dwellings. The minimum financial assistance offered should be no less than the difference in net present value life-cycle costs to the consumer between a house built to the minimum life-cycle cost level and a house built to the full residential model conservation standards level. The maximum financial assistance offered for energy savings should not exceed the Council's cost-effectiveness limit for lost-opportunity resources.

- Bonneville financial assistance should be offered regionwide--including to utilities not currently exchanging with Bonneville or purchasing power from Bonneville. Bonneville financial assistance to partial-requirements customers and potential customers not currently purchasing from Bonneville should vary to reflect the benefits Bonneville is expected to receive in reduced load requirements, reduced exchange requirements, and improved building practice.

The payments should take into consideration Bonneville's "Final Conservation Cost-Sharing Principles" (Office of Conservation, Bonneville Power Administration, January 21, 1985), which allow cost sharing with all Bonneville customers, including those with no load requirements on Bonneville.

- Refine a component trade-off system using the generalized paths shown in Table 12-1. At a minimum, component trade-offs should be included to account for variations in building thermal mass, heating system efficiency, solar orientation, envelope thermal efficiency and mechanical ventilation without heat recovery. The component trade-off system is needed to give builders the flexibility they need to meet the wide range of characteristics desired by home buyers. Moreover, the component trade-off system should be used to encourage builders to explore new strategies that might achieve the model conservation standards goals more efficiently and at lower cost, while promoting builder acceptance of the model conservation standards and regional acceptance of programs to implement the model conservation standards.

- Request utilities to submit to Bonneville, as soon as practicable, a plan that explains how they intend to comply with the model conservation standards for utility residential conservation programs. Such a plan should include a clear statement of how the utility plans to demonstrate a good-faith effort to achieve the model conservation standards goal and objectives.

- Continue Bonneville's existing Indoor Air Quality Research Program to:

  - Conduct research on technologies that improve indoor air quality beyond the level attained in homes built to current practice in 1983.

  - Assess the relative effectiveness of alternative means of reducing sources of pollutants and alternative ventilation systems and strategies for minimizing potential pollutant build-up, including, but not limited to, spot ventilation, whole-house exhaust-only ventilation, ductless heat-recovery ventilation, and whole-house heat-recovery ventilation.

  - Monitor indoor air quality in a sample of new, electrically heated homes and evaluate the effectiveness of natural ventilation (i.e., infiltration) compared to mechanical ventilation in maintaining clean air, given the same source strength and whole house ventilation rate.

  - Identify the major indoor pollutants that may be reduced significantly or eliminated through source reduction actions such as new building codes and product standards.

  - Provide findings from indoor air quality research to local and state building code officials and public health agencies for their consideration.

- Certify that heat-recovery ventilation systems and/or alternative ventilation systems without heat recovery that were installed under all programs used to achieve the residential model conservation standards meet design, installation and performance standards promulgated by Bonneville.

- Require that utilities operating the Bonneville/utility residential model conservation standards program, or an alternative program being used to comply with the residential standard, offer to monitor the indoor air quality in any new dwelling serviced by that utility.

- Continue to provide technical and financial assistance to builders, insulation contractors, architects, designers, real estate appraisers, lenders, salespersons and code officials for the implementation of a uniform, regionwide, energy-efficiency certification system for new residential buildings.

- Provide information to home buyers on energy-efficient housing. This information should include publications on how to operate an energy-efficient house and equipment, such as heat-recovery ventilators, as well as information on indoor air pollution sources and mitigation measures.

- Develop paths in the Super Good Cents program to acknowledge that some new homes will be constructed from logs. Given that some consumers will choose log homes for amenity reasons, Bonneville should recommend ways of improving the efficiency of electrically heated log homes to levels that are regionally cost-effective. Since most log construction precludes wall insulation, Bonneville should emphasize ceiling and floor insulation, improved windows and doors, and the use of heat pumps.

New Commercial Buildings

Bonneville should develop and implement a work plan that includes the following activities:

- Develop, in consultation with architects, engineers, designers, building developers and managers, building code officials, and state building code and energy agencies, a revised version of the *Northwest Energy Code, Model Conservation Standards Equivalent Code* (June 1987), so that it results in energy-efficiency requirements comparable to those set forth in the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) and Illuminating Engineering Society of North America (IES) Standard 90.1 - 1989 *Energy-Efficient Design of New Buildings Except Low-Rise Residential Buildings*, as modified by this rule. This code should include a computer-based program for determining whether a proposed building design complies with its requirements, as well as prescriptive path(s) that satisfy its requirements. This code should also be designed to apply to existing commercial buildings that undergo significant remodeling and/or renovation, where such activities involve potential lost-opportunity resources.

- Develop and implement a program that provides technical and financial assistance to states, local governments and/or utilities in their efforts to take actions through codes, utility service standards, a Bonneville/utility commercial model conservation standards program, alternative programs, or a combination thereof that will result in compliance with the commercial buildings model conservation standards.

- Develop and implement an aggressive, energy-efficient new commercial buildings marketing program (e.g., the Energy Smart Design Program) or an equally effective alternative strategy that provides technical support and financial assistance to architects, engineers, designers, building developers and other participants in the development, design and construction of new commercial buildings and existing commercial buildings undergoing renovation or major remodels. This program should promote the preparation and implementation of building designs that contain all regionally cost-effective savings when compared to the efficiency requirements of the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc.\Illuminating Engineering Society of North America, Inc. Standard 90.1 - 1989 as modified by this rule.

Financial assistance provided under this program should be used to encourage the design and construction of buildings that contain all regionally cost-effective measures. Alternative approaches for the provision of both technical and financial assistance should undergo immediate testing to determine which approaches(s) most effectively encourage the design and construction of buildings that contain all regionally cost-effective conservation measures. Bonneville should maintain an ongoing evaluation to analyze and revise, as necessary, key program elements. This program, in combination with other Bonneville activities in this sector, should be designed to achieve 85 percent of the lost-opportunity savings that could be obtained if all new commercial buildings and those existing buildings undergoing major remodels or renovations after October 1, 1993 included all regionally cost-effective measures.

Although the region's utilities will be responsible for accomplishing this action, other entities may be equally or better equipped to deliver the actual services provided under the program. Bonneville should, therefore, establish a means of testing whether other entities could more efficiently and effectively deliver all or some of the services offered through this program. Buildings built under this program should receive public recognition for their energy efficiency. This program should be made part of a comprehensive package to market energy-efficient buildings, both residential and commercial.

- Develop and implement a strategy for providing technical and financial assistance to state and local governments and utilities that develop and adopt alternative energy codes or service standards that can be shown to produce regionally cost-effective electricity savings beyond those achieved by the requirements set forth in the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc./Illuminating Engineering Society of North America, Inc. Standard 90.1 - 1989 as modified by this rule. This strategy should be developed in consultation with the Council and integrated into Bonneville's overall resource acquisition program.

- Request that utilities submit to Bonneville as soon as practicable plans declaring how they will comply with the model conservation standards utility conservation programs for new commercial buildings. Utility plans should be based upon approved approaches contained in the Bonneville Surcharge Policy (February 28, 1989), as amended to conform to this rule, and be implemented by the date specified in that policy.

- Establish an ongoing research program to demonstrate energy-efficient technologies and building designs that are commercially available, but not yet widely adopted in the region. This program should be designed to verify, using monitored results, the cost-effectiveness and reliability of the savings produced by these technologies and building designs. This program should be developed in consultation with practicing architects, engineers, designers, equipment manufacturers, personnel from schools of architecture and engineering, building owners and managers and other professionals with expertise in the field of energy-efficient commercial building design, construction and operation.

- Establish a program (e.g., the Electric Ideas Clearinghouse) to collect and disseminate information on energy-efficient commercial building products and designs to architects, engineers, designers, building developers, building owners and managers, equipment suppliers and other participants in the design, construction and operation of new commercial buildings. At a minimum, this program should collect and evaluate data on new energy-efficient commercial buildings built under the Energy Edge, Energy Smart Design and Northwest Energy Code programs. These data should be maintained and updated as necessary, so they can be used in future planning and to aid in the design and construction of energy-efficient commercial buildings.

General Activities for Both Residential and Commercial Buildings

Bonneville should develop and implement a work plan that includes the following activities:

- Maintain the model conservation standards Code Adoption Demonstration Program (e.g., the Northwest Energy Code Program), which encourages utilities and state and local governments to achieve the model conservation standards through adoption of equivalent codes. If codes adopted in a utility's jurisdiction vary in specifics from those of the model conservation standards, but result in equivalent electricity use in new buildings, the utility should be eligible for inclusion in the model conservation standards Code Adoption Demonstration Program. This model conservation standards Code Adoption Demonstration Program should be available throughout the region to jurisdictions that comply in aggregate with the model conservation standards for new residential and commercial buildings through improvements in their building codes. The Code Adoption Demonstration Program should include the following elements:

    - Financial assistance to help offset the incremental cost of electrically heated residential buildings constructed to the model conservation standards. This financial assistance should be available to any jurisdiction that adopts the model conservation standards through codes. Financial assistance to model conservation standards code adopters should be set at or above financial assistance given to utilities participating in the Bonneville/utility model conservation standards program, and should be established at levels required to meet applicable state laws, or higher. Financial assistance for model conservation standards code adopters should include additional payments for mechanical ventilation with heat recovery, if the house is built with advanced infiltration control and it otherwise meets the model conservation standards. Financial assistance for this path should include additional payments for the savings attributable to this measure up to the regionally cost-effective level.

- Technical and/or financial assistance to commercial building developers in jurisdictions that have adopted the Northwest Energy Code or an equivalent code.

- Reimbursement to utilities and state or local governments for the costs of model conservation standards-level code adoption and enforcement.

- Systematic evaluation of construction costs, fuel share impacts, thermal performance, occupant satisfaction, indoor air quality, overall compliance with code targets, and enforcement costs for both residential and commercial buildings.

- Education and training programs for builders, consumers, architects, designers, energy code enforcement officials, mechanical ventilation system designers, installers and servicing contractors, realtors, lenders and appraisers, and other appropriate participants in the design, purchase and construction of new buildings. Such programs should include education and training for codes designed to achieve only part of the savings represented by the model conservation standards, if the codes are part of an overall program designed to meet the model conservation standards.

- Shelter industry training that focuses on the most cost-effective means of achieving the model conservation standards.

- Implement programs to reimburse state and local governments throughout the region for the incremental costs of adopting and enforcing model conservation standards as codes. Reimbursement should be made available throughout the region and should continue as long as enforcement of the standards remains regionally cost-effective.

- Design and implement a method or process for estimating costs of building to the model conservation standards throughout the region. This activity should be aimed at producing annual reports on the estimated costs experienced by builders in model conservation standards code adopter jurisdictions, and by builders in the Bonneville/utility model conservation standards programs throughout the region.

- Design and implement a process to collect utility-specific data that can be used to assess yearly progress in achieving the model conservation standards goal and objectives. The data should include, but not necessarily be limited to, measures that show the amount of energy savings achieved relative to that which would have been attained under the full model conservation standards; the number of model conservation standards residences as a percentage of the total new residences with electric heat; the proportion of new commercial floor space participating in the Bonneville/utility commercial building conservation program compared to all new commercial floor space, the proportion of all cost-effective savings that are implemented by participating buildings, and information pertinent to assessing the degree of a utility's good faith effort. The data should be the basis for a report published every year, or more often if appropriate, to notify utilities and the Council of that year's progress toward achieving the model conservation standards.

- Use the results of these progress reports to make program adjustments that are likely to improve the probability of achieving the model conservation standards goal and objectives in this rule.

- Continue to collect and analyze data regarding energy use, structural specifications and operation of residences and commercial buildings through the existing End-use Load and Consumer Assessment Project and the existing New Commercial Buildings Field Test Demonstration Program (i.e., Energy Edge).

- Establish, maintain and disseminate the results of an ongoing research and demonstration effort that focuses on the refinement of new residential and commercial building conservation technologies, construction techniques and products.

- Develop the surcharge policy and impose a 10-percent surcharge on any electrical utility that has not met all of the requirements of the model conservation standards for utility conservation programs for new residential and new commercial buildings. The surcharge policy should be developed, and the surcharge should be imposed pursuant to the Council's model conservation standards and the surcharge recommendation included in this chapter.

- Bonneville should work with the region's federal agencies to achieve the Council's model conservation standards in all new electrically heated residential buildings and all new commercial buildings built under the authority of federal agencies in the region and in all buildings being converted to electric heat under the authority of federal agencies in the region. In undertaking this task, Bonneville should recognize existing authorities of federal agencies and should familiarize itself with the proposed standard for new federal residential buildings published by the U.S. Department of Energy (August 20, 1986, Federal Register) and the standard for non-residential buildings published by the U.S. Department of Energy (January 30, 1989, Federal Register).

Residential and Commercial Buildings Converting to Electric Space Conditioning

Bonneville should develop and implement a work plan that includes the following activity:

- Encourage and assist states, local governments or utilities to take actions through codes, service standards or fees, alternative programs or a combination thereof to achieve electric power savings in buildings that convert to electric space conditioning comparable to those savings that could be achieved by incorporating all efficiency improvements that could be installed up to the regionally cost-effective level. The Council will work with Bonneville to define the measures that are regionally cost-effective.

The Model Conservation Standards

The Council has adopted six model conservation standards. The model conservation standards include the model conservation standard for new electrically heated residential buildings; the model conservation standard for utility residential conservation programs; the model conservation standard for all new commercial buildings; the model conservation standard for utility commercial conservation programs; the model conservation standard for conversions; and the model conservation standard for conservation activities not covered explicitly by the other model conservation standards.

The Model Conservation Standard for New Electrically Heated Residential Buildings

The Council's model conservation standard for new single-family and multifamily electrically heated residential buildings[3] is as follows: New buildings are to be built to energy-efficiency levels that are at least equal to those which would be achieved by using the illustrative component performance paths displayed in Table 12-1 for each of the Northwest climate zones.[4] It is important to remember that these illustrative paths are provided as benchmarks against which other combinations of strategies and measures can be evaluated. Any combination of measures that results in 1) equivalent electricity used for heating, and 2) the same indoor air quality is an acceptable path to achieve the model conservation standards.

3./ Single-family residences are defined to include duplexes. Multifamily residences include triplexes and larger structures up to and including four-story, low-rise residential structures. The standard applies to site-built residences and not to residences that are regulated under the National Manufactured Housing Construction and Safety Standards Act of 1974. 42 USC 5401 et seq. (1983).

4./ The Council has established climate zones for the region based on the number of heating degree days as follows: Zone 1 - 4,000-6,000 heating degree days; Zone 2 - 6,000-8,000 heating degree days; and Zone 3 - more than 8,000 heating degree days.

Table 12-1
Illustrative Paths for the Model Conservation Standard for New Electrically Heated Residential Buildings

Component	Climate Zone Zone 1	Zone 2	Zone 3
• Ceilings			
- Attic	R-38(U-0.031)[a]	R-38(U-0.031)	R-49(U-0.020)[b]
- Vaults	R-38(U-0.027)	R-38(U-0.027)	R-38(U-0.027)
• Walls			
- Above grade[c]	R-19(U-0.058)	R-24(U-0.044)	R-26(U-0.040)
- Below grade[d]	R-19	R-19	R-19
• Floors			
- Crawlspaces and Unheated Basements	R-30(U-0.029)	R-30(U-0.029)	R-30(U-0.029)
- Slab-on-grade Perimeters[e]	R-10	R-10	R-10
• Glazing[f]	R-2.5 (U-0.40)	R-2.5 (U-0.40)	R-2.5 (U-0.40)
• Maximum Glazed Area (% floor area)	15	15	15
• Exterior Doors	R-5(U-0.19)	R-5(U-0.19)	R-5(U-0.19)
• Assumed Thermal Infiltration Rate[g]	0.35 ach	0.35 ach	0.35 ach
• Mechanical Ventilation[h]	See footnote h, below.		

a R-values listed in this table are for the insulation only. U-factors listed in this table are for the full assembly of the respective component and are based on the methodology defined in the *Super Good Cents Heat Loss Reference - Volume I: Heat Loss Assumptions and Calculations* and *Super Good Cents Heat Loss Reference - Volume II - Heat Loss Coefficient Tables*, Bonneville Power Administration (October, 1988).

b Attics in single-family structures in Zone 3 shall be framed using techniques to assure full insulation depth to the exterior of the wall. Attics in multifamily buildings in Zone 3 should be insulated to nominal R-38 (U-0.031).

c All walls are assumed to be built using advanced framing techniques (e.g., studs on 24-inch centers, insulated headers above doors and windows, etc.) that minimize unnecessary framing materials and reduce thermal short circuits. Multifamily exterior walls above grade in Zone 3 should be insulated to a nominal R-24 (U-0.044).

d Only the R-value is listed for below-grade wall insulation. The corresponding heat-loss coefficient varies due to differences in local soil conditions and building configuration. Heat-loss coefficients for below-grade insulation should be taken from the Super Good Cents references listed in footnote "a" for the appropriate soil condition and building geometry.

e Only the R-value is listed for slab-edge insulation. The corresponding heat-loss coefficient varies due to differences in local soil conditions and building configuration. Heat-loss coefficients for slab-edge insulation should be taken from the Super Good Cents references listed in footnote "a" for the appropriate soil condition and building geometry and assuming a thermally broken slab.

f U-factors for glazing shall be the tested values for thermal transmittance, due to conduction resulting from either the American Architectural Manufacturers Association (AAMA) 1503.1-1988 test procedure or the American Society for Testing and Materials (ASTM) C236 or C976 test procedures. Testing shall be conducted under established winter horizontal heat-flow test conditions using a 15-mile-per-hour wind speed and product sample sizes specified under AAMA 1503.1-1988. Testing shall be conducted by a certified testing laboratory. When insulating glass is used, it shall be tested and certified under a Society of Insulated Glass Manufacturers of America (SIGMA) approved certification program as class "A," in accordance with the American Society for Testing and Materials (ASTM) E-744-81. EXCEPTION: Site-built fixed glazing shall be exempt from the thermal testing requirements, provided that it is installed either in an aluminum frame having a minimum 0.25-inch low-conductance thermal break or in vinyl or wood framing in accordance with SIGMA glazing specifications; and provided further that site-built, double-glazed units with fixed panes shall have a dead air space between panes of not less than 1/2 inch and site-built, triple-glazed units with fixed panes shall have a dead air space between panes of not less than 1/4 inch.

g Assumed air changes per hour (ach) used for determination of thermal losses due to air leakage.

h Indoor air quality should be comparable to levels found in non-model conservation standards dwellings built in 1983. To ensure that indoor air quality comparable to 1983 practice is achieved, Bonneville's programs must include pollutant source control (including, but not limited to, combustion by-products, radon and formaldehyde), pollutant monitoring, and mechanical ventilation, that may, but need not, include heat recovery. An example of source control is a requirement that wood stoves and fireplaces be provided with an outside source of combustion air. At a minimum, mechanical ventilation shall have the capability of providing the outdoor air quantities specified in the American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE) Standard 62-89, *Ventilation for Acceptable Indoor Air Quality*. Natural ventilation through operable exterior openings and infiltration shall not be considered acceptable substitutes for achieving the requirements specified in ASHRAE Standard 62-89.

Trade-offs among the components may be made as long as the overall efficiency and indoor air quality of the building are at least equivalent to a building containing the measures listed in Table 12-1. Bonneville, in consultation with the Council, should develop other illustrative approaches for building to this standard and publish these as code versions of the standard.

The Model Conservation Standard for Utility Conservation Programs for New Residential Buildings

The model conservation standards for utility conservation programs for new electrically heated residences requires utilities to implement, in accordance with the requirements detailed below, the Bonneville/utility new residential model conservation standards program, an equivalent alternative program, or rely on building codes/standards that are equivalent to the model conservation standards shown in Table 12-1. The Bonneville/utility residential model conservation standards program consists of an aggressive marketing and financial assistance program made available to home builders by Bonneville and the local utility.[5]

Financial Assistance

Financial assistance offered through the Bonneville/utility residential model conservation standards program should be no less than the difference in net present value of life-cycle cost to the consumer between a house built to the minimum life-cycle cost level and a house built to the full residential model conservation standards level. The maximum financial assistance should be the regional cost-effective limit for lost-opportunity resources. Bonneville and the region's utilities should provide financial assistance at levels sufficient to achieve 85 percent of the savings that would be achieved if all residential buildings were constructed to model conservation standards levels set forth in Table 12-1. Efforts to achieve the model conservation standards should continue as long as their acquisition remains regionally cost-effective.

Submission of Utility Plans for Compliance with the Model Conservation Standard for New Residential Programs

Utilities should submit to Bonneville a plan declaring how they intend to meet the model conservation standards for utility conservation programs for new residences. The ultimate goal for such programs is to obtain, in combination with codes and other regional programs, at least 85 percent of the savings that would have been obtained if all electrically heated residential buildings had been constructed to the residential model conservation standards level shown in Table 12-1.[6]

There are several ways utilities can comply with the model conservation standards for utility conservation programs for new residences. These are:

1. Submit to and have approved by Bonneville a declaration that the model conservation standards for new residential buildings have been or will be met through codes that are equivalent to model conservation standards levels. Such codes must be adopted and enforced by a state and/or local government not later than the date specified by Bonneville, and annually thereafter; or

2. Submit to Bonneville a declaration agreeing to adopt and implement the Bonneville/utility model conservation standards program for new residential buildings not later than the date specified by Bonneville;

3. Submit to and have approved by Bonneville an alternative program that will be implemented and enforced not later than the date specified by Bonneville. This alternative program should be capable of providing savings equivalent to the Bonneville/utility model conservation standards program for new

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5./ Super Good Cents is the current name given to the Bonneville marketing program to encourage residential construction at the model conservation standards level of efficiency.

6./ Eighty-five percent is the level of compliance that the Council believes is achievable.

residential buildings and not duplicate the acquisition of other resources that are already in the Council's plan. Alternative programs may include, but are not limited to, state or local government or utility marketing programs, financial assistance, codes that achieve part of the model conservation standards level of savings, or combinations of these and/or other measures to encourage energy-efficient construction of new residential buildings or other lost-opportunity conservation resources.

The Model Conservation Standard for New Commercial Buildings

The Council's model conservation standard for new commercial buildings is as follows: by a date specified by Bonneville, new commercial buildings and existing commercial buildings that undergo major remodels or renovations are to be constructed to achieve savings equivalent to those achievable through constructing buildings to the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) and the Illuminating Engineering Society of North America (IES) Standard 90.1 - 1989 *Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings* with the following modifications:

1. The lighting requirements for new commercial buildings are those specified in Section 435.103 Lighting of the U.S. Department of Energy's *Energy Conservation Voluntary Performance Standard for New Commercial and Multifamily High Rise Residential Buildings* (10 CFR Part 435, January 30, 1989), except that determination of the Interior Lighting Power Allowance shall be based on the buildings' gross square footage and include only permanently installed lighting;

2. The minimum efficiencies for electric heating, ventilating, air conditioning, service water heating equipment and electrical motors are those specified as applicable on January 1, 1992 in ASHRAE/IES Standard 90.1 - 1989 for all products not covered by the National Appliance Efficiency Act of 1987. The minimum efficiencies for equipment covered by the National Appliance Efficiency Act of 1987 are those set forth in that statute or developed through rulemaking pursuant to the statute;

3. The application of the "Building Energy Cost Budget Method" (Section 13 of ASHRAE/IES Standard 90.1 - 1989) shall be limited to the comparison of annual design energy use as an alternative compliance path; and,

4. The application of this standard to existing buildings shall be consistent with the intent of Section 101.3.2 (Application to Existing Buildings) of the *Northwest Energy Code, Model Conservation Standards Equivalent Code* (December, 1990).

The Council finds that the measures required to meet the ASHRAE/IES Standard 90.1 - 1989 as modified by this rule, are commercially available, reliable and economically feasible for consumers without financial assistance from Bonneville.

Illustrative ways for a commercial building to meet this standard are described in those portions of Bonneville's Model Conservation Standards Equivalent Code Amendments to the *Model Energy Code*, dated December 1990, or Model Conservation Standards Equivalent Code to Chapter 53 of the *Uniform Building Code*, dated December 1990, which apply to all buildings except low-rise residential buildings. As with the residential model conservation standard, flexibility is encouraged in designing paths to achieve the commercial model conservation standards.

The Model Conservation Standard for Utility Conservation Programs for New Commercial Buildings

The model conservation standard for utility conservation programs for new commercial buildings requires utilities to implement, in accordance with the requirements detailed below, the Bonneville/utility new commercial model conservation standard program, implement an equivalent alternative program, or rely on building codes that capture all regionally cost-effective electricity savings. The Bonneville/utility new commercial model conservation standards program consists of an aggressively marketed technical and financial assistance program made available by Bonneville and local utilities to commercial building developers and owners.[7]

Financial Assistance

Financial assistance offered through the Bonneville/utility new commercial model conservation standards program should be no less than the difference in net present value between a building built to levels of efficiency that minimize the consumer's life-cycle cost and a building built with all regionally cost-effective conservation measures. The maximum financial assistance should be the regional cost-effective limit for lost-opportunity resources. Bonneville and the region's utilities should set the financial assistance at levels sufficient to achieve 85 percent of the savings that would be achieved if all new commercial buildings and all existing commercial buildings undergoing major remodels or renovations were constructed with all regionally cost-effective electricity conservation measures. Efforts to achieve the penetration goal of model conservation standards for new commercial buildings should continue as long as the program remains regionally cost-effective.

Submission of Utility Plans for Compliance with the Model Conservation Standard for Commercial Programs

Utilities should submit to and have approved by Bonneville a plan declaring how they intend to meet the model conservation standard for utility conservation programs for new commercial buildings. The ultimate goal for such programs is to obtain, in combination with codes and other regional programs, at least 85

7./ Energy Smart Design is the name given to the Bonneville marketing program to encourage commercial construction that captures all regionally cost-effective electricity savings.

percent of the savings that would have been obtained if all new commercial buildings and all existing commercial buildings undergoing major remodels or renovations had been constructed with all regionally cost-effective electricity conservation measures. The dates Bonneville sets for utility plan submission and plan implementation should reflect the urgent need to capture all regionally cost-effective lost-opportunity savings in new and existing commercial buildings.[8] In subsequent years, a utility may change its declaration, subject to the same Bonneville approvals required for the initial plan submission.

There are several ways utilities can comply with the model conservation standard for utility conservation programs for new commercial buildings. These are:

1. Submit to and have approved by Bonneville a declaration that a code for new commercial buildings that captures all regionally cost-effective electricity savings has been or will be adopted and enforced by a state and/or local government not later than the date specified by Bonneville, and annually thereafter;[9]

2. Submit to Bonneville a declaration agreeing to adopt and implement the Bonneville/utility new commercial model conservation standard program not later than the date specified by Bonneville; or

3. Submit to and have approved by Bonneville an alternative program that will be implemented and enforced not later than the date specified by Bonneville. This alternative program should be capable of providing savings equivalent to the Bonneville/utility new commercial model conservation program and not duplicate acquisition of other resources that are already in the Council's plan. Alternative programs may include, but are not limited to, state or local government or utility marketing programs, financial assistance, codes that capture only a portion of all the regionally cost-effective savings available from the model conservation standards for new commercial buildings or combinations of these and/or other measures to encourage energy-efficient construction of new commercial buildings or other lost-opportunity conservation resources.

8./ Eighty-five percent is the level of compliance that the Council believes is achievable.

9./ State and/or local adoption of codified versions of ASHRAE/IES Standard 90.1 - 1989, the U.S. Department of Energy's *Energy Conservation Voluntary Performance Standard for Commercial and Multi-family High Rise Residential Buildings*, the codified versions of model conservation standard for new commercial buildings (i.e., the *Northwest Energy Code*, December 1990) or an equivalent code does not satisfy the model conservation standard for utility conservation programs for new commercial buildings because these codes/standards, without modification, do not capture all regionally cost-effective electricity savings.

Surcharge Recommendation

The Council recommends that a 10-percent surcharge be imposed on utilities that have not complied with the deadlines established above to submit to Bonneville: 1) an initial plan for implementation of the Bonneville/utility new residential and new commercial model conservation standards programs; 2) a plan for implementation of an alternative program, which is approved by Bonneville as being equivalent, as set forth above; 3) or a declaration, approved by Bonneville, that the model conservation standards for new residential and new commercial buildings will be met by building codes that capture all regionally cost-effective electricity savings. This surcharge continues in effect until a utility has filed a plan and has obtained the necessary Bonneville approvals. Bonneville should judge alternative plans against whether they will be as effective as the Bonneville/utility conservation programs for new residential and new commercial buildings in contributing to the regional goal to achieve 85 percent of all regionally cost-effective electricity savings.

Exemptions

The Council finds there is no need for exemptions at this time. If Bonneville finds that hardship exists, Bonneville should assist in the implementation of the Bonneville/utility new residential and/or new commercial model conservation programs in those jurisdictions.

Minimum Performance Standard

The Council does not propose a minimum performance standard for utilities to achieve in the operation of conservation programs for new residential and commercial buildings in this plan. However, the Council still remains strongly convinced that given the value of the model conservation standards to the region, utilities should be responsible for working vigorously toward attainment of the model conservation standards in their service territories. Bonneville should measure and report to the Council the performance of utilities in attaining the goals of the model conservation standards for new residential and commercial buildings.

The Model Conservation Standard for Buildings Converting to Electric Space-Conditioning Systems

The Council's model conservation standard for residential and commercial buildings converting to electric space-conditioning systems is that state or local governments or utilities should take actions through codes, alternative programs or a combination thereof to achieve electric power savings from such buildings. These savings should be comparable to savings that would be achieved if each building converting to electric space-conditioning were upgraded to include all regionally cost-effective electricity conservation measures.

Financial Assistance

The Council recommends that no financial assistance be offered to consumers to offset the cost of conservation investments that are required prior to conversion to an electric space-conditioning system from another energy form.

Surcharge Recommendation

The Council believes that utilities should adopt conversion standards. However, the Council does not recommend, at this time, that a surcharge be imposed for failure to act accordingly.

The Model Conservation Standard for Conservation Programs not Covered by Other Model Conservation Standards

This model conservation standard applies to all conservation actions except those covered by the model conservation standard for new electrically heated residential buildings, the standard for utility conservation program for new residential buildings, the standard for all new commercial buildings, the standard for utility conservation programs for new commercial buildings and the standard for electric space-conditioning system conversions. This model conservation standard requires that all conservation programs be operated in a manner consistent with the long-term goals of the region's electrical power system. In order to achieve this goal, the following objectives should be met:

1. Conservation acquisition programs should not create lost-opportunity resources, and should develop as much of the resource as is cost-effective to the region. A lost-opportunity resource in a conservation measure or program is one that, due to physical or institutional characteristics, will become non-cost-effective unless actions are taken now to develop it or hold it for future use. Installing only the easiest and least-expensive conservation measures (i.e., "cream skimming"), for example, often can mean that it is no longer cost-effective to return to install added measures.

2. Conservation acquisition programs should be designed to secure all measures in the most cost-effective manner possible. Expenditures for conservation resource acquisition should recognize that administrative costs and incentive payments must be balanced to achieve the lowest overall cost for the resource. Under some circumstances, for example, it may be more cost-effective to make 100-percent payments for conservation measures than to incur the administrative costs associated with partial payments.

3. Conservation acquisition programs should acknowledge that for certain measures there is a limited "window of opportunity" during which all of the conservation potential should be secured. In some cases this will mean matching the conservation acquisitions to the schedule of the host facilities. In industrial plants, for example, retrofit activities should match the plant's scheduled downtime; in the commercial sector, measures should be installed at the time of renovation or remodel; and in all sectors, energy codes revision should incorporate all regionally cost-effective measures.

4. Conservation acquisition programs should be designed to ensure that regionally cost-effective levels of efficiency are economically feasible for the consumer. Economic feasibility is defined as that level of conservation investment that results in lowest life-cycle cost to the consumer. Conservation investments beyond that point, which result in electricity savings that are cost-effective for the region, should be paid for by the region's utilities.

5. Conservation acquisition programs should be designed so that their benefits are equitably distributed throughout the region. If the program is operated on less than a regional level, its benefits should be equitably distributed throughout its target market area.

6. Conservation acquisition programs should be designed to maintain or enhance environmental quality. Acquisition of conservation measures that result in environmental degradation should be avoided or minimized.

7. Conservation acquisition programs should be designed to enhance the region's ability to refine and improve programs as they evolve. Acquisition programs should undergo both process and impact evaluations. These evaluations should provide reliable information that can be used to verify program costs and savings and to improve future programs and estimates of conservation's cost and availability.

8. Conservation acquisition programs should be designed to encourage increased electrical energy efficiency and should not be used to increase the market penetration of electricity. Marketing programs, while potentially an effective means of securing conservation savings, should not attempt to influence a consumer's choice of fuel.

9. Conservation acquisitions should be given credit for characteristics that are not specifically accounted for in the Council's computation of regional cost-effectiveness. For example, since conservation actions may avoid the need for increased transmission capacity, such actions should be assigned an appropriate credit for this impact on transmission system needs.

10. Conservation acquisition efforts should not be reduced, because some consumers might otherwise have invested their own money in increased efficiency. Utility acquisition of regionally cost-effective conservation may sometimes pay for measures that some consumers would have purchased on their own. Concern for this "free-rider" potential should not keep utilities from purchasing all regionally cost-effective conservation.

Surcharge Recommendation

The Council is not at this time recommending that this model conservation standard be subject to a surcharge.

Surcharge Methodology

Section 4(f)(2) of the Northwest Power Act provides for Council recommendation of a 10-percent to 50-percent surcharge on Bonneville customers for those portions of their regional loads that are within states or political subdivisions that have not, or on customers who have not, implemented conservation measures that achieve savings of electricity comparable to those which would be obtained under the model conservation standards. The purpose of the surcharge is twofold: 1) to recover costs imposed on the region's electric system by failure to adopt the model conservation standards or achieve equivalent electricity savings; and 2) to provide a strong incentive to utilities and state and local jurisdictions to adopt and enforce the standards or comparable alternatives.

Bonneville's administrator is responsible for implementing the surcharge in accordance with the Council methodology for the surcharge calculation. The Council recommends that the Bonneville administrator impose surcharges as specified above. The method is set out below.

Identification of Customers Subject to Surcharge

In accordance with the schedule set forth above, the administrator should identify those customers, states or political subdivisions that have failed to comply with the model conservation standards for utility residential and commercial conservation programs, including meeting all filing deadlines.

Calculation of Surcharge

The annual surcharge for non-complying customers or customers in non-complying jurisdictions is then calculated by the Bonneville Administrator as follows:

1. If the customer is purchasing firm power from Bonneville under a power sales contract and is not exchanging under a residential purchase and sales agreement, the surcharge is 10 percent of the cost to the customer of all firm power purchased from Bonneville under the power sales contract for that portion of the customer's load in jurisdictions not implementing the model conservation standards or comparable programs.

2. If the customer is not purchasing firm power from Bonneville under a power sales contract, but is exchanging (or is deemed to be exchanging) under a residential purchase and sales agreement, the surcharge is 10 percent of the cost to the customer of the power purchased from Bonneville in the exchange (or deemed to be purchased) for that portion of the customer's load in jurisdictions not implementing the model conservation standards or comparable programs.

3. If the customer is purchasing firm power from Bonneville under a power sales contract and also is exchanging (or is deemed to be exchanging) under a residential purchase and sales agreement, the surcharge is: a) 10 percent of

the cost to the customer of firm power purchased under the power sales contract; plus b) 10 percent of the cost to the customer of power purchased from Bonneville in the exchange (or deemed to be purchased) multiplied by the fraction of the utility's exchange load originally served by the utility's own resources.

This calculation of the surcharge is designed to eliminate the possibility of surcharging a utility twice on the same load. In the calculation, the portion of a utility's exchange resource purchased from Bonneville and already surcharged under the power sales contract is subtracted from the exchange resources before establishing a surcharge on the exchange load.

Evaluation of Alternatives and Electricity Savings

A method of determining the estimated electrical energy savings of an alternative conservation plan should be developed in consultation with the Council and included in Bonneville's policy to implement the surcharge.

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