1983

Northwest Conservation and Electric Power Plan

Meeting the region's electrical energy needs... with confidence, flexibility, and at the lowest possible cost

Volume II

Northwest Power Planning Council

1983 **Northwest Conservation and Electric Power Plan** Volume II

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Contents

Appendix G
WPPSS 4 and 5 Versus Coal

In developing the draft plan, the Council felt that, even though the probability that new baseload thermal resources would be required during the planning period was small, the high level of public interest in the fate of WPPSS 4 and 5 justified comparison of eventual completion of these plants to construction of new coal-fired generation. This initiated a set of studies carried out by the Council comparing WPPSS 4 and 5 to coal. During the subsequent public comment period and finalization of the plan, additional coal/nuclear studies were performed by both the Council, and by the WPPSS 4 and 5 Participants (Participants) with technical support from PNUCC. The objective of this appendix is to summarize the assumptions and results of the technical work done in this area.

Methodology

The analytical framework used in these studies was one of simple cost/benefit analysis. Two alternative methods for meeting the future electric demands of the region were constructed and the costs of meeting demands through different alternatives were estimated. The alternatives were designed in such a way as to have equal benefits (i.e., equal reliability). All other things being equal, the alternative with the lowest cost would be the region's preferred choice. In all of the studies, one alternative included completion of WPPSS 4 and 5 and the other substituted new coal-fired generation in place of these units. All studies were performed under the Council's draft plan high growth forecast.

All studies performed by the Council, the Participants, and PNUCC were carried out through use of the System Analysis Model (SAM). The criteria used for comparison in all cases was the present value of life-cycle system costs, also known as revenue requirements. Under the accounting methods used in SAM this quantity consists of production costs and secondary sale revenues associated with all existing and new resources, and includes capital recovery only for new resources (the sunk capital cost for the existing power system is not included).

Assumptions and Results

For the draft plan studies, the data for coal and nuclear cost and operating characteristics was taken principally from two sources. The Nuclear Task Force cost estimates were used for WPPSS 4 and 5, and the PNUCC Thermal Resources Committee data were used for coal. Exceptions to recommendations of these groups were on nuclear-equivalent availability where the Council used 60 percent instead of 65 percent, coal availability of 70 percent instead of PNUCC's 75 percent, and coal fuel escalation where the Council used an EPRI value of 1.2 percent real escalation as opposed to the original PNUCC recommendation of over 3 percent. In the coal case, Creston units 1-4 were used as the substitute for WPPSS 4 and 5. All conservation and renewables were consistent with those under the draft plan high growth forecast; however, no new combustion turbines were added to the resource mix. This schedule required an in-service date for the first new coal or nuclear unit of July 1995.

The results of this first set of studies are shown in table G-1. (The same results were shown in table 3-18 of the draft plan.) In addition to the base case (Study 1A), several sensitivities were performed on the effect of changing debt/equity ratios for the private ownership of coal, the effect of higher real financing rates for WPPSS 4 and 5, and inclusion of 4/5 sunk costs. Using the December 1982 version of SAM, the results range from $20 million to $3.6 billion in favor of coal.

Case 1A was later rerun with the February 1983 version of SAM and the cost advantage of coal increased by about $1 billion to over $1.4 billion. While the other cases were not rerun with the newer model, the model changes were such that the $1 billion should be a consistent adder for all cases.

After publication of the draft plan, the Participants formed a subcommittee to review the Council's WPPSS 4 and 5 versus coal comparison. This group enlisted technical support from PNUCC and used SAM for a series of their own studies. Data changes were extensive and included modifications to nuclear-equivalent availability, coal and nuclear capital costs, coal fuel and capital escalation rates, nuclear operating costs, and coal ownership. The comparisons were also framed in resources schedules which were more consistent with the draft plan high growth forecast. New combustion turbines were included, and the in-service date for the first new coal or nuclear was moved back to the 1998 operating year.

Results of two of the subcommittee's studies are shown in table G-2. The base case projected WPPSS 4 and 5 to have an advantage over coal of about $1.9 billion. This was a swing of over $3.3 billion from the Council's draft plan base case, and was due largely to the changes in coal fuel and capital escalation, reduced nuclear capital and hold costs, and reduced nuclear operating costs. The subcommittee also performed a study which had one less new generic coal plant in the 4/5 case, made possible because of the higher assumed nuclear-equivalent availability, increasing the nuclear advantage to $2.9 billion. (This group performed numerous other studies, not described here.) For a comprehensive description of the subcommittee's work see Appendix D5.1 of PNUCC's public comment, or the testimony of Donald Mazur.

During the public comment period, attempts were made to reconcile the considerable differences in the various assumptions. The following sections briefly summarize the discussion and resolution (if any) on the major assumptions.

Hold Costs

The Participants provided NRC-approved budgets showing WPPSS 4 and 5 hold costs to be on the order of $5 million per year, as opposed to $40 million per year originally recommended by the Nuclear Task Force. The Council believes the $2.5 million per year per plant (1980 dollars) to be an appropriate value.

Capital Costs for Nuclear and Coal

On further examination of their assumptions, the Participants agreed that the Council's original costs were correct.

Nuclear Fuel Costs

On further examination of their assumptions, the Participants agreed that the Council's original costs were correct.

Capital Escalation Rates

The Council agrees that there is a high degree of uncertainty in capital escalation rates for both nuclear and coal. For purposes of further analysis, the Council assumed 0.8 percent for both types of resources.

Coal Fuel Escalation

Many comments were received stating that the Council's original assumption of 1.2 percent for rail coal escalation, based on the 1982 EPRI Technical Assessment Guide, was low and that a value of 2 to 3 percent was more appropriate. The Council was reluctant to use values this high because the escalation treatment in SAM carried these rates forward for nearly fifty years, magnifying small differences in early years into very large differences in later years. Given SAM's methodology, the Council's philosophy with respect to all fuel escalations was to keep absolute values low and the range across fuel types narrow. However, newer versions of SAM are being developed which will force real escalations to zero after twenty years, allowing this constraint to be relaxed. Factors such as monopolistic supply conditions into the Northwest, recent liberal interpretations of the Staggers Rail Act, and a robust demand for coal that is likely to accompany the high growth forecast (all frequently mentioned in public comment), may very well place upward pressure on rail coal prices, yielding twenty-year escalations higher than the original assumption of 1.2 percent. While exact escalations are impossible to predict, a range from 1.2 percent to 3.5 percent for real twenty-year escalations may not be unreasonable.

Equivalent Availability

This was a difficult issue for the Council and considerable effort was spent trying to reconcile differences.

Utility comments uniformly argued for nuclear-equivalent availabilities near 70 percent, basing arguments primarily on North American Electric Reliability Council (NERC) data. However, the Council had concerns about the reporting techniques and assumptions used to derive and interpret the data. The Council eventually adopted the Nuclear Task Force recommendation of 65 percent for nuclear, and maintained the NERC spread of 7 percent between nuclear and coal to obtain a coal-equivalent availability of 72 percent.

WPPSS 1/4 Shared Costs

The Nuclear Task Force stated in its report that the estimates provided for WPPSS 4 and 5 capital costs contained no shared costs with twinned units WPPSS 1 and 3.

However, the Participants claimed that WPPSS 4 capital costs included $241 million of shared costs with WPPSS 1, which would be transferred to WPPSS 1 in the event of final termination of WPPSS 4, thereby increasing the cost of any scenario in which WPPSS 4 was not completed. Attempts by the Council to get clarification on this issue were unsuccessful, and considerable confusion still remains. For purposes of further analysis, the Council assumed the original cost estimates to be free of shared costs.

Resource Ownership

The Council's original assumptions for ownership shares of new resources were based on projections of demand growth for the different sectors. About 60 percent of the demand growth over the planning period was forecast to occur in the private sector and 40 percent in the public sector, causing the Council to use a 60/40 private/public ownership ratio for all new resources. However, in the draft plan 4/5 versus coal studies, the current 5/95 ownership for WPPSS 4 and 5 was maintained, with a 60/40 split on coal. This tended to favor 4/5 because public utility ownership is modeled as being less expensive than private utility ownership. Concerns about consistency with section 9(f) of the Act led the Council to investigate which customers would be allocated the energy of new thermal resources under the Act's rate pool structure. The analysis concluded that 97 percent of new thermal energy required by 2002 would be allocated to private utilities and other private customers of Bonneville. Based on this conclusion, the Council felt it appropriate to conduct analyses based on 97 percent private and 3 percent public ownership of both WPPSS 4 and 5 and new coal.

After discussion of the public comment received on this topic, the Council performed another set of comparative studies. The results were presented in public on April 7, 1983 and are depicted in table G-3.

The treatment of reliability and fuel escalation was changed slightly for this set of studies. For all model runs, nuclear and coal-equivalent availabilities were fixed at 65 percent and 72 percent, respectively. Under these availabilities, WPPSS 4 and 5 have a combined energy capability of 161 average megawatts more than the four coal units they were compared with in previous studies. To equalize reliability and ensure that the nuclear scenario receive all due capacity credit, a fractional coal unit was introduced in the comparison coal case. It was modeled with a capacity of 224 megawatts and had all capital and fixed operating costs prorated accordingly. Additionally, coal and nuclear fuel escalations in these studies were limited to twenty years. To prevent this version of SAM from continuing real escalations beyond 2002, the escalations were accelerated between 1982 and 1997, and then held at zero from 1997 to 2002. As SAM uses the last five years of operating history to project operating costs over the remainder of plants' lives, this approach will yield real escalations of zero beyond 2002. However, it will slightly overestimate the fuel costs for coal in the 1997 to 2002 time period. The other resources included in both scenarios were consistent with the draft plan high growth forecast.

Sensitivities were performed on a coal fuel escalation and nuclear and coal ownership. Examination of table G-3 reveals that the range of outcomes for these studies was tight and relatively balanced around zero, ranging from $240 million in favor of coal to $450 million in favor of WPPSS 4 and 5. These studies would represent the Council's current best estimate as to assumptions, and would indicate no significant advantage to either resource. However, as discussed later, the Council feels the potential range of outcomes is much wider than this. This analysis also excluded the sunk costs associated with WPPSS 4 and 5. The present value of the debt service on these costs is over $2 billion, and while the Council has yet to decide on the appropriate treatment of sunk costs for these resources, any analysis which included the impact of sunk costs would be heavily skewed against WPPSS 4 and 5.

An issue related to WPPSS 4 and 5 sunk costs is that of replacement on sunk costs. A component of capital revenue requirement calculated by SAM is that of interim replacements on plant and equipment. The model uses dispersed retirement (Iowa) curves to calculate the amount of original capital investment that must be replaced in any given year. The size of this replacement cost is proportional to the plant's installed cost. In all the analysis of capital costs for WPPSS 4 and 5, only costs to complete were included in the construction cash flows; sunk costs were excluded. This significantly understates the full installed cost, and therefore underestimates the cost of replacements. If replacements on sunk costs were calculated, SAM's methodology would add on the order of $500 million in present value cost to the WPPSS 4 and 5 scenarios.

Estimates of the Sensitivity of Present Value Costs to Parameter Changes

While the coal/nuclear studies performed to date have not been structured to allow rigorous sensitivity analysis, the quantity of studies is large enough to begin to develop rough estimates of the effects of changing parameters. The impacts that follow are just that: rough approximations of changes in bottom-line, life-cycle present values for a unit change in a given input parameter. The nuclear estimates are for the combined impact of WPPSS 4 and 5, and those for coal represent the combined impact of four 508-megawatt units plus the fractional coal unit used to equalize reliability. In-service dates for all units are in the late 1990's. The impacts are presented generally as independent, linear estimates of what in reality are highly correlated, non-linear functions. However, they should be reasonable rules-of-thumb for the ranges of assumptions over which the studies were run. They are presented here solely to give an appreciation for the potential range of outcomes.

1. Twenty-Year Fuel Escalation Rates.

   Coal — $60 million per 0.1 percent change.
   Nuclear — $25 million per 0.1 percent change.

   A 2 percent change in rail coal escalation rates would impact present value costs by approximately $1.2 billion.

2. Capital Escalation.

   Coal — $40 million per 0.1 percent change.
   Nuclear — $70 million per 0.1 percent change.

   A 2 percent change in nuclear capital escalation would impact present value costs by approximately $1.4 billion.

3. Equivalent Availability.

   The effect of changes in availability can be separated into two categories. The first concerns capacity credit. The higher the availability of a resource, the more other new resources can be avoided. Cost impacts for the relationship between nuclear and coal can be estimated based on the change in spread between nuclear and coal equivalent availabilities. A 1 percent change in the spread is worth approximately $70 million.

   In addition, each absolute change of 1 percent for nuclear is worth $30 million in fuel savings from other higher cost resources and/or secondary revenues. For coal, this factor is effectively zero.

   E.g., moving from availabilities of 70 percent for nuclear and 70 percent for coal to, say, 60 percent for nuclear and 72 percent for coal, would give nuclear a relative cost penalty on the order of:

   $$12x70 + 10x30 = 1140 \text{ or } \$1.1 \text{ billion.}$$

   Obviously this relationship is strongly dependent on all capital and operating cost and escalation assumptions.

4. Operating Costs.

For both nuclear and coal a change in 1981 variable fuel and operation and maintenance costs of 1 mill/kWh, or a change in 1981 fixed fuel or fixed operation and maintenance of 5-6$/kW/yr, is worth on the order of $170 million.

Obviously, combining changes in assumptions leads rapidly to very large changes in system cost. Changes in nuclear capital escalation of 2 percent, combined with a change in availability of 10 percent, could impact costs by $2.5 billion. On the other hand, changing rail coal escalation by 2 percent, combined with a 3-mill (approximately 15 percent) change in first-year operating costs, could cause a $1.7 billion change in the bottom line. If all changes were in opposite directions, the result could be a $4 billion-plus swing.

Acquisition Schedules for Nuclear and Coal-Fired Electric Plants

A key element of the Council's resource planning strategy focuses on planning lead times of resources. This has been discussed in detail in chapter 5, Volume I.

The construction period for coal plants is estimated to be four years. The region can bring a potential coal plant through the preconstruction schedule for approximately $180/kWh or about $90 million. The construction schedule for WPPSS 4 and 5 is estimated to be seven years, but this would require that the region maintain these plants and their licenses until *1991* at a cost of about $20 million dollars per plant. These costs have been factored into the analysis presented above.

From a planning perspective, if all other costs and the expected reliability are the same, a resource with a shorter lead time is preferable to one with a longer lead time. Since the cost assessment could determine no clear cost advantage for coal or nuclear plants, the Council has included coal plants in its portfolio rather than nuclear because of the shorter lead time. The additional flexibility offered by a shorter-lead-time resource would be reflected in a lowered probability of the region overbuilding resources. For example, if demand growth decreased two years into the construction of the nuclear plant, making the resource surplus, the region would have made a large unnecessary investment that might have been avoided if long-term plans had included a shorter-lead-time coal plant instead. That is, given the three-year longer construction schedule for WPPSS 4 and 5 over coal, construction would not yet have begun on the coal plant.

Conclusion

From the preceding discussion of sensitivities and the wide range of study outcomes already observed, it becomes apparent that reaching a conclusion as to the relative cost-effectiveness of opting for either construction of new coal or completion of WPPSS 4 and 5 would require a high degree of certainty on cost and operating assumptions for both types of resources. However, large uncertainties remain on important parameters such as fuel escalation, capital escalation, equivalent availability, and appropriate treatment of sunk costs. Therefore, the Council cannot at this time conclude that there is a significant cost advantage to either construction of new coal or completion of WPPSS 4 and 5.

The Council's decision to include coal plants in their twenty-year resource portfolio is based on the considerably shorter construction times for coal plants relative to nuclear plants.

Table G-1.
Draft Plan Study Assumptions and Results[1]

Major Assumptions	1A 4/5	1A Coal	1B 4/5	1B Coal	1C 4/5	1C Coal	1D 4/5	1D Coal
Capacity (MW)	1259/1240	508	Same as 1A		Same as 1A		Same as 1A	
Equivalent Availability (%)	60	70	with		with		with	
Fuel Escalation (%)	1.5	1.2	following		following		following	
Capital Escalation (%)	0.8	0.	changes		changes		changes	
WNP 4/5 Capital (millions)	3,603	—						
4/5 Hold Costs (millions/unit/yr)	23.8	—						
WNP 1/4 Shared Costs (millions)	—	0.						
Coal 1-4 Capital (millions)	—	2,366						
Fixed O&M ($/kW-yr)	50.2	18.2						
Variable O&M (m/kWh)	0.	1.6						
Fixed Fuel ($/kW-yr)	32.5	2.4						
Variable Fuel (m/kWh)	0.	15.4						
Ownership (private %/public %)[2]	5/95	60/40						
Private D/E Ratio	50/50	80/20		60/40		50/50		
Public Cost of Debt (%)	3.0	3.0					6.0	
Private Cost of Debt (%)	4.0	4.0						
Private Cost of Equity (%)	7.5	7.5						
Rev Reqts on Sunk Costs Included[3]	No	—					Yes	
Life-Cycle Present Value:[4]								
Dec 1982 Version of SAM	55,960	55,540	55,960	55,810	55,960	55,940	59,130	55,540
Feb 1983 Version of SAM	51,340	49,900	Not Modeled		Not Modeled		Not Modeled	
4/5—Coal:								
Dec 1982 Version of SAM	420		150		20		3,590	
Feb 1983 Version of SAM	1,440		—		—		—	

See Table G-3, page G-6 for Footnotes.

Table G-2.
WPPSS 4 and 5 Participants Study Assumptions and Results[1]

Major Assumptions	2A 4/5	2A Coal	2B 4/5	2B Coal
Capacity (MW)	1259/1240	508	Same as 2A one with	
Equivalent Availability (%)	70	70	less generic coal	
Fuel Escalation (%)	1.5	2.3	scheduled in the	
Capital Escalation (%)	0.8	0.8	WNP 4/5 scenario	
WNP 4/5 Capital (millions)	3,234	—		
4/5 Hold Costs (millions/unit/yr)	3.0	—		
WNP 1/4 Shared Costs (millions)	—	241		
Coal 1-4 Capital (millions)	—	2,210		
Fixed O&M ($/kW-yr)	44.0	18.2		
Variable O&M (m/kWh)	0.	1.6		
Fixed Fuel ($/kW-yr)	29.1	2.4		
Variable Fuel (m/kWh)	0.	15.4		
Ownership (private %/public %)[2]	5/95	90/10		
Private D/E Ratio	60/40	60/40		
Public Cost of Debt (%)	3.0	3.0		
Private Cost of Debt (%)	4.0	4.0		
Private Cost of Equity (%)	7.5	7.5		
Rev Reqts on Sunk Costs Included[3]	No	—		
Life-Cycle Present Value:[4]				
Feb 1983 Version of SAM	48,260	50,160	47,270	50,160
4/5—Coal	-1,900		-2,890	

See Table G-3, page G-6 for Footnotes.

Table G-3.
Final Plan Study Assumptions and Results[2]

	3A		3B		3C		3D		3E	
Major Assumptions	**4/5**	**Coal**	**4/5**	**Coal**	**4/5**	**Coal**	**4/5**	**Coal**	**4/5**	**Coal**
Capacity (MW)	1259/1240	508	Same as 3A with		Same as 3A with		Same as 3A with		Same as 3A with	
Equivalent Availability (%)	65	72	following changes		following changes		following changes		following changes	
Fuel Escalation (%)	1.5	1.2						2.3		2.3
Capital Escalation (%)	0.8	0.8								
WNP 4/5 Capital (millions)	3,603	—								
4/5 Hold Costs (millions/unit/yr)	3	—								
WNP 1/4 Shared Costs (millions)	—	0.								
Coal 1-4 Capital (millions)	—	2,366								
Fixed O&M ($/kW-yr)	50.2	18.2								
Variable O&M (m/kWh)	0.	1.6								
Fixed Fuel ($/kW-yr)	32.5	2.4								
Variable Fuel (m/kWh)	0.	15.4								
Ownership (private %/public %)[2]	5/95	60/40	60/40		97/3	97/3	60/40		97/3	97/3
Private D/E Ratio	80/20	80/20								
Public Cost of Debt (%)	3.0	3.0								
Private Cost of Debt (%)	4.0	4.0								
Private Cost of Equity (%)	7.5	7.5								
Rev Reqts on Sunk Costs Included[3]	No	—								
Life-Cycle Present Value:[4] Feb 1983 Version of SAM	48,250	48,230	48,430	48,230	48,550	48,310	48,430	48,880	48,550	48,950
4/5—Coal	20		200		240		-450		-400	

Footnotes for Tables G-1 through G-3.

[1]All costs are expressed in July, 1981 dollars, and all escalation rates and financing costs are expressed in real terms.

[2]Actual ownerships used in the 5/95 cases are 0/100 for WPPSS 4 and 10/90 for WPPSS 5.

[3]The present value of revenue requirements on the WPPSS 4/5 sunk costs are estimated at $2,010 million for the public debt and $120 million for PP&L's 10% share of WPPSS 5.

[4]Present values are discounted to July 1981, at a 3% real discount rate.

[5]Real fuel escalation for the studies in table G-3 is limited to a period of twenty years.

[6]In-service dates for the nuclear and coal units used in the studies represented in tables G-1 through G-3 are shown below:

For Table G-1. (Council Draft Plan Studies)
WPPSS 4 - 7/95 - Coal 1 - 7/95
WPPSS 5 - 7/96 - Coal 2 - 7/96
- Coal 3 - 7/96
- Coal 4 - 7/97

For Table G-2. (Participants/PNUCC Studies)
WPPSS 4 - 1998 - Coal 1 - 1998
WPPSS 5 - 1999 - Coal 2 - 1999
- Coal 3 - 1999
- Coal 4 - 2000

For Table G-3. (Council Final Plan Studies)
WPPSS 4 - 7/97 - Coal 1 - 7/97
WPPSS 5 - 7/98 - Coal 2 - 7/97
- Coal 3 - 7/98
- Coal 4 - 7/99
- Coal 5 - 7/99 (224 MW)

Appendix H
Economic and Demographic Assumptions

The process of developing economic and demographic assumptions began early in 1982. The first step was the development of illustrative economic forecasts by the Council's contractor. The contractor also developed a simple economic forecasting model to facilitate the development by Council staff of its own forecasts. In June, Council staff circulated an issue paper on economic and demographic forecasts that was accompanied by a questionnaire soliciting advice and information on many significant areas of uncertainty. Responses to that questionnaire, staff analyses, review of other forecasts for the region, and comments received on the contractor's illustrative forecasts all played a role in the development of the Council's economic and demographic assumptions. Preliminary forecasts were presented at the September 16, 1982 Council meeting. Revisions were incorporated based on Council and public comment and additional research.

Consistency among the Council's forecast regional economic and demographic conditions is ensured by a relatively simple model that links the various aspects of the region's economy. Forecasts of employment are developed following an economic base approach. The basic industries are those that serve markets outside the region. Economic base theory suggests that employment and income in the basic sector generates additional employment and income in the local economy. Workers in the basic industries spend income locally, which generates jobs in the secondary industries. These workers, in turn, spend their income, which generates additional employment. The sum of employment impacts resulting from employment in the basic sector is the multiplier effect.

In the Council's set of economic and demographic assumptions, basic industry projections are linked with secondary employment projections through an employment multiplier. Basic industries are defined as manufacturing, agriculture, mining, and federal government. The secondary industries include industries such as wholesale and retail trade, services, transportation and public utilities, and construction. This categorization of industries into basic or secondary has some limitations.

A number of manufacturing industries depend on regional or local markets for their products. Growth in these industries depends on regional economic and population growth, rather than on the national market. For example, the manufacturing category of food and kindred products includes enterprises such as bakeries, dairies, and beverage bottling plants, which depend primarily on local or regional markets.

On the other hand, employment related to tourism, financial and banking services, and port activity serving Alaska and Pacific Rim countries are export-oriented, and, as such, depend on demand from outside the region. In this definition described here, all employment in these industries falls into the secondary category.

Total employment is the sum of basic and secondary employment. Population is derived from total employment through projections of an employment/population ratio. Change in the employment/population ratio reflects a combination of changes in variables such as the age composition of the population, the unemployment rate, and the proportion of each age group in the labor force.

The number of households is linked with total population through a projection of the average number of persons per household. As with the employment/population ratio, shifts in age composition affect average household size. Other factors include divorce rates, fertility rates, and social and economic effects on household formation.

Figure H-1 illustrates the relationships embodied in the Council forecasts. Table H-1 summarizes and compares the relationship between variables in the Council's high and low forecasts.

The economic and demographic assumptions are important elements in assessing the range of future needs for electricity. For the industrial sector, production, wage rates, and employment are provided to the industrial model. The commercial sector model utilizes projections of secondary employment to derive estimates of commercial building space. Forecasts of the housing stock provide the basic unit of analysis for the residential model. These assumptions, in combination with electricity and fuel prices, building codes, and other variables, underlie the projections of future needs for electricity.

This appendix provides some additional detail on economic and demographic assumptions developed by the Council. Initially, three forecasts were developed: a high, a medium, and a low. These forecasts are described in detail in a Council staff working paper, "Economic and Demographic Assumptions." (The working paper is available upon request from the Council.) The Council adopted the low and high forecasts as acceptable bounds within which to plan for the region's future needs for electricity. For planning purposes, two additional forecasts were developed based on combining assumptions from the original three forecasts; these are the medium-high and medium-low. The assumptions embodied in them are shown in table H-2.

The rest of the information in this appendix consists of various tables extracted from the Council staff working paper and other documents. Persons who are interested in description and explanation of the forecasts should request a copy of the working paper.

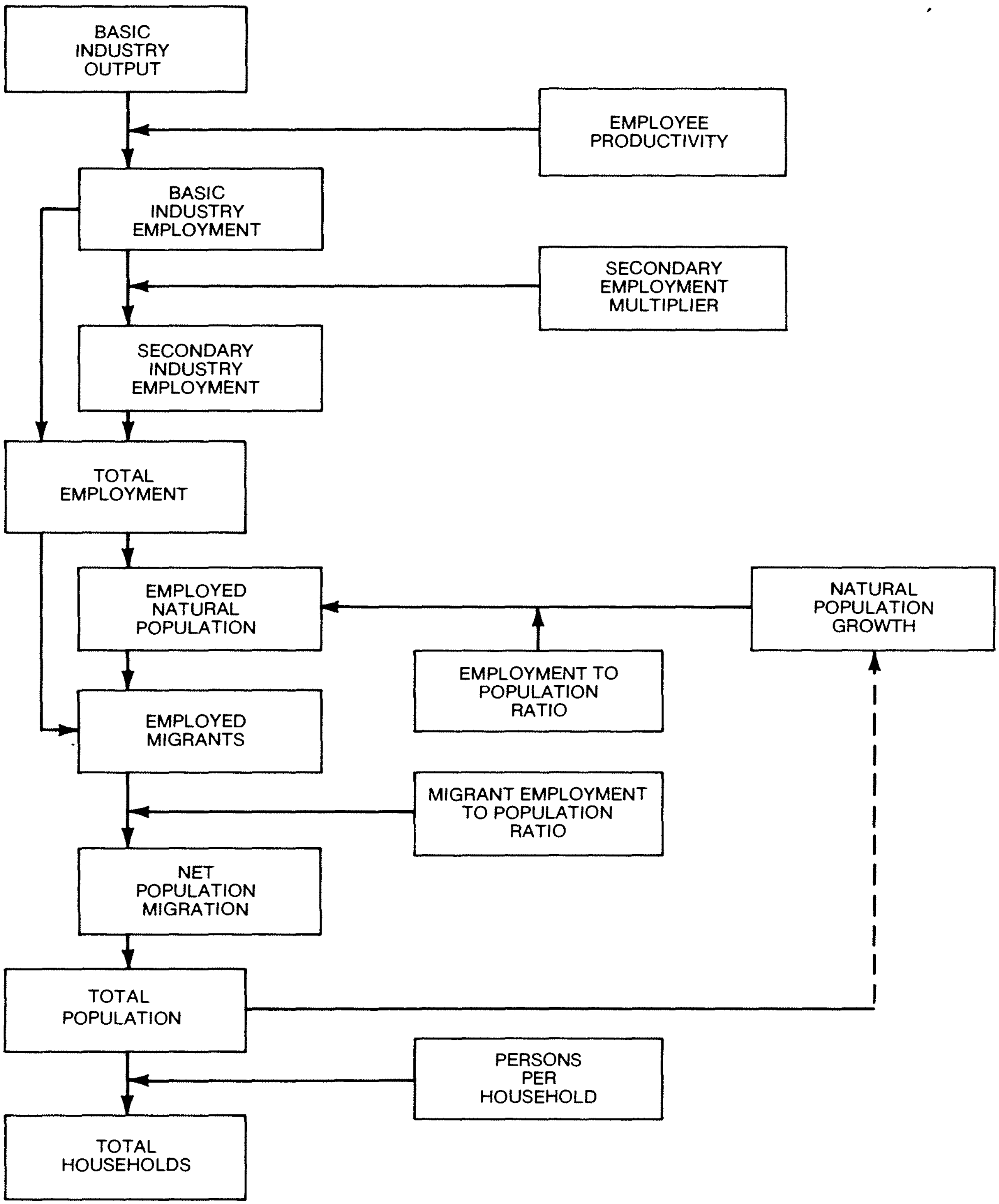


Figure H-1.
Structure of Economic Relationships

Table H-1.
Relationships Among Employment, Population, and Households—Historical and Projected

	1960	1980	2002 High	2002 Medium-High	2002 Medium-Low	2002 Low
Basic Employment (thousands)	708.0	875.9	1,299.2	1,161.9	1,037.4	899.8
Employment multiplier	2.46	3.69	5.12	4.92	4.56	4.36
Total Employment (thousands)	1,743.2	3,235.2	6,645.7	5,712.1	4,734.9	3,919.7
Employment/Population Ratio	0.318	0.406	0.519	0.469	0.447	0.420
Population (thousands)	5,489.7	7,969.3	12,807.0	12,180.1	10,591.2	9,341.3
Persons per Household	3.2	2.7	2.2	2.4	2.4	2.6
Households (thousands)	1,708.0	2,950.6	5,762.5	5,091.6	4,425.8	3,593.5

Table H-2.
Two Intermediate Scenarios—Economic and Demographic Assumptions

MEDIUM-HIGH

Characterized by rapid growth in high-technology industries, chemicals, and commercial industries; moderate growth in traditional industries such as forestry products, aluminum, and aerospace. Results in total employment growth of 2.9 percent per year, population growth of 2.1 percent per year, and household growth of 2.8 percent per year.

Medium-High—combination of assumptions from high forecast and medium forecast.

From High Forecast

SIC 27 - Printing and publishing
SIC 30 - Rubber and plastic products
SIC 34 - Fabricated metals
SIC 35 - Machinery
SIC 36 - Electric equipment
SIC 38 - Professional instruments
SIC 2812 - Chlorine and Caustic soda
SIC 28XX - Other chemicals

Average of medium and high forecast employment multiplyer.

All other assumptions from medium forecast.

MEDIUM-LOW

Characterized by moderate growth in high-technology industries, chemicals, and commercial industries; low growth in forestry industries and elemental phosphorus. Results in total employment growth of 1.9 percent per year, population growth of 1.4 percent per year, and household growth of 2.0 percent per year.

Medium-Low—combination of assumptions from medium forecast and low forecast.

From Low Forecast

SIC 24 - Lumber and wood products
SIC 26 - Pulp and paper
SIC 2819 - Elemental phosphorus

Low forecast housing additions by type.

All other assumptions from medium forecast.

Table H-3.
Summary and Comparison of Economic Assumptions

	Average Annual Rates of Change (%)						
	1960-1980		1980-2002				
	PNW	U.S.	PNW				U.S.**
			High	Medium-High	Medium-Low	Low	
Employment							
Total*	3.13	2.60	3.67	2.88	1.92	0.96	1.27
Manufacturing	1.95	0.95	2.47	1.90	1.14	0.35	0.37
Basic Industry	1.01	—	1.99	1.42	0.85	0.14	—
Population	1.88	1.14	2.40	2.14	1.43	0.79	0.8
Household	2.77	2.12	3.40	2.76	2.04	0.99	—

	Comparison of 1980 and 2002 PNW				
	1980	2000			
		High	Medium-High	Medium-Low	Low
Persons Per Household	2.7	2.22	2.39	2.39	2.60
Housing Stock Shares by Type (Percent of Total)					
Single-Family (1-4 units)	78.2	75.7	71.3	68.2	71.9
Multi-Family (5 and more)	14.4	15.0	17.4	19.9	18.0
Mobile Homes	7.4	9.3	11.3	11.9	10.1

*Excludes non-agricultural self-employed.

s projected by DRI, *U.S. Long-Term Review*, Spring 1982. Total Employment is total non-agricultural establishment employment. The growth rate for total employment and manufacturing employment is from the TRENDLONG2007A projection.

Table H-4.
Comparison of Regional and U.S. Growth Rates—Total Employment

	Average Annual Rates of Growth		Ratio PNW/U.S. Growth Rates
	PNW	U.S.	
Historical			
Twenty years (1960-80)	3.1	2.1	1.5
Highest 10 years (1970-80)	3.8	2.4	1.6
Highest 5 years (1974-79)	4.9	2.6	1.9
Forecast (1980-2002)			
High	3.7	1.4	2.6
Medium-High	2.9	1.3	2.2
Medium-Low	1.9	1.3	1.5
Low	1.0	1.0	1.0

Table H-5.
Employment by Industry—Pacific Northwest
Historical and Projected

	Thousands of Employees				Average Annual Rate of Growth		
	1960	1980	2002		1960-1980	1980-2002	
			High	Low		High	Low
Total Employment (Establishment)*	1,743.2	3,235.2	6,645.7	3,919.7	3.1	3.7	1.0
Basic Employment	708.0	875.9	1,299.2	899.8	1.1	2.0	0.1
Agriculture	214.4	156.7	163.7	121.2	-1.6	0.2	-1.3
Mining	10.2	13.2	19.2	15.0	1.3	1.9	0.6
Manufacturing	400.3	591.2	962.4	633.6	2.0	2.5	0.3
Federal Government	83.1	114.8	153.9	130.0	1.6	1.5	0.6
Secondary Employment	1,035.2	2,359.3	5,346.5	3,019.9	4.2	4.2	1.2
Construction	82.4	158.7	386.0	218.4	3.3	4.5	1.6
Trans., Comm., Public Utilities	125.8	179.3	335.9	190.1	1.8	3.2	0.3
Wholesale and Retail Trade	341.8	745.7	1,787.3	1,009.4	4.0	4.5	1.5
Finance, Insurance, & Real Estate	67.9	185.3	408.1	230.0	5.1	4.0	1.1
Services	195.2	578.7	1,473.0	831.6	5.6	4.8	1.8
State and Local Government	222.1	511.6	956.3	540.4	4.3	3.2	0.3
Ratio of Total Employment to Basic Employment	2.46	3.69	5.12	4.36			

*Total Employment figures does not include estimate of non-agricultural self-employed.

Table H-6.
Consumption of Electricity by Industry—Pacific Northwest, 1977

	Electricity Consumed (10^6 kWh)	Share of Total (%)
SIC 20 - Food and Kindred Products	2,085.9	3.6
SIC 24 - Lumber and Wood Products	4,769.4	8.2
SIC 26 - Pulp and Paper	11,024.0	18.9
SIC 28 - Chemicals and Allied Products	7,996.7	13.7
SIC 33 - Primary Metals	28,234.1	48.4
SIC 37 - Transportation Equipment	905.3	1.6
SIC 35, 36, 38 - "Electronics"	592.4	1.0
Other Manufacturing	2,703.7	4.6
TOTAL MANUFACTURING	58,311.5	100.0

Source: Synergic Resources Corporation, *Industrial Process Energy End-Use Data Base for the Pacific Northwest*, Report to the Bonneville Power Administration, May 1981, p. I-II.

Table H-7.
Forecasts of Employment—Lumber and Wood Products
Pacific Northwest, 1980-2002 (in thousands)

SIC	1980	1985			2002		
		High	Med	Low	High	Med	Low
Lumber (SIC 2421)	51.9	57.8	51.6	43.6	48.0	44.1	37.0
Plywood (SIC 2436)	26.7	40.2	32.1	24.2	38.8	28.4	22.8
Other 24 (24XX)	60.7	75.4	65.6	58.6	72.1	66.1	55.4
Total SIC 24	140.2	173.3	149.3	126.4	158.8	138.6	115.2

Table H-8.
Forecasts of Employment—Pulp and Paper (SIC 26)
Pacific Northwest, 1980-2002 (in thousands)

SIC	1980	2002		
		High	Med	Low
Pulp (SIC 2611)	3.5	3.4	3.3	3.3
Paper (SIC 2621)	13.6	18.6	17.9	17.7
Paperboard (SIC 2631)	5.1	4.8	4.5	4.4
Other Paper (26XX)	7.8	11.8	10.3	8.7
Total SIC 26	30.0	38.5	36.0	34.2

Table H-9.
Forecasts of Employment—Chemicals (SIC 28)
Pacific Northwest, 1980-2002 (in thousands)

SIC	1980	2002		
		High	Med	Low
Chlorine/Caustic Soda (SIC 2812)	0.9	1.0	0.9	0.8
Elemental Phosphorus (SIC 2819)*	1.3	1.2	1.0	1.0
Other Chemicals (28XX)	11.3	17.5	14.5	13.0
Total SIC 28**	13.5	19.7	16.4	14.8

*Employment in SIC 2819 in Washington is in nuclear fuels and processing. In this table, it is included in the residual category.

**Totals may not add because of rounding.

Table H-10.
Employment Projections in Selected Industries
Pacific Northwest, 1980-2002 (in thousands)

Industry	1980	Employment (in thousands) 2002	Average Annual Rate of Growth (%) 1980 - 2002
Food and Kindred Products (SIC 20)			
High		99.2	1.5
Medium	74.2	90.1	1.0
Low		82.4	0.5
Transportation Equipment (SIC 37)**			
High		161.5	2.0
Medium	109.1	107.2	-0.1
Low		83.4	-1.3
Aerospace (SIC 372)*			
High		90.0	0.6
Medium	80.0	62.0	-1.3
Low		45.0	-2.8
Electronics (SIC 35, 36, 38)			
High		226.1	4.9
Medium	86.5	168.8	3.4
Low		128.6	2.0

*State of Washington only

*Includes Aerospace in Washington

Appendix I
Analysis of the Inclusion of Combustion Turbines in the Plan

This appendix is an illustration of the advantages of a flexible resource when demand growth is not known with any certainty. The flexibility of combustion turbines is in low capital investment, where the majority of the cost is in the operating expense. Thus, the total cost responds relatively directly to demand. Water uncertainty and demand uncertainty combine to ensure that combustion turbines operate infrequently, so that the total cost of owning and operating them is low.

The example is unrealistic in that it assumes that all planning decisions need to be made today and that there will be no opportunity to respond to actual demands as they develop, by changing the plan. Nonetheless, it makes one valid point: planning for multiple demand forecasts, as the Council does, requires that the probabilities of those demand forecasts be taken into account in planning resources to meet them. This applies especially to the high growth forecast, since the probability of meeting or exceeding that forecast is quite low.

To test the value of the combustion turbine flexibility for planning purposes, the Council analyzed each of the four growth forecasts for each of three resource portfolios: (a) no additional combustion turbines, (b) 1,470 average megawatts of additional combustion turbines, and (c) 2,940 average megawatts of additional combustion turbines. Each increase in level of combustion turbines was offset by a reduction in coal plants of equivalent capability. For each portfolio, the distribution of total system cost at each of the four growth forecasts was estimated. These distributions were combined with the Council's subjective probability distribution on demand to produce one distribution for total system cost across the entire demand forecast range. Figure I-1 graphically represents the distributions for 0, 1,470, and 2,940 average megawatts of new combustion turbines, respectively. Net present value of total system cost is represented on the horizontal axis, and frequency of occurrence on the vertical axis. Examination reveals that as combustion turbine capacity is added to the system, the expected value of total system cost decreases.

The analysis was not pushed beyond 2,940 average megawatts of combustion turbines because of the expectation that any additional combustion turbine energy would cause costs to begin to rise. Two factors would combine to cause this. First, with the limited secondary available for combustion turbine displacement, addition of more combustion turbines would soon result in significant levels of turbine operation (and sharply increased levels of production costs) in all but the best water conditions under the high forecast. Secondly, with a difference between the high and medium-high forecast of 3,500 megawatts, and firm existing turbine capability of about 300 megawatts, addition of more than 3,200 megawatts of new combustion turbines would ensure some combustion turbine operation under poor water conditions in the much higher probability medium-high growth forecast. As combustion turbine operation increases across all demand states, the operating cost penalty will force expected costs upward.

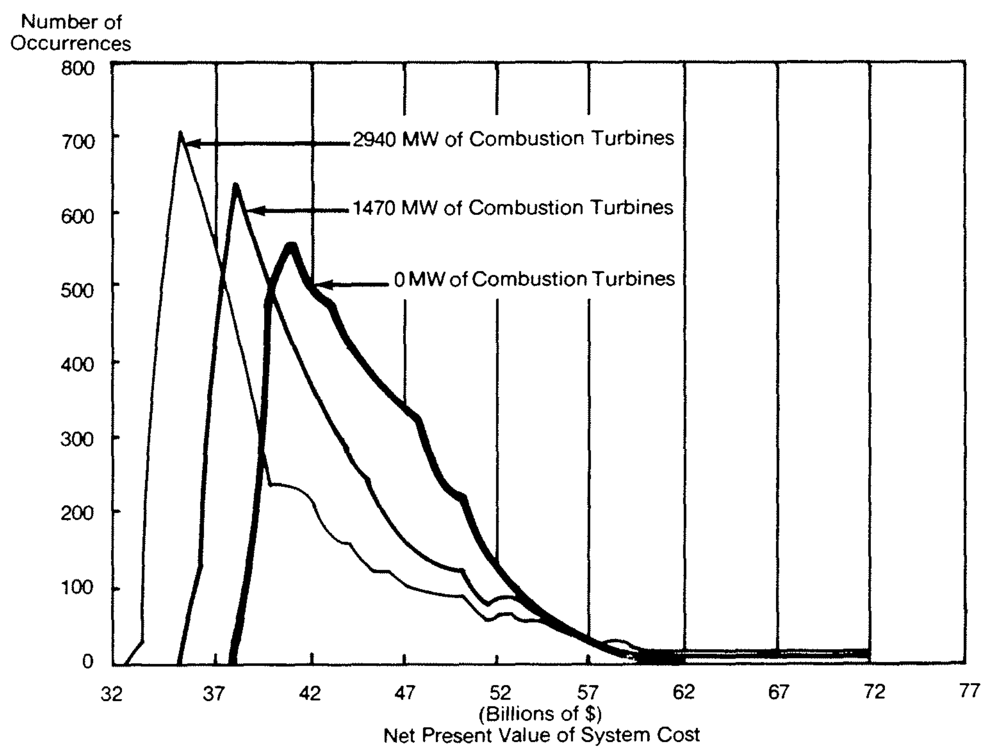


Figure I-1.
Frequency Histogram of Net Present-Value System Costs

This analysis was conducted for illustrative purposes only. It has simulated what the decisionmaker might do with complete uncertainty about future demands and with no way of revising decisions once they were made. This is not the case in the real world. For example, the region will know better in ten years whether it is on the Council's high growth forecast or closer to the low. And the Council will make appropriate revisions to the twenty-year plan in each of the plan updates. The analysis has shown the Council that some level of combustion turbines, beyond the 300 megawatts of existing oil/gas-fired generation, should be included in the twenty-year plan—whether or not they are ever built—to hedge against unexpected increases in demand. The level included in the plan, 1,050 megawatts, was based on the Council's judgment, taking into consideration that the total amount that works best with the hydropower system is about 1,000 megawatts.

Northwest Conservation and Electric Power Plan

Appendix J

Model Standard for Energy Conservation in New Buildings

PREFACE

This Model Standard may be adopted and enforced on or before January 1, 1986 by state or local governments or by utilities where legally authorized to do so. Those entities which choose not to adopt and enforce the standard should prepare an alternative standard or plan for achieving electric energy savings that are comparable to those achievable through the use of this Standard. The alternative plan may employ electric service requirements, rate designs, or any other technique for achieving conservation. Failure to implement the Standard or achieve comparable savings will subject utilities to the surcharge provisions of the Northwest Power Planning and Conservation Act.

Northwest Power Planning Council
700 S. W. Taylor
Portland, Oregon
97205

Contents

Chapter 1
Summary and Administration

Section 000. Summary

Residential buildings three stories or less in height and non-residential buildings less than 5,000 square feet in area may satisfy the requirements of this standard by application of one of three different approaches:

Component Performance Approach (Chapter 4)
Energy Budgets Approach (Chapter 5)
Prescriptive Approach (Chapter 6)

Residential buildings over three stories in height and non-residential buildings 5,000 square feet or greater in area may satisfy the requirements of this standard by application of either:

Component Performance Approach (Chapter 4)
Energy Budgets Approach (Chapter 5)

Exemptions for passive solar features are included in chapters 4 and 6 and for all non-depletable energy sources in chapter 5.

Section 100. Title

This Standard shall be known as the "Standard for Energy Conservation in New Buildings" and will be referred to herein as "the Standard."

Section 101. Purposes and Policies

A. Purposes.

The purpose of this Standard is to achieve efficient use of energy in buildings and structures.

B. Policies.

In the implementation, administration, and enforcement of this Standard, it will be the policy of the (State, County, City) to:

1. develop public awareness of energy conservation which will result in the use of energy-efficient systems and technology and a reduction of energy waste;

2. establish acceptable and appropriate standards for building design and construction which, while not assuring that optimal energy efficiency is attained for every building, will apply and be beneficial to all new buildings and achieve a high level of energy conservation;

3. permit alternative methods of meeting Standard requirements in order to allow and encourage innovative design;

4. encourage the use of solar and other new technologies which may result in future energy efficiency and increased use of non-depletable energy sources;

5. establish a framework of design parameters which will be supplemented with design specifications and instructions in a manual for untrained persons, and in rules and regulations interpreting the Standard;

6. implement and enforce the Standard through the (State, County, City) in a manner that will be convenient and expeditious to those seeking permits;

7. provide regular review and monitoring of the Standard and its administration to make it responsive to users, technological developments, and change; and

8. provide an appeal process, if none exists, for those buildings or occupancies where the productive needs of the Owner cannot be met under the provisions of this Standard.

C. Energy Source.

The provisions of this Standard do not consider the efficiency of various energy forms as they are delivered to the building envelope ("delivered energy efficiency"). The appropriate factor for delivered energy efficiency should be considered prior to the selection of the mechanical, electrical, and illumination systems, and energy form for specific uses. A determination of delivered energy efficiencies when used in conjunction with this Standard will provide the most efficient use of available energy in new building construction.

Section 102. Scope

A. Intent.

This Standard sets forth certain requirements for the design of exterior envelopes, heating, ventilating and air conditioning systems (HVAC), service water heating, electric distribution, and illuminating systems and equipment to achieve more efficient use of energy. This Standard is intended to supplement the provisions of local structural, mechanical and electrical codes.

B. Exempt Buildings.

1. Buildings and structures or portions thereof whose peak design rate of energy use is less than one (1) watt per square foot or three and four-tenths (3.4) Btu/hour per square foot of floor area for all buildings.

2. Buildings which are neither heated nor cooled.

3. Buildings with heating appliances which meet all of the following criteria:

    (a.) Sized for a maximum interior design temperature of less than 50° F, and

    (b.) Equipped with thermostatic control(s) that has a maximum temperature of less than 50° F.

Section 103. Special Provisions for Major Projects

A design conference with the Building Official to discuss building energy-efficiency is required for all proposed buildings over 50,000 square feet of conditioned floor area. The conference shall be held not less than 60 days prior to the application for a building permit. At this conference, the energy-efficiency provisions to be provided shall be outlined. It shall be demonstrated that the preliminary design will meet the requirements of this Standard.

Section 104. Application to Existing Buildings

A. Additions, Alterations, and Repairs to Existing Buildings.

Additions, alterations, and repairs may be made to existing buildings or structures without making the entire building or structure comply with all of the requirements of this Standard for new buildings or structures, provided the additions, alterations or repairs that are made shall comply with the applicable requirements of the Standard. The Building Official may approve designs of alterations or repairs which do not fully conform with all of the requirements of this Standard where in his/her opinion full conformance is physically impossible and/or economically impractical and (1) the alteration or repair improves the energy efficiency of the building, or (2) the alteration or repair is energy efficient and is necessary for the health, safety, and welfare of the general public.

B. Historic Buildings and Structures.

The Building Official may modify the specific requirements of this Standard as it applies to the historically significant elements of buildings and structures designated as landmarks or situated in historic districts and require, in lieu thereof alternate requirements which, in his opinion, will result in a reasonable degree of energy conservation.

C. Change of Occupancy or Use.

Any change in the occupancy or use of an existing unheated or uncooled building, structure, or portion of a building to a use or occupancy which provides conditioned space shall not be permitted unless the building, structure, or portion of the building complies with this Standard.

Section 105. Materials and Equipment

A. Identification.

All materials and equipment used to comply with this Standard shall be identified in order to show compliance with this Standard.

B. Alternative Systems, Materials, Methods of Construction, and Design.

The provisions of this Standard are not intended to prevent the use of any material, method of construction, or design not specifically prescribed by this Standard, provided any such alternate has been approved.

The Building Official may approve any such alternate provided he finds the proposed alternate meets or exceeds the provisions of this Standard and that the material, method, design, or work offered is, for the purpose intended, at least the equivalent of that prescribed in this Standard in quality, strength, effectiveness, fire resistance, durability, safety, and energy consumption.

The Building Official may require that sufficient evidence or proof be submitted to substantiate any claims that may be made regarding its performance capabilities.

C. Maintenance Information.

When equipment is supplied which requires preventive maintenance to maintain efficient operation, the Owner shall be furnished with complete maintenance information and necessary actions shall be clearly stated and incorporated on a readily accessible label. Such label may be limited to identifying, by title or publication number, the operation and maintenance manual for that particular product and model.

Section 106. Plans and Specifications

With each application for a building, mechanical, or electric permit, plans and specifications shall be submitted showing all information pertinent to the applicable sections of this Standard.

Submission of all pertinent information shall be a condition precedent to the processing of any of the above permits and approval of the submitted information shall be a condition precedent to the issuance of any of the above permits.

Section 107. Details

The plans and specifications shall show in sufficient detail all pertinent data and features of the building and the equipment and systems as herein governed including, but not limited to: exterior envelope component materials, U values of the respective elements including insulation, R values of insulating materials, size and type of apparatus and equipment, equipment and system controls, and other pertinent data to indicate conformance with the requirements herein.

Section 108. Enforcement and Inspections

A. Scope.

The Building Official is authorized and directed to enforce this Standard. All construction or work for which a permit is required shall be subject to inspection by the Building Official in connection with inspections performed pursuant to the local structural, mechanical, and electric codes.

B. Authority.

The Building Official is authorized and directed to promulgate, adopt, and issue those rules and regulations necessary to the effective and efficient administration of this Standard, which may include:

1. "Building Construction Standards" to promulgate standards which are acceptable as a method or as an alternative design for meeting code-required performance criteria, or to edit or update national standards which are referenced in this Standard;

2. "Standard Interpretations" to interpret and clarify conditions or language expressed in this Standard; and

3. "Product Approvals" to approve a specific building construction material or product or a particular component fabricator which has been found acceptable as meeting this Standard's required performance criteria.

C. Procedure for Adoption of Rules.

The Building Official shall promulgate, adopt, and issue rules according to the procedures as specified in the "Administrative Code" of the *(State, County, City.)*

Section 109. Validity

If any section, subsection, sentence, clause, or phrase of this Standard is, for any reason, held to be unconstitutional, such decisions shall not affect the validity of the remaining portions of this Standard. The *(legislative body)* hereby declares that it would have passed this Standard, and each section, subsection, clause, or phrase thereof, irrespective of the fact that any one or more sections, subsections, sentences, clauses, and phrases be declared unconstitutional.

Section 110. Violations and Penalties

It shall be unlawful for any person, firm, or corporation to erect, construct, enlarge, alter, repair, move, improve, remove, convert or demolish, equip, use, occupy, or maintain any building or structure in the city, or allow the same to be done, contrary to or in violation of any of the provisions of this Standard or without obtaining the applicable construction permits prior to commencement of any of the above actions.

Every offense defined by this ordinance or conduct made unlawful thereby shall constitute a violation. A violation may be punished by a civil fine or forfeiture not to exceed $ (Fine Amount), but a conviction of a violation shall not give rise to any disability or legal disadvantage based on the conviction of a criminal offense. Each day's violation or failure to comply shall constitute a separate offense.

Notwithstanding the civil nature of the penalty provided herein for violations, nothing in this section shall deny any constitutional rights which a defendant would have were the penalty deemed criminal.

Compliance with the requirements of this Standard shall be the obligation of the owner of the building within its scope, and not of the *(State, County, City)* or any of its officers or employees.

Section 111. Liability

Nothing contained in this Standard is intended to be nor shall be construed to create or form the basis for any liability on the part of the *(State, County, City)* or its officers, employees, or agents, for any injury or damage resulting from the failure of a building to conform to the provisions of this Standard, or by reason of/in consequence of any inspection, notice, order, certificate, permission, or approval authorized or issued or done in connection with the implementation or enforcement of this Standard, or by reason of any action or inaction on the part of the *(State, County, City)* related in any manner to the enforcement of this Standard by its officers or agents. The Building Official or any employee charged with the enforcement of this Standard, acting in good faith and without malice for the *(State, County, City)* in the discharge of his duties, shall not thereby render himself liable personally and he is hereby relieved from all personal liability for any damage that may accrue to persons or property as a result of any act required or by reason of any act or omission in the discharge of his duties. Any suit brought against the Building Official or employee, because of such act or omission performed by him in the enforcement of any provision of this Standard, shall be defended by the *(State, County, City)*.

Chapter 2
Definitions

Section 200. General

For the purpose of this Standard, certain abbreviations, terms, phrases, words, and their derivatives shall be construed as specified in this section. Words used in the singular include the plural and the plural the singular. Words used in the masculine gender include the feminine and the masculine.

Section 201. "A" Definitions

"Accepted analysis methods" means heating/cooling and lighting load calculations performed in accordance with the most current procedures developed by a nationally recognized professional organization (such as ASHRAE, ARI, SMACNA, etc.), one developed by an HVAC equipment manufacturer and approved by Bonneville Power Administration (BPA), one which results from a BPA approved computer simulation model or simplified calculation method.

"Accessible" (as applied to equipment) means admitting close approach not guarded by locked doors, elevation or other effective means. (See "Readily accessible")

"Air conditioning, comfort" means the process of treating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution to meet requirements of the conditioned space.

"Air transport factor" means the ratio of the rate of space design sensible heat removal from the conditioned space to the energy input to the supply, return, relief, and exhaust fan motor(s), expressed in consistent units and under the designated operating conditions.

"ASHRAE" means the American Society of Heating, Refrigeration, and Air Conditioning Engineers, Inc.

"Automatic" means self-acting, operating by its own mechanism when actuated by some impersonal influence, as for example, a change in current strength, pressure, temperature, or mechanical configuration.

Section 202. "B" Definitions

"Boiler capacity" means the rate of heat output in Btu/h measured at the boiler outlet, at the design inlet and outlet conditions, and rated fuel/energy input.

"British thermal unit (Btu)" means approximately the amount of heat required to raise the temperature of one pound of water by one Fahrenheit degree at 60° F.

"Building envelope" means the elements of a building which enclose conditioned spaces through which thermal energy may be transferred to or from the exterior, or to or from spaces exempted by the provisions of Section 102(b).

"Building Official" means the authorized representatives of the local building code enforcement entity.

"Building project" means a building or group of buildings, including on-site energy conversion or electric-generating facilities, which utilize a single submittal for a construction permit or are within the boundary of a contiguous area under one ownership.

Section 203. "C" Definitions

"Clerestory" means a window placed in a wall or projecting from a roof plane at 30° or less from the vertical to admit daylight into the interior of a building or structure.

"Coefficient of Performance (COP) Heating" as applied to HVAC System Heating Equipment, Heat Pumps, Heating Mode COP shall mean: The ratio of the rate of net heat output to the rate of total on-site energy input to the heat pump expressed in consistent units and under designated rating conditions.

The rate of net heat output shall be defined as the change in the total heat content of the air entering and leaving the equipment (not including supplementary heat).

Total on-site energy input to the heat pump shall be determined by combining the energy inputs to all elements, except supplementary heaters, of the heat pump, including, but not limited to, compressor(s), compressor sump heater(s), pump(s), supply-air fan(s), return-air fan(s), outdoor-air fan(s), cooling-tower fan(s), heat generators (boilers), and the HVAC system equipment control circuit.

"Coefficient of Performance (COP) Cooling" as applied to HVAC System Equipment Electrically Operated, Cooling Mode COP shall mean: The ratio of the rate of net heat removal to the rate of total on-site energy input to the air conditioner, expressed in consistent units and under designated rating conditions.

The rate of net heat removal shall be defined as the change in the total heat content of the air entering and leaving the equipment (without reheat).

Total on-site energy input shall be determined by combining the energy inputs to all elements supplied with the package of the equipment including, but not limited to, compressor(s), compressor sump heater(s), pump(s), supply-air fan(s), return-air fan(s), condenser-air fan(s), cooling-tower fan(s), circulating water pump(s), and the HVAC system equipment control circuit.

"Coefficient of Performance (COP) Cooling" as applied to HVAC System Components, Electrically Operated, Cooling Mode COP shall mean: The ratio of the rate of net heat removal to the rate of total on-site energy input, expressed in consistent units and under designated ratings conditions.

The rate of net heat removal from the component is defined as the difference in total heat contents of the water or refrigerant entering and leaving the component.

Total on-site energy input to the component shall be determined by combining the energy inputs to all elements and accessories as included in the component including, but not limited to, compressor(s), internal circulating pump(s), condenser-air fan(s), evaporative-condenser cooling water pump(s), purge devices, and the HVAC system component control circuit.

"Comfort envelope" means the area on a psychometric chart enclosing all those conditions described in the most current version of ASHRAE Standard 55 "Thermal Environmental Conditions for Human Occupancy."

"Conditioned floor area" means the horizontal projection of that portion of interior space which is contained within exterior walls and which is conditioned directly or indirectly by an energy-using system.

"Conditioned space" means space within a building which is conditioned directly or indirectly to maintain a temperature of 50° F or higher for heating and/or 85° F or below for cooling. It shall also include spaces with humidification or dehumidification means which maintain a space condition falling within the comfort zone set forth in the most current version of ASHRAE Standard 55 "Thermal Environmental Conditions for Human Occupancy." Enclosed corridors between conditioned spaces shall be considered as conditioned space.

"Cooled space" means space within a building which is provided with a positive cooling supply.

Section 204. "D" Definitions

"Deadband" means the temperature range in which no heating or cooling is used.

"Degree day, heating" means a unit, based upon temperature difference and time, used in estimating fuel consumption and specifying nominal heating load of a building in winter. For any one day, when the mean temperature is less than 65° F (18° C), there exists as many degree days as there are Fahrenheit (Celsius) degrees difference in temperature between the mean temperature for the day and 65° F (18° C).

"Dwelling unit" means a single unit providing complete, independent living facilities for one or more persons including provisions for living, sleeping, eating, cooking, and sanitation.

Section 205. "E" Definitions

"Efficiency, HVAC system" means the ratio of useful energy output (at the point of use) to the energy input for a designated time period, expressed in percent.

"Efficiency, overall system" means the ratio of the useful energy (at the point of use) to the thermal energy input for a designated time period, expressed in percent.

"Energy" means the capacity for doing work, taking a number of forms which may be transformed from one into another, such as thermal (heat), mechanical (work), electric; in customary units, measured in kilowatt-hours (kWh) or British thermal units (Btu).

"Energy-efficiency ratio (EER)" means the ratio of net equipment cooling capacity in Btu/h to total rate of electric input in Watts under designated operating conditions. When SI units are used this becomes equal to COP. (See "COP")

"Energy, new." See "New energy."

"Energy, recovered." See "Recovered energy."

"Enthalpy" means a thermodynamic property of a substance defined as the sum of its internal energy plus the quantity PV/J: where P = pressure of the substance, V = its volume, and J = the mechanical equivalent of heat, formerly called total heat and heat content.

"Exterior envelope." See "Building envelope."

Section 206. "F" Definitions

"Fireplace (for the purpose of this Standard only) means any any open hearth, solid fuel burning feature made of metal or masonry with or without an enclosure.

"Floodlighting" means a lighting system designated to light an area using projector-type luminaires usually capable of being pointed in any direction.

Section 207. "G" Definitions

"General lighting" means lighting designed to provide an approximately uniform level of illumination in an area.

"Glazed area" means the rough opening for a window or skylight, including the glass and the sash.

"Glazing, special." See "Special glazing."

"Gross floor area" means the sum of the areas of the several floors of the building, including basements, mezzanine, and intermediate floored tiers and penthouses of headroom height, measured from the exterior faces of exterior walls or from the center line of walls separating buildings, but excluding:

Covered walkways, open roofed-over areas, porches and similar spaces; and

Pipe trenches, exterior terrace or steps, chimneys, roof overhangs, and similar features.

"Gross roof/ceiling area" means the sum of the areas of the roof/ceiling assemblies consisting of the total interior surface area of all assemblies, including skylights, which enclose a heated and/or mechanically cooled space.

"Gross wall area" means the sum of the areas of the exterior walls consisting of all opaque wall areas (including foundation walls, between-floor spandrels, and peripheral edges of floors), window areas (including sash and clerestory), and door areas, which enclose a heated and/or mechanically cooled space (including interstitial areas).

Section 208. "H" Definitions

"Heat" means the form of energy that is transferred by virtue of a temperature difference.

"Heat storage capacity" means the physical property of materials (mass) located inside the building envelope which absorb, store, and release heat daily as a function of the building heat gains and losses, as calculated in Section 402(b)7. Units of Btu/° F.

"Heated space" means space, within a building, which is provided with a positive heat supply. The presence of finished living space within a basement, or registers or heating devices designed to supply heat to a basement space, shall automatically define that space as heated space.

"Humidistat" means a regulatory device, actuated by changes in humidity, used for automatic control of relative humidity.

"HVAC" means heating, ventilating, and air conditioning.

"HVAC system" means a system that provides either collectively or individually the processes of comfort heating, ventilating, and/or air conditioning within or associated with a building.

"HVAC system components" mean components which provide, in one or more factory-assembled packages, means for chilling and/or heating water with controlled temperature for delivery to terminal units serving the conditioned spaces of the building. Types of HVAC system components include, but are not limited to, water chiller packages, reciprocating condensing units, and water source (hydronic) heat pumps. (See "HVAC system equipment")

"HVAC system equipment" means equipment which provides, in one (single package) or more (split system) factory-assembled packages, means or air circulation, air cleaning, air cooling with controlled temperature and dehumidification; and optionally either alone or in combination with a heating plant, the functions of heating and humidifying. The cooling function may be either electrically or heat-operated and the refrigerant condenser may be air-, water-, ground-, or evaporatively cooled. Where the equipment is provided in more than one package, the separate packages shall be designed by the manufacturer to be used together. The equipment may provide the heating function as a heat pump or by the use of electric or fossil fuel-fired elements. (The word "equipment" used without modifying adjective may, in accordance with common industry usage, apply either to HVAC system equipment or HVAC system components.)

Section 209. "I" Definitions

"Infiltration" means the uncontrolled inward air leakage through cracks and interstices in any building element and around windows and doors of a building, caused by the pressure effects of wind and/or the effect of differences in the indoor and outdoor air density.

Section 210. "J" (Reserved)

Section 211. "K" (Reserved)

Section 212. "L" Definitions

"Low-rise residential building" means a building not exceeding 35 feet or three stories in height and containing solely one or more dwelling units. Height and grade are as defined in the local building code. Occupancy Groups R-1 and R-3.

"Luminaire" means a complete lighting unit consisting of a lamp or lamps together with the parts designated to distribute the light, to position and protect the lamps, and to connect the lamps to a power supply.

Section 213. "M" Definitions

"Manual" means capable of being operated by personal intervention.

"Marked rating" means the design load operating conditions of a device as shown by the manufacturer on the nameplate or otherwise marked on the device.

"May," as used in this Standard, means permissive for compliance.

"Multi-family dwelling" means a building containing three or more dwelling units. Occupancy groups R-1.

Section 214. "N" Definitions

"New energy" means energy, other than recovered energy, used for the purpose of heating or cooling.

"Non-depletable energy sources" mean sources of energy (excluding minerals) derived from incoming solar radiation, including natural daylighting and photosynthetic processes; from phenomena resulting therefrom including wind, waves and tides, lake or pond thermal differences; and energy derived from the internal heat of the earth, including nocturnal thermal exchanges. Neither natural gas, fuel oil, propane, coal, nor any utility-supplied electricity shall be considered a non-depletable energy source.

Section 215. "O" Definitions

"Opaque areas" mean all exposed areas of a building envelope which enclose conditioned space, except openings for windows, skylights, doors, and building service systems.

"Operable window insulation" means movable window covers (indoors and outdoors) which have the following features:

Readily accessible controls or operating mechanisms for the occupants;

Means to create an edge fit better than a loose fit (i.e., interlocking edge, cushion seal, mechanical or magnetic seal); and

A total-assembly thermal resistance of R-5 or higher.

"Outdoor air" means air taken from the outdoors and, therefore, not previously circulated through the HVAC system of a building or structure.

"Overall system efficiency." See "Efficiency, overall system."

Section 216. "P" Definitions

"Packaged terminal air-conditioner" means a factory-selected combination of heating and cooling components, assemblies, or sections intended to serve a room or zone.

"Packaged terminal heat pump" means a factory-selected combination of heating and cooling components, assemblies or sections, intended for application in an individual room or zone.

"Pool cover" means a vapor-proof cover which lies on or at the surface of the pool and is intended for such use.

"Positive cooling supply" means mechanical cooling deliberately supplied to a space, such as through a supply register. Also, mechanical cooling indirectly supplied to a space through uninsulated or insufficiently insulated surfaces of space-cooling components, such as evaporator coil cases and cooling distribution systems which continually maintain air temperatures within the space of 85° F or lower during normal operation. To be considered exempt from inclusion in this definition, such surfaces shall comply with the insulation requirements of this Standard.

"Positive heat supply" means heat deliberately supplied to a space by design, such as a supply register, radiator, or heating element. Also, heat indirectly supplied to a space through uninsulated or insufficiently insulated surfaces of service water heaters and space-heating components, such as furnaces, boilers, and heating and cooling distribution systems which continually maintain air temperature within the space of 50° F or higher during normal operation. To be considered exempt from inclusion in this definition, such surfaces shall comply with the insulation requirements of this Standard.

"Power," in connection with machines, means the time rate of doing work. In connection with the transmission of energy of all types, "power" means the rate at which energy is transmitted; in customary units, it is measured in Watts (W) or British thermal units per hour (Btu/h).

"Power factor," the ratio of the true power (Watts) to the apparent power (volts x amperes); the cosine of the angle of lag between the alternating current and the voltage waves.

"Primary zone" means an area with a single weather exposure and similar thermal loading.

Section 217. "Q" Definitions (Reserved)

Section 218. "R" Definitions

"R value." See "Thermal resistance (R)."

"Readily accessible" means capable of being reached quickly for operation, renewal, or inspection without requiring those to whom ready access is requisite to climb over or remove obstacles or resort to portable ladders, chairs, etc. (See "Accessible")

"Recommend" means suggest as appropriate; not required.

"Recooling" means the removal of heat by sensible cooling of the supply air (directly or indirectly) that has been previously heated above the temperature to which the air is to be supplied to the conditioned space for proper control of the temperature of that space.

"Recovered energy" means energy used which would otherwise be wasted (i.e., would not contribute to a desired end use) from an energy utilization system.

"Reheat" means the application of sensible heat to supply air that has been previously cooled below the temperature of the conditioned space by either mechanical refrigeration or the introduction of outdoor air to provide cooling.

"Reset" means adjustment of the set point of a control instrument to a higher or lower value, automatically or manually, to conserve energy.

"Roof/ceiling assembly" means all elements of the roof/ceiling envelope through which heat flows, thus creating a building transmission heat loss or gain, where such assembly is exposed to outdoor air and encloses a heated and/or mechanically cooled space. This does not include elements which are separated from a heated and/or mechanically cooled space by a vented air space.

"Room air conditioner" means an encased assembly designed as a unit primarily for mounting in a window or through a wall, or as a console. It is designed primarily to provide free delivery of conditioned air to an enclosed space, room, or zone. It includes a prime source of refrigeration for cooling and dehumidification and means for circulating and cleaning air, and may include means for ventilating and heating.

Section 219. "S" Definitions

"Sequence" means a consecutive series of operations.

"Service systems" means all energy-using systems in a building that are operated to provide services for the occupants or processes housed therein, including HVAC, service water heating, illumination, transportation, cooking or food preparation, laundering, or similar functions.

"Service water heating" means supply of hot water for domestic or commercial purposes other than comfort heating.

"Service water heating demand" means the maximum design rate of energy withdrawal from a service water heating system in a designated period of time-Btu/hour or Btu/day.

"Shall," as used in this Standard, means mandatory.

"Should" means not mandatory but desirable as good practice.

"Skylight" means any transparent opening in a wall or roof/ceiling assembly covered with glass, plastic, or similar material which is tilted up from the horizontal less than 60°.

"Slab-on-grade" means any slab including internally heated slabs poured in contact with the ground, where the top of the finished slab is less than 12 inches below the final elevation of the nearest exterior grade.

"Solar energy source" means a source of natural daylighting and of thermal, chemical, or electric energy derived directly from conversion of incident solar radiation.

"Special glazing" means glazing which has a maximum U value of 0.47, including the sash. Insulating glass with at least one-half inch (1/2") air space and with wood sash or other sash incorporating a thermal break or approved storm sash will be considered to provide the U value required.

"System" means a combination of equipment and/or controls, accessories, interconnecting means, and terminal elements by which energy is transformed to perform a specific function, such as HVAC, service water heating, or illumination.

Section 220. "T" Definitions

"Terminal element" means the delivery device at the end of a building mechanical heating/cooling or ventilating system (diffusers, grills, registers, etc.).

"Thermal conductance" means the thermal transmission in unit time through unit area of a particular body or assembly having defined surfaces when the unit average temperature is established between surfaces ($Btu/ft^2 \cdot h \cdot °F$).

"Thermal resistance (R)" means the reciprocal of thermal conductance ($ft^2 \cdot h$‡F/Btu).

"Thermal transmittance (U)" means the coefficient of heat transmission (air to air). It is the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films ($Btu/ft^2 \cdot h \cdot °F$). The U value applies to combinations of different materials used in series along the heat flow path, single materials that comprise a building section, cavity air spaces, and surface air films on both sides of a building element.

"Thermal transmittance, overall (U_o)" means the overall (average) heat transmission of a gross area of the exterior building envelope ($Btu/ft^2 \cdot h \cdot °F$). The U_o value applies to the combined effect of the time rate of heat flows through the various parallel paths, such as windows, doors, and opaque construction areas, comprising the gross area of one or more exterior building components, such as walls, floors, or roof/ceiling inclusive of air films.

"Thermostat" means an automatic control device actuated by temperature and designed to be responsive to temperature.

"Transmission coefficient" means the ratio of the solar heat gain through a glazing system to that of an unshaded single pane of double strength window glass under the same set of conditions.

Section 221. "U" Definitions

"U value." See "Thermal transmittance (U)."

"U_o value." See "Thermal transmittance, overall (U_o)."

"Unitary cooling and heating equipment" means one or more factory-made assemblies which normally include an evaporator or cooling coil, a compressor and condenser combination, and may include a heating function as well. Where such equipment is provided in more than one assembly, the separate assemblies shall be designed to be used together.

"Unitary heat pump" means one or more factory-made assemblies which normally include an indoor conditioning coil, compressor(s), and outdoor coil or refrigerant-to-water heat exchanger, including means to provide both heating and cooling functions. When such equipment is provided in more than one assembly, the separate assemblies shall be designed to be used together.

Section 222. "V" Definitions

"Ventilation" means the process of supplying or removing air by natural or mechanical means to or from any space. Such air may or may not have been conditioned.

"Ventilation air" means that portion of supply air which comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space as specified in the most current version of ASHRAE Standard 62 "Ventilation for Acceptable Indoor Air Quality." (See "Outdoor air")

Section 223. "W", "X", "Y", and "Z" Definitions

"Water-chilling package, absorption" means a factory-designed and prefabricated assembly (not necessarily shipped as a single package) of one or more condensers, evaporators (water coolers), absorbers, and generators with interconnections and accessories used for chilling water.

"Water-chilling package, centrifugal or rotary" means a factory-designed and prefabricated assembly (not necessarily shipped as one package) of one or more centrifugal or rotary compressors, condensers, and water coolers (evaporators) with interconnections and accessories used for chilling water.

"Water-chilling package, reciprocating" means a factory-designed and prefabricated assembly, self-contained or condenserless, of one or more reciprocating compressors, condensers (self-contained only), water coolers (evaporator), and interconnections and accessories used for chilling water. The condenser may be air-, evaporatively, or water-cooled.

"Wood stove" means a listed or approved free standing solid fuel burning appliance conforming to local safety requirements.

"Zone" means a space or group of spaces within a building with heating and/or cooling requirements sufficiently similar so that comfort conditions can be maintained throughout by a single controlling device.

Chapter 3
Design Requirements

Section 300. General

This chapter establishes the design parameters for building envelope and HVAC design, and establishes the requirements for the outdoor air quantities for ventilation.

A building designed to be both heated and cooled shall meet the more stringent of the heating or cooling requirements of the exterior envelope provided in this Standard.

Section 301. Insulation and Vapor Barriers

A. General.

Thermal and accoustical insulation located on or within floor/ceiling and roof/ceiling assemblies, crawl spaces, walls, partitions, and insulation on pipes and tubing shall comply with this section. Duct insulation in plenums shall conform to the requirements of the Uniform Mechanical Code.

EXCEPTIONS: 1. Roof insulation shall comply with Section 3204 of the Uniform Building Code.

2. Roof insulation in vaulted ceilings over 3 in 12 shall conform with Section 3204 of the Uniform Building Code.

3. Exposed deck ceiling insulation shall conform with Section 3204 of the Uniform Building Code.

B. Insulation Materials.

All insulation materials including facing such as vapor barriers or breather papers installed within floor/ceiling assemblies, roof/ceiling assemblies, walls, crawl spaces, or attics shall have a flame-spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with UBC Standard No. 42-1.

EXCEPTIONS: 1. Foam plastic insulation shall comply with Section 1717 of the Uniform Building Code.

2. When such materials are installed in concealed spaces of Types III, IV, and V construction, the flame-spread and smoke-developed limitations do not apply to facing, provided that the facing is installed in substantial contact with the unexposed surface of the ceiling, floor or wall finish.

3. Cellulose insulation shall conform to Section 6001 of the Uniform Building Code.

C. Clearances.

Thermal insulation shall not be installed within 3 inches of a recessed light fixture enclosed or ballast and shall not be so installed above the fixture as to entrap heat and prevent the free circulation of air unless the fixture is otherwise approved for the purpose.

Thermal insulation shall not be installed within 3 inches of any metal chimney or gas vent.

Thermal insulation shall not be installed in a manner that would obstruct openings required for attic ventilation.

A permanent sleeve of fine wire mesh screen, sheet metal, or other non-combustible material, shall be installed to maintain the required clearances.

Loose fill insulation may be used in attic spaces where roof slope is 4 in 12 or greater and there is at least 44 inches of headroom at the roof ridge. (Clear headroom is defined as the distance from the top of the bottom chord of the truss or ceiling joists to the underside of the roof sheathing.) Adequately baffle the surface of the installed blown or poured insulation. Baffles shall be of weather-resistant, rigid material capable of retaining the insulation and shall be in place at the time of framing inspection.

D. Moisture Control.

To insure the effectiveness of insulation materials and reduce the hazard of decay and other degradation due to condensation within the structure, these moisture control measures shall be included in all buildings when required.

1. Vapor barrier shall be installed on the warm side (in winter) of all insulation as specified in this subsection.

(a.) Exterior walls of new buildings shall have a continuous vapor barrier installed when thermal insulation is installed. The warm-side vapor barrier shall have a one perm dry cup rating or less. The vapor barrier need not be an integral part of the insulation material.

(b.) Roof/Ceiling: In all exterior ceilings without an attic space above, an approved vapor barrier having a 0.5 perm cup rating or less shall be installed on the warm side (in winter) of the insulation material. In the ceiling, flanges shall be lapped at the framing members. (See Section 3205 of the Uniform Building Code for required ventilation.)

EXCEPTION: When insulation is installed in ceilings in existing structures and ventilation is provided as specified in Section 3205 of the Uniform Building Code, a vapor barrier need not be installed.

(c.) Floors of both new and existing buildings shall have installed an approved vapor barrier having a one perm dry cup rating or less on the warm side (in winter) of the insulation. The vapor barrier need not be an integral part of the insulation material.

(d.) Ground cover shall be installed on the ground in crawl space for both new and existing buildings when insulation is installed. Ground cover shall be 6-mill black polyethylene or other approved material of equivalent perm rating. Ground cover shall be lapped 12 inches at all joints and cover the entire surface area extending the full width and length of the crawl space and turn 12 inches up the foundation wall. Ground cover of 55-lb roll roofing or an approved equal (that is as durable) shall be installed on the ground beneath concrete floor slabs.

Section 302. Design Parameters

The following design parameters shall be used for calculations required under this Standard:

A. Heating or Cooling Design Temperatures.

The heating or cooling design temperatures shall be selected from the latest edition of the ASHRAE Handbook of Fundamentals. For locations not listed in the ASHRAE Handbook of Fundamentals, other ASHRAE-approved design temperatures may be used, provided they have been accepted by the Building Official. Winter design temperatures shall be selected from the 97.5% column. Summer design dry-bulb and wet-bulb temperatures shall be selected from the 5% column.

B. Indoor Design Temperature.

Indoor design temperature shall be 68° F for heating and 78° F for cooling.

C. Indoor Design Relative Humidity.

Indoor design relative humidity for heating shall not exceed 30 percent. For cooling, new energy shall not be used to control relative humidity in the range between 30 percent and 60 percent.

Section 303. Ventilation

This Standard specifies air quantities only. For all other requirements see the Mechanical Code. Both the Mechanical Code and Standard will require the same quantities for consistency.

A. Minimum Outdoor Air Requirements for Ventilation.

The minimum requirements for openable exterior opening areas to provide natural ventilation are specified in the Building Code. If the mechancial ventilation system is provided in lieu of openable exterior openings for natural ventilation, outdoor air quantities for both areas where smoking is permitted or smoking is prohibited shall be as specified in the most recent edition of ASHRAE Standard 62, "Ventilation for Acceptable Indoor Air Quality."

EXCEPTIONS: 1. The quantity of outdoor air for smoking and non-smoking may be reduced according to approved engineering analysis standards when proper air cleaners and adequate temperature controls allow this air to be recirculated and/or when the smoking area is limited, partially isolated, or mechanically purified.

EXCEPTIONS: 2. In spaces where the Building Official determines that fixed occupancy will be less than that in the most recent edition of ASHRAE Standard 62, he may allow a ventilation rate based on the actual occupancy.

EXCEPTIONS: 3. In spaces where the Building Official determines that number and type of occupants may vary considerably, he may allow ventilation for a lesser requirement if an acceptable volume control is installed with capacity to meet the requirements of the most recent edition of ASHRAE Standard 62.

B. Heating and/or Cooling Equipment Sizing.

The maximum outdoor air quantities allowed for the purpose of sizing heating and/or cooling equipment shall not exceed the smoking values given in the most recent edition of ASHRAE Standard 62.

EXCEPTION: If outdoor air quantities other than those specified in the most recent edition of ASHRAE Standard 62 are used or required because of special occupancy or process requirements, source control or air contamination, or other standards, the required outdoor air quantities shall be used as the basis for calculating the heating and/or cooling design loads.

Chapter 4
Building Design by Component Performance Approach

Section 400. General

This chapter establishes design criteria in terms of the thermal performance of the various components of a building. Component U values can be combined for complete walls, roofs, etc., and adjusted by increased insulation in one for a decreased insulation in another, providing that the overall U_O for the building does not change.

A building that is designed to be both heated and cooled shall meet the more stringent of the heating or cooling requirements as provided in this Standard when requirements differ.

Section 401. Overall Thermal Performances.

A. Trade-off Procedures.

The stated U_O value of any one element of a building, such as roof/ceiling, wall, or floor, may be increased and the U_O value for other components decreased provided that the overall heat gain or loss for the entire building envelope does not exceed the total resulting from the conformance to the stated U_O values, except that the R value for slab-on-grade floor insulation shall not be less than that specified in table J4-1. Equation 5 shall be used to determine conformance.

EXCEPTIONS: The following are not eligible for the trade-off procedure:

1. For street-level commercial space in buildings three stories and under or of wood frame construction where either the building or the tenant space has only one exterior wall, the overall thermal transmittance value (U_O) of the gross area of the exterior wall may be increased to .35.

2. For existing street-level commercial space where either the building or the tenant space has only one exterior wall, the overall thermal transmittance value (U_O) of the gross area of the exterior wall may be increased to the sum of the existing percentage of the exterior wall area which is opaque multiplied by .08 plus the existing percentage of the exterior wall area which has openings multiplied by .47.

B. Return Air Ceiling Plenums.

Where return air ceiling plenums are employed, the roof/ceiling assembly shall:

1. for thermal transmittance purposes, not include the ceiling proper or the plenum space as part of the assembly, and

2. for gross area purposes, be based upon the interior face of the upper plenum surface.

C. General Insulation and Vapor Barriers.

General insulation and vapor barriers shall be installed in accordance with chapter 3, Section 302.

Section 402. Thermal Performance Criteria for Low-Rise Residential Buildings

Criteria for heated and/or mechanically cooled residential buildings three (3) stories or less in height: Group R-Div. 3—detached one- and two-family dwellings; Group R-Div. 1—all other residential buildings three stories or less.

A. General Requirements.

1. Walls. the overall thermal transmittance value (U_O) of the gross wall area of exterior walls shall not exceed the value given in table J4-1. Equations 1 and 2 shall be used to determine acceptable combinations to meet this requirement. For glazing in residential buildings, the R value of operable window insulation may be multiplied by .5 for calculation purposes.

2. Roof/Ceiling. the overall combined thermal transmittance value (U_O) for the gross roof/ceiling area of the roof/ceiling assembly shall not exceed the value given in table J4-1. Equations 1 and 3 shall be used to determine acceptable combinations to meet this requirement.

3. Floors Over Unconditioned Spaces. The overall thermal transmittance value (U_O) for floors exposed to outdoor air, such as floors over vented crawl spaces, garages, or overhangs, shall not exceed the value given in table J4-1. The overall thermal transmittance value (U_O) for all other floors over unconditioned spaces shall not exceed the value given in table J4-1.

4. Slab-on-Grade Floors. For slab-on-grade floors in low-rise residential buildings, the thermal resistance value (R) of the insulation around the perimeter of the floor shall not be less than the value given in table J4-1. The insulation shall extend downward from the top of the slab for a minimum distance of 24 inches or downward to the bottom of the slab then horizontally beneath the slab for a minimum total distance of 24 inches, and shall be an approved type.

B. Exemption for Passive Solar Features.

Subject to the following limitations, glazing areas or mass- or water-wall areas in residential spaces which qualify by meeting all of the criteria below may be exempted from the U_O calculations.

For new construction, qualifying areas equal to 8 percent of conditioned floor area must be provided and included in the ordinary U_O calculations before any passive solar exemption may be claimed. Only qualifying areas in excess of the 8 percent minimum may be exempted.

For existing buildings, only newly added qualifying glazing may be exempted.

1. The glazing must be special glazing.

2. The glazing area shall be oriented within 90 degrees of due south. Only 60 percent of glazing oriented between 31 degrees and 90 degrees of due south shall be considered qualifying glazing.

3. If glazing is mounted other than vertically, it must be tilted at least 30 degrees up from the horizontal to face south.

4. The glazing shall be translucent (transmission coefficient numerically greater than or equal to .80 for each light of the glazing itself).

5. The glazing area oriented within 30 degrees of due south must receive direct solar exposure for 50 percent of the hours between 9:00 a.m. and 3:00 p.m. on December 21st.

6. The glazing area oriented between 31 and 90 degrees east or west of due south must receive direct solar exposure for 85 percent of the hours between 9:00 a.m. and 12:00 noon, if east of south, and 12:00 noon and 3:00 p.m., if west of south, on March 21.

7. The building shall contain a heat storage capacity equivalent to at least 20 Btu/°F·ft^2 for each square foot of qualifying area between 9 percent and 14 percent of the conditioned floor area, and at least 45 Btu/°F·ft^2 for each square foot of qualifying area in excess of 15 percent of the conditioned floor area. This heat storage capacity shall be located inside the insulated shell of the structure and not covered with insulation materials, such as carpet, yielding an R value of 1.0 or greater. If the heat storage medium is not within the space containing the qualifying glazing, an acceptable natural or mechanical means of transferring the heat to the heat storage medium shall be provided. Heat storage capacity shall be calculated by Equation 6.

Opaque wall area covered with glazing, such as mass- or water-walls, which meets all of the requirements of this subsection, shall be considered solar glazing.

Section 403. Thermal Performance Criteria for Buildings Other Than Low-Rise Residential Buildings

This section applies to criteria for heated and/or mechanically cooled buildings other than low-rise residential buildings.

A. Walls.

The combined thermal transmittance Value (U_O) of the gross wall area of exterior walls shall not exceed the values given in table J4-2. Equations 1 and 2 shall be used to determine acceptable combinations to meet this requirement.

B. Roof/Ceiling.

The combined thermal transmittance value (U_O) for the gross roof/ceiling area of roof/ceiling assembly shall not exceed the value given in table J4-2. Equations 1 and 3 shall be used to determine acceptable combinations to meet this requirement.

C. Floors Over Unconditioned Spaces.

The overall thermal transmittance value (U_O) for floors exposed to outdoor air, such as floors over vented crawl spaces, garages, or overhangs, shall not exceed the value given in table J4-2. The overall thermal transmittance value (U_O) for all other floors over unconditioned spaces shall not exceed the value given in table J4-2.

D. Slab-on-Grade Floors.

For slab-on-grade floors, the thermal resistance value (R) of the insulation around the perimeter of the floor shall not be less than the value given in table J4-2. The insulation shall extend downward from the top of the slab for a minimum distance of 24 inches or downward to the bottom of the slab or to the base of the foundation footing then horizontally beneath the slab for a minimum total distance of 24 inches, and shall be an approved type.

Section 404. Air Leakage for All Buildings

The requirements of this section shall apply to all buildings and structures and only to those locations separating outdoor ambient conditions from interior spaces that are heated or mechanically cooled. The requirements of this section are not applicable to the separation of interior conditioned spaces from each other.

A. Windows and Exterior Doors.

1. All windows and exterior doors shall conform to the air infiltration requirements specified in table J4-3. Site-built windows shall be constructed to minimize leakage.

2. All exterior doors shall be designed to limit air leakage around their perimeter when in a closed position and shall meet the following criteria:

(a.) All doors shall be provided with gasketing or weatherstripping at the head and jamb, including double-acting doors.

(b.) Doors requiring vertical tracks or guides shall use a continuous mounting angle and standard jamb weatherstripping.

(c.) Meeting rails of sectional doors and meeting stiles or rails of bi-parting doors shall be provided with standard weather seals.

(d.) Revolving doors shall be weatherstripped at the head and stiles.

(e.) Pairs of doors shall be provided with weatherstripping at the meeting stile.

Doors which comply with the infiltration requirements of table J4-3 shall be deemed to comply with the foregoing criteria.

EXCEPTION: Required fire doors with a fire-resistant rating over one hour, and fire windows are exempt from this section.

B. Caulking and Sealing.

The following openings in the building envelope shall be caulked or otherwise sealed to limit infiltration:

1. exterior joints and between double studs in window and door frames, between wall soleplates and floors, and between exterior wall panels;

2. openings for plumbing, electricity, and gas lines in walls, ceilings, and floors;

3. openings in the attic floor (such as where ceiling panels meet interior and exterior walls and masonry fireplaces); and

4. all other such openings in the building envelope.

C. Electrical Outlet Plate Gaskets.

Electrical outlet plate gaskets shall be installed on all receptacle, switch, or other electric boxes in exterior and interior walls.

D. Exhaust Systems.

1. Fan or other exhaust systems exhausting air from the building to the outside shall be provided with backdraft dampers or automatic dampers to prevent air leakage.

2. Bathrooms shall have exhaust fans with a positive closure damper vented to the outside or through a heat exchanger to the outside. Timed switches or humidistats shall be installed to prevent unnecessary operation. Exhaust fan capacity shall be at least 50 cfm.

E. Fireplaces.

Fireplaces shall be provided with:

1. tight fitting closeable metal or glass doors covering the entire opening of the firebox;

2. a combustion air intake to draw air from the outside of the building directly into the firebox, which is at least six square inches in area and is equipped with a readily accessible, operable, and tight-fitting damper; and

3. a tight-fitting flue damper with a readily accessible control.

EXCEPTION: Dampers in fireplaces with gas-burning equipment shall have minimum position stop on the fireplace damper.

F. Buildings Over Three Stories.

For all buildings more than three stories, all entrances which are the principal means of access for the public shall be protected with a revolving door or an enclosed vestibule with all doors opening into or out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior doors to be open at the same time. Elevator lobbies do not qualify as vestibules. Minor entrances and service entrances are exempted from this requirement.

Section 405. Building Mechanical Systems

The following sections cover the determination of heating and cooling loads, design requirements, equipment and component performance, and control requirements.

Requirements are established for insulating HVAC systems and for duct construction.

EXCEPTIONS: Special applications including, but not limited to, hospitals, laboratories, thermally sensitive equipment, and computer rooms may be exempted from the requirements of this section when approved by the Building Official.

Exceptions shall be specific and allowed only to the extent necessary to accommodate the special use.

Section 406. Calculations of Heating and Cooling Loads

A. Loads.

Heating and cooling design loads for the purpose of sizing HVAC systems are required and shall be calculated in accordance with accepted engineering practice.

B. Design Parameters.

The design parameters specified in Section 304 shall apply as the maximum for all computations.

C. HVAC Equipment Size.

HVAC equipment for low-rise residential buildings shall be sized no greater than 125 percent of the design load as calculated above.

Section 407. Infiltration

Infiltration for heating and cooling design loads shall be calculated using accepted engineering practice and Section 404. The outside air quantities due to the larger of infiltration or required ventilation shall be used in calculating heating and cooling loads.

Section 408. Simultaneous Heating and Cooling

Simultaneous heating and cooling by reheating or recooling supply air, or by concurrent operation of independent heating and cooling systems serving a common zone, shall be restricted as delineated below.

A. Recovered Energy.

Recovered energy in excess of the new energy expended in the recovery process may be used for control of temperature and humidity.

B. New Energy.

New energy may be used for control of temperature if minimized as delineated in subsections C through G.

C. Reheat Systems.

Systems employing reheat and serving multiple zones shall be provided with control that will automatically reset the system cold air supply to the highest temperature level that will satisfy the individual thermostat or primary zone requiring the coolest air. Single-zone reheat systems shall be controlled to sequence heating and cooling. The total installed capacity of all reheat using new energy shall be limited to 15 percent of the total system design cooling capacity.

D. Dual Duct and Multi-Zone Systems.

These systems shall be provided with control that will automatically reset (1) the cold deck air supply to the highest temperature that will satisfy the zone requiring the coolest air, and (2) the hot deck air supply to the lowest temperature that will satisfy the zone requiring the warmest air.

Primary zone temperature and/or flow volume may be used as the control for this section.

The systems must be provided with heat pumps or recovery devices so that the new energy is not required on the hot and cold deck or plenum simultaneously, with the exception of limited warmup periods.

Constant volume dual duct or multi-zone systems which utilize new energy to simultaneously heat and cool air streams, which are subsequently mixed for temperature control, shall not exceed 10,000 cfm total capacity in any one building.

E. Recooling systems.

Systems in which heated air is recooled, directly or indirectly, to maintain space temperature shall be provided with control that will automatically reset the temperature to which the supply air is heated to the lowest and/or optimum level that will satisfy the zone requiring the warmest air. The system design shall limit the use of new energy for recooling of heated air to 15 percent of the total system design heating capacity.

1. A multi-zone system that employs reheating or recooling for control of not more than 5,000 ft^3/min or 20 percent of the total supply air for the building, whichever is less, shall be exempt from the supply air temperature reset requirement of subsections C through G.

2. Concurrent operation of independent heating and cooling systems serving common spaces and requiring the use of new energy for heating or cooling shall be minimized by one or both of the following:

(a.) by providing sequential temperature control of both heating and cooling capacity in each zone, and/or

(b.) by limiting the heating energy input through automatic reset control of the heating medium temperature (or energy input rate) to only that necessary to offset heat loss due to transmission and infiltration and, where applicable, to heat the ventilation air supply to the the space.

Section 409. Energy Recovery

Consideration shall be given to the use of recovery systems which will conserve energy (provided the amount expended is less than the amount recovered) when the energy transfer potential and the operating hours are considered.

Section 410. HVAC Equipment Performance Requirement

This section applies to equipment and component performance for heating, ventilating, and air conditioning systems. Where equipment efficiency levels are specified, approved data furnished by the equipment supplier or certified under a nationally recognized certification program or rating procedure shall be used to satisfy these requirements. Equipment efficiencies shall be based on the standard rating conditions shown in tables J4-8, J4-9, J4-10, and J4-11.

A. HVAC System Heating Equipment, Heat Pumps Heating Mode.

Heat pumps whose energy input is entirely electric shall have a Coefficient of Performance (COP) heating not less than the values shown in table J4-4.

1. These requirements apply to, but are not limited to, unitary (central) heat pumps (air source and water source) in the heating mode, water source (hydronic) heat pumps as used in multiple-unit hydronic HVAC systems, and heat pumps in the packaged terminal air conditioner and room air conditioner forms in the heating mode.

2. Supplementary Heater, Air-to-Air Heat Pumps. The heat pump shall be installed with a control to prevent electric supplementary heater operation when the operating load can be met by the heat pump alone. Supplementary heater operation is permitted during transient periods, such as startups, following room thermostat set-point advance and during defrost.

A two-stage thermostat, which controls the supplementary heaton its second stage, shall be accepted as meeting this requirement. The cut-on temperature for the compression heating shall be higher than the cut-off temperature for the supplementary heat. Supplementary heat may be derived from any source including, but not limited to, electric resistance, combustion heating, or solar or stored-energy heating.

3. Supplementary Heater, Liquid-Source Heat Pumps. A heat generating device connected to the liquid (water) loop of a liquid source (hydronic) heat pump system shall be considered as supplementary heat if it meets all of the following criteria:

(a.) Sufficient design information (design calculations, control diagrams, equipment data, etc.) shall be submitted to demonstrate that the internal heat gain of the internal zones is equal to at least 50 percent of the building heat loss at winter design conditions;

(b.) The heat pump shall be installed with a control to prevent supplementary heater operation when the heating load can be met without the supplementary heater operation;

(c.) Supplementary heater operation is permitted during transient periods, such as startups, and following room thermostat set-point advance;

(d.) The supplementary heater shall be controlled to provide at least two stages;

(e.) The custom temperature for the compression heating shall be higher than the custom temperature for the supplementary heater, and the cut-off temperature for the compression heating shall be higher than the cut-off temperature for the supplementary heater; and

(f.) Supplementary heat may be derived from any source of electric resistance heat or combustion heating subject to the above limitations.

B. Mechanical Ventilation.

Each mechanical ventilation system (supply and/or exhaust) shall be equipped with a readily accessible, or other means for, shutoff or volume reduction and shutoff when ventilation is not required. Automatic or gravity dampers that close when the system is not operating shall be provided for outdoor air intakes and exhausts. Automatic or manual dampers installed for the purpose for shutting off ventilation systems shall be designed with tight shutoff characteristics to minimize air leakage.

EXCEPTIONS: 1. Manual dampers for outdoor air intakes may be used in the following cases:

a. for residential buildings

b. when the fan system capacity is less than 5000 cfm

2. Dampers are not required when ventilation air flow is less than 500 cfm.

C. HVAC System Equipment, Electrically Operated Cooling Mode.

HVAC system equipment as listed below, whose energy input in the cooling mode is entirely electric, shall have an Energy Efficiency Ratio (EER) or a Coefficient of Performance (COP) cooling not less than values shown in table J4-5.

These requirements apply to, but are not limited to, unitary (central) cooling equipment (air-cooled, water-cooled and evaporatively cooled), the cooling mode of unitary (central) and packaged terminal heat pumps (air-source and water-source), packaged terminal air conditioners, and roof air conditioners.

EXCEPTION: These requirements do not apply to equipment used in areas such as supermarkets having open refrigerated food display cases or to computers or other equipment contributing a large amount of heat to the area served.

D. Applied HVAC System Components, Electrically Operated Cooling Mode.

HVAC system components, as listed in tables J4-6 and J4-7, whose energy input is entirely electric, shall have an Energy Efficiency Ratio (EER) or a Coefficient of Performance (COP) cooling not less than the values shown in tables J4-6 and J4-7.

E. Fireplaces.

Fireplaces shall be provided with:

1. Tightly fitting flue dampers operated with a readily accessible manual or approved automatic control.

   EXCEPTION: Dampers in fireplaces with gas-burning equipment shall have a minimum position stop on the fireplace damper.

2. An outside source for combustion air to the combustion chamber. The duct shall be at least six square inches in area and shall be provided with a readily operable damper.

3. Tightly fitting closeable, solid metal or glass doors.

Section 411. Transport Energy

A. All-Air Systems.

The air transport factor for each all-air system shall not be less than 5.5. The factor shall be based on design system air flow. Energy for transfer of air through heat recovery devices shall not be included in determining the factor; however, such energy shall be included in the evaluation of the effectiveness of the heat recovery system.

Air Transport Factor =
Space Design Sensible Heat Removal*

Supply, Return, Relief, and Exhaust
Fan(s) Power Input*

*Expressed in Btu/h or Watts

For purposes of these calculations, Space Design Sensible Heat Removal is equivalent to the maximum coincident design sensible cooling load of all spaces served for which the system provides cooling. Fan Power Input is the rate of energy delivered to the fan prime mover.

B. Other Systems.

Air and water, all-water, and unitary systems employing chilled, hot, dual-temperature or condenser-water transport systems to space terminals shall not require greater transport energy (including central and terminal fan power and pump power) than an equivalent all-air system providing the same space design sensible heat removal and having an air transport factor not less than 5.5.

Section 412. Balancing

The HVAC system design shall provide means for balancing the air and water systems. In doing so, these considerations shall include, but not be limited to, dampers, temperature and pressure test connections, and balancing valves.

Section 413. Cooling With Outdoor Air (Economizer Cycle)

Each supply fan system shall be designed to use up to and including 100 percent of the fan system capacity for cooling with outdoor air automatically. Activation of economizer cycle shall be controlled by sensing outdoor air dry-bulb temperature alone, or outdoor air enthalpy and dry-bulb temperature jointly.

EXCEPTION: Cooling with outdoor air is not required if any one or more of the following conditions is met:

1. Fan system capacity less than 3,500 cfm or 90,000 Btu/hr total cooling capacity;
2. The quality of the outdoor air is so poor as to require extensive treatment of the air;
3. The need for humidification or dehumidification requires the use of more energy than is conserved by outdoor air cooling on an annual basis;
4. The use of outdoor air cooling may affect the operation of other systems so as to increase the overall energy consumption of the building;
5. Energy recovered from an internal/external zone heat recovery system exceeds the energy conserved by outdoor air cooling on an annual basis;

6. All space cooling is accomplished by a circulating liquid which transfers space heat directly or indirectly to a heat rejection device, such as a cooling tower, without the use of a refrigeration system. When the use of 100 percent outside air will cause coil frosting, controls may be added to reduce the quantity of outside air. However, the intent of this exception is to use 100 percent air in lieu of mechanical cooling when less energy usage will result, and this exception applies only to direct expansion systems when the compressor(s) is running.

Section 414. Controls

A. Temperature Control.

Each system shall be provided with at least one adjustable thermostat for the regulation of temperature. Each thermostat shall be capable of being set by adjustment or selection of sensors as follows:

1. Where used to control heating only: 55 to 75° F;

2. Where used to control cooling only: 70 to 85° F;

3. Where used to control both heating and cooling, it shall be capable of being set from 55° F to 85° F and shall be capable of operating the system heating and cooling in sequence. The thermosat and/or control system shall have an adjustable deadband of up to 10° F or more except as allowed in Section 408 G.

B. Humidity Control.

If a system is equipped with a means for adding moisture to maintain specific selected relative humidities in spaces or zones, a humidistat shall be provided. This device shall be capable of being set to prevent new energy from being used to produce space relative humidity above 30 percent. Where a humidistat is used in a system for controlling moisture removal to maintain specific selected relative humidities in spaces or zones, it shall be capable of being set to prevent new energy from being used to produce space relative humidity below 60 percent.

EXCEPTION: Special occupancies requiring different elative humidities may be permitted by the Building Official.

C. Zoning for Temperature Control.

1. One and two-Family Dwellings (R-1 and R-3 Occupancies). At least one thermosat for regulation of space temperature shall be provided for each separate HVAC system. In addition, a readily accessible manual or automatic means shall be provided to partially restrict or shut off the heating and/or cooling input to each zone or floor not controlled by thermostat.

2. Other Dwellings. For other dwellings, each individual dwelling unit shall have at least one thermostat for regulation of space temperature. A readily accessible manual or automatic means shall be provided to partially restrict or shut off the heating and/or cooling input to each room. Spaces other than dwelling units shall meet the requirements of Section 414 C.3.

3. All Other Types of Buildings or Occupancies. At least one thermostat for regulation of space temperature shall be provided for:

(a.) Each separate system, and

(b.) Each separate zone as defined in Section 223. As a minimum, each floor of a building shall be considered as a separate zone. In a multi-story building where the perimeter system offsets only the transmission losses of the exterior wall, an entire side of uniform exposure may be zoned separately. A readily accessible manual or automatic means shall be provided to restrict partially or shut off the heating and/or cooling input (for the exposure) to each floor.

4. Control Setback and Shutoff

(a.) Residential Occupancy Groups (R-1 and R-3). The thermostat required in paragraphs 1 and 2 of Section 414 C or an alternate means such as a switch or clock, shall provide a readily accessible manual or automatic means for reducing the energy required for heating and cooling during the periods of nonuse or reduced need such as, but not limited to, unoccupied periods and sleeping hours. Lowering thermostat set-points to reduce energy consumption of heating systems shall not cause energy to be expended to reach the reduced setting.

(b.) Other Buildings and Occupancies. Each system shall be equipped with a readily accessible automatic means of shutting off or reducing the energy used during periods of nonuse or alternate uses of the building spaces or zones served by the system. Acceptable means include, but are not limited to:

(i.) manually adjustable automatic timing devices

(ii.) automatic control systems

Section 415. Air Handling Duct System Insulation

All ducts, plenums, and enclosures installed in or on buildings shall be thermally insulated to meet the requirements of table J4-12.

EXCEPTION: Duct insulation (except where required to prevent condensation) is not required in any of the following cases:

1. When the heat gain or loss of the ducts, without insulation, will not increase the energy requirements of the building;
2. Within HVAC equipment; or
3. Exhaust air ducts.

Section 416. Duct Construction

All duct work shall be constructed and erected in accordance with the Mechanical Code.

Section 417. Piping Insulation

A. Thermal Insulation.

All piping installed to serve buildings and within buildings shall be thermally insulated in accordance with table J4-13, except as stated herein.

EXCEPTION: Piping insulation is not required in any of the following cases:

1. Piping installed within HVAC equipment;
2. Piping at fluid temperatures between 55° F and 100° F; or
3. When the heat loss and/or heat gain of the piping without insulation does not increase the energy requirements of the building.

B. Other Insulation Thicknessess.

Insulation thicknesses in table J4-13 are based on insulation having thermal resistivity in the range of 4.0 to 4.6 Btu/sq ft/° F/hr per inch of thickness on a flat surface at a mean temperature of 75° F. Minimum insulation thickness shall be increased for materials having R values less than 4.0 or may be reduced for materials having R values greater than 4.6, as follows:

1. For materials with thermal resistivity greater than 4.6, the minimum insulation thickness may be reduced as follows:

   4.6 x Table J4-13 Thickness

   Actual R

   = New Minimum Thickness

2. For materials with thermal resistivity less than 4.0, the minimum insulation thickness shall be increased as follows:

   4.0 x Table J4-13 Thickness

   Actual R

   = New Minimum Thickness

C. Insulation and Vapor Barriers.

Additional insulation and vapor barriers shall be provided to prevent condensation where required.

D. Recirculation Systems.

For recirculation systems, piping heat loss shall be limited to a maximum of 17.5 Btu/h per linear foot of pipe in accordance with table J4-14, which is based on design external temperature no lower than 65° F. Other design temperatures must be calculated.

EXCEPTION: Piping insulation is not required when the heat loss of the piping, without insulation, does not increase the annual energy requirements of the building.

Section 418. Service Water Heating

A. General.

Hot water for domestic, sanitary, and swimming pool purposes shall be generated and delivered in a manner conducive to saving energy.

B. Scope.

The purpose of the following provisions is to provide criteria for design and equipment selection that will produce energy savings when applied to service water heating.

Section 419. Water Heaters, Storage Tanks, and Boilers

A. Performance Efficiency.

1. All automatic, electric storage ater heaters having a storage capacity of 120 gallons or less and an input rating of 12kW or less shall have all storage tank top and side surfaces insulated to at least R-20, or have a standby loss rate not exceeding 2.8 W/sq ft of external tank surface area when tested in accordance with Section 430.22e of the D.O.E. water heater test procedure published in the October 4, 1977 Federal Register, amended as to final rule in the September 7, 1979 Federal Register, and calculated at a 44.4° C (80° F) temperature difference. All storage tanks must be placed on an incompressible insulated surface at least equivalent to a thermal resistance of 10 (R-10).

2. All automatic, electric storage water heaters having either a storage capacity greater than 120 gallons or an input rate greater than 12kW shall have all water-backed storage tank surfaces insulated to at least R-20 or have a standby loss not exceeding 2.8 W/sq ft of tank surface when tested in accordance with Section 4.3.1 of ANSI C 72.1-72 Household Automatic Electric Storage-Type Water Heaters.

B. Insulation.

Heat loss from unfired hot water storage tanks shall be limited to a maximum of 9.6 Btu/h/ft^2 of external tank surface area. The design ambient temperature shall be not higher than 65° F.

C. Combination Service Water Heating/Space Heating Boilers.

Electric service water heating equipment shall not be dependent on year-round operation of space heating boilers (i.e., boilers that have as anchor function, winter space heating).

EXCEPTION: Systems with service/space heating boilers having a standby loss Btu/h less than:

$$\frac{13.3\ \text{pmd} + 400}{n}$$

by the fixture count method

pmd = probable maximum demand in gallongs/hour

n = fraction of year when outdoor daily mean temperatures exceeds 64.9° F

The standby loss is to be determined for a test period of 24 hours duration while maintaining a boiler water temperature of 90° F above an ambient of 60° F to 90° F and a 5-foot stack-on appliance.

D. Temperature Controls.

1. Service water heating systems shall be equipped with automatic temperature controls capable of adjustment from the lowest to the highest acceptable temperature settings for the intended use.

2. Shutdown. A separate switch shall be provided to permit turning off the energy supplied to electric service water heating systems.

3. Swimming Pools. Heating swimming pools shall be equipped with:

(a.) Controls which allow water temperature to be regulated from the maximum design temperature down to 65° F;

(b.) An on/off switch for the pool heater, mounted for easy access, to allow shutting off the operation of the heater without adjusting the thermostat setting and to allow restarting without relighting a pilot light; and

(c.) A pool cover at the surface of the water, or

(d.) A solar pool water heating system or heat pump pool heater.

Section 420. Pump Operation

Circulating hot water systems shall be arranged so that the circulating pump(s) can be conveniently turned off, automatically or manually, when the hot water system is not in operation.

Section 421. Conservation of Hot Water

A. Showers.

Showers used for other than safety reasons shall be equipped with flow-control devices to limit total flow to a maximum of 2.75 gpm per shower head.

B. Lavatories.

Lavatories in restrooms of public facilities shall be equipped with outlet devices which limit the flow of hot water to a maximum of 0.5 gpm.

Section 422. Electric Power—General

Electric distribution and lighting systems shall be designed for efficient distribution and use of electric energy from the service entrance to and at the points of use as provided herein.

Section 423. Electric Distribution

A. Power Factor.

Utilization equipment rated greater than 4 hp and lighting equipment greater than 15W, with an inductive reactance load component, shall have a power factor of not less than 85 percent under full load conditions.

B. Lighting Switching.

Switching for building lighting systems shall be designed and installed to permit efficient use of energy and to permit maximum flexibility in the use of the installed lighting. The following mandatory requirements respresent the minimum lighting controls to be installed in any building. Additional controls should be provided where deemed appropriate and where the installation of such controls can significantly reduce energy consumption.

1. General. All lighting controls, except automatic controls, those for special purpose applications which require trained operators, or those which would pose a safety problem or a security hazard, shall be installed so as to be readily accessible to personnel occupying or using the lighting space.

2. Specific Requirements.

(a.) All lighted spaces enclosed by walls or ceiling height partitions, and with floor area less than 400 square feet shall be provided an individual, local lighting control.

(b.) All lighted spaces in office occupancies with floor area greater than 400 square feet shall be provided with local controls to permit reducing the lighting by at least one-half or automatic controls, such as occupancy sensors.

(c.) All building areas in office, school, and retail occupancies where natural lighting is available shall be provided with local controls or automatic controls, such as photoelectric switching, which permit control of lights independent of general area lighting and reduction of artificial lighting power to at least one-half, to completely off.

For office and school occupancies, at a minimum, lighting service of a zone within 12 feet of a window wall, or the zone between an interior wall and the window wall of less than feet, shall comply with this provision.

For retail occupancies, at least the row of lights nearest the window shall comply with this provision.

(d.) The maximum lighting power that may be controlled from a single switch shall not exceed that provided by a 20-ampere circuit loaded to no more than 80 percent. A master control may be installed provided the individual switches retain their capability to function independently.

(e.) All display, exhibition, or specialty lighting shall be controlled independently of general area lighting.

(f.) All exterior building lighting, including facade lighting, parking lots, driveways, and walkways, shall be furnished with automatic controls to reduce or turn off all lights during periods of nonuse or daylight hours, except those required for safety and security. Sign lights shall be exempt from this provision.

EXCEPTIONS: 1. Vacant building space or open unoccupied areas need not meet the provisions of the switching requirements unti tenant occupancy is determined.

EXCEPTIONS: 2. One- and two-family detached dwellings and the dwelling portion of multi-family buildings are exempt from the requirements of this section.

Section 424. Lighting Power Budget

A lighting power budget is the upper limit of the power to be available to provide lighting needs in accordance with the criteria specified herein.

A lighting power budget for a building shall be the sum of the power limits computed for all lighted interior and exterior spaces and shall be determined in accordance with the procedures specified in this section.

A. Installed Wattage Budgets.

The installed lighting wattage in the building shall not exceed the budget level calculated in this section. The budget wattage level shall be the sum of the interior budget calculated in accordance with subsection B and the exterior budget calculated in accordance with subsection C. Lighting wattage includes lamp and ballast wattage.

B. Interior Lighting Budget Calculation.

The interior lighting budget shall be calculated by multiplying the gross building area, in square feet, by the appropriate unit power budget, in Watts per square foot, specified in table J4-15. The adjusted wattage for a zone with daylighting and automatic controls shall be multiplied by 0.6, provided that the zone is located within 15 feet or less of a perimeter window or 10 feet horizontally from a skylight or skylight well, and provided that all electric lighting within the zone is controlled by automatic devices capable of reducing electric lighting power consumption continuously or, in two or more steps, to one-third or less of maximum power.

The lighting power budget shall be based on the primary occupancy for which the space within the building is intended. If multiple occupancies are intended, the lighting power for each type of occupancy shall be separately calculated and summed to obtain the lighting budget for the interior spaces of the building. In cases where a lighting plan for only a portion of a building is submitted, the interior lighting budget shall be based on the gross floor area covered by the plan.

Power required for trickle-charging for battery-powered emergency lighting may be excluded from the interior power budget.

C. Exterior Lighting Budget Calculation.

The exterior lighting budget shall be calculated by multiplying the building perimeter in feet by 7.5 Watts per foot. An allowance for outdoor parking and circulation lighting may be added at 0.05 Watts per square foot of area. Lighting for signs that are not an integral part of the building shall be exempted from inclusion in these calculations.

D. Exempted Applications.

Lighting for the following applications shall be exempted from inclusion in the calculation of this section:

1. Stage lighting, entertainment, or audiovisual presentations where the lighting is an essential technical element for the function performed;

2. Lighting for medical and dental tasks;

3. Lighting in areas specifically designed for visually handicapped people; and

4. For restaurant occupancies, lighting for kitchens and food preparation areas.

5. For Class I, II, and III retail occupancies (as defined in table J4-15), lighting for highlighting applications may be exempted from inclusion in the power budget up to the following limits:

Class I —3.0 W/sq ft
Class II —2.0 W/sq ft
Class III—1.0 W/sq ft

EXCEPTION: One- and two-family detached dwellings (R-1 and R-3 occupancies) and the dwelling unit portions of other buildings are exempt from the requirements of this section.

EQUATION 1—Assembly Thermal Transmittance

$$U = \frac{1}{\frac{1}{f_o} + R1 + R2 \ldots Rn + \frac{1}{f_i}}$$

Where:

U = the thermal transmittance of the assembly (Btu/hr/sq ft/° F)

f_o = outside air film conductance, $1/f_o$ = .17 for all exterior surfaces

f_i = inside air film conductance, $1/f_i$ = .60 for interior horizontal surfaces
.68 for interior vertical surfaces

R = 1/C = X/K = measure of the resistance to the passage of heat for each element (hr/sq ft/° F/Btu)

C = conductance, the heat flow through a specific material of specific thickness

K = insulation value of a material (Btu/ft/hr/° F)

X = the thickness of the material

EQUATION 2—Gross Wall Area Overall Thermal Performance Value

$$U_o = \frac{(U_w \times A_w) + (U_g \times A_g) + (U_d \times A_d) \ldots}{A_o}$$

Where:

U_o = the overall thermal transmittance of the gross wall area (Btu/hr/sq ft/° F)

A_o = the gross wall area of exterior walls (sq ft)

U_w = the thermal transmittance of all elements of the opaque wall area

A_w = opaque wall area

U_g = the thermal transmittance of the glazing area

A_g = glazing area, including sash

U_d = the thermal transmittance of the door area

A_d = door area

Note: Where more than one type of wall, window, and/or wall, window, and/or door is used, the U and A terms for those items shall be expanded into subelements, as:

$$(U_{w1} \times A_{w1}) + (U_{w2} \times A_{w2}) + (U_{w3} \times A_{w3}) + \ldots \text{(etc.)}$$

Calculations shall include the effects of all heat flow paths, such as framing members. Framing as a percent of opaque wall area is typically:

17 percent for 2-inch studs at 12 inches on center
15 percent for 2-inch studs at 16 inches on center
12 percent for 2-inch studs at 24 inches on center

EQUATION 3—Gross Ceiling Area Overall Thermal Transmittance

$$U_o = \frac{(U_r \times A_r) + (U_s \times A_s)}{A_o}$$

Where:

U_o = the overall thermal transmittance of the gross roof/ceiling area (Btu/hr/sq ft/° F)

A_o = the gross roof/ceiling area of a roof/ceiling assembly (sq ft)

U_r = the thermal transmittance of all elements of the opaque roof/ceiling area

U_s = the thermal transmittance of all skylight elements in the roof/ceiling assembly

A_s = skylight area (including frame)

Note: Where more than one type of roof/ceiling and/or skylight is used, the U x A term for that exposure shall be expanded into subelements, as:

$$(U_{r1} \times A_{r1}) + (U_{r2} \times A_{r2}), + \ldots \text{(etc.)}$$

Calculations shall include the effects of all heat flow paths, such as framing members. Framing as a percent of opaque roof/ceiling area is typically:

13 percent for 2-inch joist at 12 inches on center
10 percent for 2-inch joist at 16 inches on center
6 percent for 2-inch joist at 24 inches on center

EQUATION 4—Gross Floor Area Overall Thermal Transmittance

$$U_o = \frac{(U_f \times A_f)}{A_o}$$

Where:

U_o = the overall thermal transmittance of the gross floor area over unconditioned space (Btu/hr/sq ft/° F)

A_o = the gross floor area over an unconditioned space of a floor assembly (sq ft)

U_f = the thermal transmittance of all elements of the opaque floor area

A_f = the gross floor area of the opaque floor assembly (sq ft)

Note: Where more than one type of floor assembly is used, the U x A term for that exposure shall be expanded into subelements, as:

$$(U_{f1} \times A_{f1}) + (U_{f2} \times A_{f2}), + \ldots \text{(etc.)}$$

Calculations shall include the effects of all heat flow paths, such as framing members. Framing as a percent of floor area is typically:

13 percent for 2-inch joist at 12 inches on center
10 percent for 2-inch joist at 16 inches on center
6 percent for 2-inch joist at 24 inches on center

EQUATION 5—Overall Thermal Transmittance of Building Envelope (U_o)

The following formula shall be used to determine whether the overall thermal transmittance (U_o) of the entire building enevelope for a proposed building is in conformance with the values stated in table J4-1.

U_{op} shall be less than or equal to ($\leq$)U_o

Where:

U_{op} = the overall thermal transmittance of the building envelope for the proposed design calculated as the sum of the component U_o derived from Equations 2 through 4 using the proposed U_o value for each building component

U_o = the overall thermal transmittance of the building envelope for the proposed design calculated as the sum of the component U_o derived from Equations 2 through 4 using the U_o value stated in table J4-1 for each building component

EQUATION 6—Heat Storage Capacity

$$HS = \frac{(WM) \times (SH)}{A}$$

Where:

HS = heat storage capacity for each square foot of solar glazing and for one degree F change in temperature, Btu/° F·ft^2

WM = the weight of the materials (lbs) inside the insulated shell of the building to a depth yielding a resistance of R-1, except in the case of slab floors where only the slab itself is credited. Mass located in heated or unheated basements without solar glazing shall not be counted.

SH = specific heat of those materials, Btu/lb/° F

A = area of passive solar glazing excluding sash (ft^2)

The following will allow a quick method of calculation of mass needed for each square foot of exempted glazing:

15 square feet of interior stud partition wall (2" x 4" at 16" o.c. with 1/2" gypsum two sides).

30 square feet of exterior stud wall or ceiling (2" x 4" at 16" o.c. with 1/2" gypsum inside insulation, and various external treatments).

5 square feet of 8-inch lightweight concrete block masonry exterior wall insulated externally, cores filled for structural support only.

5 square feet of concrete slab floor provided with a steel trowel finish, exposed aggregate, tile (vinyl, asbestos, or ceramic), or terrazo.

Table J4-1.
Thermal Performance Criteria for Low-Rise Residential Buildings (Occupancy Groups R-1 and R-3)

	Climate Zone*					
	Zone 1 Group R		Zone 2 Group R		Zone 3 Group R	
Element	**Div. 3**	**Div. 1**	**Div. 3**	**Div. 1**	**Div. 3**	**Div. 1**
Walls[1] (U_O Value)	.10	.115	.09	.115	.09	.115
Roof/Ceiling[2] (U_O Value)	.028	.035	.028	.035	.028	.035
Floors over Unconditioned Spaces (U_O Value)[3] Exposed to Outdoor Air	.05	.05	.035	.035	.035	.035
All Others (U_O Value)	.08	.08	.05	.05	.05	.05
Slab-on-Grade Floors Unheated[4] (R Value)	5	5	10	10	10	10
Heated (R Value)	10	10	12	12	15	15

*Zone 1 = 4000 - 6000 heating degree days at 65° F
*Zone 2 = 6001 - 8000 heating degree days at 65° F
*Zone 3 = over 8000 heating degree days at 65° F

[1]Includes all components of gross wall area (see definition)

[2]Includes all components of skylights in gross roof/ceiling area (see definition)

[3]Includes all components of gross floor area (see definition)

[4]Not incorporating a heating system within floor slab

Table J4-2.
Thermal Performance Criteria for Buildings Other Than Low-Rise Residential Buildings

Element	**Non-Residential Buildings 3 Stories and Under or Wood Frame Construction**	**All Other Buildings**
Walls (U_O Value)	.25	.30
Roof/Ceiling (U_O Value)	.050	.085
Fllors over Unconditioned Spaces Exposed to Outdoor Air (U_O Value)	.050	.080
All Others (U_O Value)	.080	.080
Slab-on-Grade Floors Unheated (R Value)	4.25	.425
Heated (R Value)	6.35	6.35

Table J4-3.
Allowable Air Infiltration Rates

Windows	Residential Doors (R-1 & R-3) Swinging & Sliding	Non-Residential Doors Swinging, Sliding, & Revolving[1]
(cfm per linear ft of operable sash crack)	**(cfm per linear ft of perimeter)**	**(cfm per linear ft of crack)**
0.3	0.2	11.0

[1]If other types of coverings are used for door openings, they shall be designed not to exceed the same air leakage rate.

Compliance with the criteria for air leakage of all types shall be determined by ANSI/ASTM E283-73 "Standard Test Method for Rate of Air Leakage through Exterior Windows, Curtain Walls and Doors."

EXCEPTION: Site-built and millwork shop made wooden sash are exempt from testing but shall be made tight fitting. Fixed lights shall have glass retained by stops with sealant or caulking all around. Operating sash shall have weatherstripping working against overlapping trim, and a closer/latch which will hold the sash closed. The space between rough framing and door or window frames shall be made tight with caulking, overlapping membrane, or other approved technique.

Table J4-4.
HVAC System Heating Equipment and System Components, Electrically Driven (Heat Pumps)[1, 2] Minimum COP[3]

Heat Source Entering Temperature °F	Air-Source		Water-Source
	47 DB/43 WB	**17 DB/15 WB**	**70**
	2.8	2.0	3.0

[1]Applies to the following equipment tested in accordance with the standard cited:

Air-Source Unitary Heat Pump Equipment, ARI Standard 240-77
Central Water-Source Heat Pumps, ARI Standard 320-76
Commercial and Industrial Heat Pump Equipment, ARI Standard 340-76
Packaged Terminal Heat Pumps, ARI Standard 380-82

All performances are at sea level and exclude supplementary heat.

[2]"Equipment" here refers to central heat pumps, both air-source and water-source; "Components" refers to water-source heat pumps in hydronic systems.

[3]For both central and hydronic system water-source heat pumps, the COP values in the table do not include the power consumed by the water pump. In order to determine total system performance, it is the system designer's responsibility to take this power consumption into account.

In addition, new (fossile fuel or electric) energy supplied to a boiler or other water heating device to restore the water-source temperature entering the heat pump shall be taken into account by the system designer.

Table J4-5.
HVAC System Equipment, Electrically Driven[1]
Minimum COP (EER)[2]—Cooling

Standard Rating Capacities: Under 19kW (65,000 Btu/h)		19kW (65,000 Btu/h) and Over	
Air-Cooled	**Evap. or Water-Cooled**	**Evap. or Air-Cooled**	**Water-Cooled**
2.28(7.8)	2.58(8.8)	2.40(8.2)[3]	2.69(9.2)

[1]Applies to the following equipment tested in accordance with the standard cited:

Central Air Conditioners—Air-, Evaporatively and Water-Cooled, ARI Standard 210-78

Commercial/Industrial Unitary Air Conditioning Equipment, ARI Standard 360-75

Central Unitary Heat Pumps—Air Source, ARI Standard 240-77 (Cooling Mode)

Central Unitary Heat Pumps—Water Source, ARI Standard 320-76 (Cooling Mode)

Commercial and Industrial Unitary Heat Pumps—Air and Water Source, ARI Standard 340-76 (Cooling Mode)

Packaged Terminal Air Conditioners, ARI Standard 310-82

Packaged Terminal Heat Pumps, ARI Standard 380-82 (Cooling Mode)

Room Air Conditioners, ANSI Standard Z234.1-1972

All performances are at sea level.

[2]EER is Energy Efficiency Ratio; COP is Coefficient of Performance

[3]Applies when return-air fans are not included under the manufacturer's model no. When return-air fans are included, the required minimum values are 2.34(8.0).

Table J4-6.
Applied HVAC System Components, Electrically Driven[1]
Minimum COP (EER)[2]—Cooling

	Water-Chilling Packages		Hydronic Heat Pumps	
	Condenser Air	**Cooling Means Water**	**19kW (65,000 Btu/h)**	**(65,000 Btu/h) and Over**
Centrifugal or Rotary Type	Condenser Included 2.34(8.0)[3]	4.04(13.8)[3]	2.64(9.0)	2.75(9.4)
Reciprocating Type	Condenser Included 2.46(8.4)	3.51(12.0)	—	—
	Condenserless 2.90(9.9)	3.51(12.0)	—	—

[1]Applies to the following equipment tested in accordance with the standard cited:

Centrifugal or Rotary Water-Chilling Packages, ARI Standard 550-77

Reciprocating Water-Chilling Packages, ANSI/ARI Standard 590-76

Water-Source Heat Pumps, ARI Standard 320-76 (For Hydronic Systems)

All performances are at sea level.

[2]Performance of water-chilling packages does not include energy to drive chilled water and condenser-water pumps, or cooling tower fans; for hydronic heat pumps it does not include the energy to drive circulating water pump(s) and cooling tower fan(s), but does include the conditioned supply-air fan-motor energy when included as part of the model number of the heat pump. The system designer shall determine the amount of the non-included energies and take them into account in determining the HVAC System COP (EER) and annual energy consumption.

[3]Where double-bundle heat recovery is employed on centrifigual or screw compressor units, a lower EER is acceptable, provided that the gain by heat exchange exceeds the loss by lower EER.

Table J4-7.
Applied HVAC System Components, Electrically Driven Condensing Units 19kW (65,000 Btu/h) and Over[1] Minimum COP (EER)—Cooling

Condensing Means	Air	Positive Displacement Evaporative	Water
	2.78(9.5)	3.66(12.5)	3.66(12.5)

[1]Applies to the following equipment tested in accordance with the standard cited:
Positive Displacement Refrigerant Compressors, Compressor Units and Condensing Units, ARI Standard 520-78.

All performances are at sea level.

Table J4-8.
HVAC System Heating Equipment (Heat Pumps), Electrically Operated[1] Standard Rating Conditions[2]

Conditions	Type		
	Air-Source		Water-Source
Air Entering Equipment (° F)	70DB	70DB	70DB
Outdoor Unit Ambient (° F)	47DB/43WB	17DB/15WB	
Entering Water Temp. (° F)	—	—	70
Water Flow Rate	—	—	As used in cooling mode[3]

[1]Applies to equipment listed in table J4-4.

[2]Additional standard rating requirements are specified in the applicable package.

[3]See applicable procedure for central water-source heat pumps and commercial and industrial heat pump equipment.

Table J4-9.
HVAC System Equipment, Electrically Driven[1] Standard Rating Temperatures[2]—Cooling

	Temperatures			
	Air-Cooled		Water-Cooled	
	DB	WB	Inlet	Outlet
Room Air Entering Equipment (° F)	80	67	—	—
Condenser Ambient (Air-Cooled) (° F)	95	75	—	—
Refrigerant Water Heat Exchanger[3] (° F)	—	—	85	95

[1]Applies to equipment listed in table J4-5.

[2]Standard ratings are also based on other standard rating conditions, such as, but not limited to, electric conditions, cooling coil air quantity, condenser air quantity, requirements for separated (split) assemblies, and minimum external static conditioned-air flow resistances, as provided in the applicable procedures.

[3]Refrigerant water heat exchanger serves as condenser in cooling mode and as evaporator in heating mode, of water source heat pumps.

Table J4-10.
Applied HVAC System Components, Electrically Driven[1] Standard Rating Conditions[2]—Cooling

Item	Centrifugal or Self-Contained Reciprocating Water-Chilling Package	Condenserless Reciprocating Water-Chilling Package	Hydronic System Water-Source Heat Pump
Leaving Chilled Water Temp. (° F)	44	44	—
Entering Chilled Water Temp. (° F)	54	54	—
Leaving Condenser Water Temp. (° F)	95	—	95
Entering Condenser Water Temp. (° F)	85	—	85
Air Temperature Entering	—	—	80DB/
Indoor Portion of Unit (° F)	—	—	67WB
Fouling Factor, Water[3]			
Non-Ferrous Tubes	0.0005	0.0005	—
Steel Tubes	0.0010	0.0010	—
Fouling Factor, Refrigerant[3]	0.0000	0.0000	—
Condenser Ambient (° F)	95DB/	—	—
(Air- or Evap. Cooled)	75WB	—	—
Compressor Saturated Discharge Temp. (° F)			
Water- or Evap. Cooled	—	105	—
Air-Cooled	—	120	—
Refrigerant Liquid Temp. (° F)			
Water- or Evap. Cooled	—	95	—
Air-Cooled	—	110	—
Air Temp. Surrounding Unit (° F)	—	—	80

[1]Applies to equipment listed in table J4-6.

[2]Standard ratings are also based on other standard rating conditions, such as but not limited to, electric conditions, indoor or condenser air quantities, minimum external flow resistances, etc., as provided in the applicable standards.

[3]Fouling Factors Units: ft²h° F/Btu.

Table J4-11.
Applied HVAC System Components, Electrically Driven[1] Standard Rating Conditions—Cooling[2] Temperature (° F)

(Evaporator)[2]		Condenser[3]			
		Air-Cooled[4]	Water-Cooled		Evaporatively Cooled
Saturation	Return Gas	Air Entering (Dry-Bulb)	Water In	Water Out	Air Entering (Wet-Bulb)
45	65	95	—	—	—
40	65	—	85	95	75

[1]Applies to equipment listed in table J4-7.

[2]Not part of condensing unit; conditions to be maintained by separately furnished condenser.

[3]Rerigerant liquid subcooling in ° F shall be stated by the manufacturer as obtained under the conditions below as measured at the liquid line leaving the condensing unit.

[4]With 95 ° F dry-bulb ambient air temperature surrounding unit.

Table J4-12.
***Insulation of Ducts*[1]**

Duct Location	Mechanically Cooled	Heated
On roof or exterior of building[2]	C, V, and W	B and W
Attics, garages, and crawl spaces	B and V	B
In walls, within floor/ceiling spaces[3]	B and V	B
Within the conditioned space or in basements	None required	None required
Cement slab or within ground	None required	None required

[1]Where ducts are used for both heating and cooling, the minimum insulation shall be as required for the most restrictive condition.

[2]Insulation types:

B 2 inch 0.60 lb/cu ft mineral fiber blanket
1 inch 1.5 to 3 lb/cu ft mineral blanket (duct liner)
1 inch 3 to 10 lb/cu ft mineral fiber board or equivalent to provide an installed thermal conductance = 0.24

C 3 inch 0.60 lb/cu ft mineral fiber blanket
1-1/2-inch 1.5 to 3 lb/cu ft mineral blanket (duct liner)
1-1/2-inch 3 to 10 lb/cu ft mineral fiber board or equivalent to provide an installed thermal conductance = 0.16

V Vapor barrier, with perm rating not greater than 0.05 perm, all joints sealed.

W Approved weatherproof barrier.

[3]Insulation may be omitted on that portion of a duct which is located within a wall or a floor/ceiling space where both sides of this space are exposed to conditioned air and where the space is not ventilated or otherwise exposed to unconditioned air.

Table J4-13.
***Minimum Pipe Insulation*[1]**

Piping System Types	Fluid Temp. Range (°F)	Insulation Thickness In Inches for Pipe Sizes[2]					
		Run-Outs[3] 2"	1" and Less	1.25" to 2"	2.5" to 4"	5" to 6"	8" and Larger
Heating Systems							
Steam and Hot Water							
High-Pressure/Temp.	306-450	1.5	2.5	2.5	3.0	3.5	3.5
Med-Pressure/Temp.	251-305	1.5	2.0	2.5	2.5	3.0	3.0
Low-Pressure/Temp.	201-250	1.0	1.5	1.5	2.0	2.0	2.0
Low Temperature	120-200	0.5	1.0	1.0	1.5	1.5	1.5
Steam Condensate (for Feed Water)	Any	1.0	1.0	1.5	2.0	2.0	2.0
Cooling Systems							
Chilled Water	40- 55	0.5	0.5	0.75	1.0	1.0	1.0
Refrigerant or Brine	Below 40	1.0	1.0	1.5	1.5	1.5	1.5

[1]For piping exposed to ambient temperatures, increase thickness by 0.5 in.

[2]Pipe sizes are nominal dimensions.

[3]Runouts to individual terminal units (not exceeding 12 ft in length).

Table J4-14.
Minimum Pipe Insulation for Recirculation Systems
Insulation Thickness in Inches for Pipe Sizes[1]

Service Water Heating Temp. (°F)	Noncirculating Runouts Up to 1"	Circulating Mains and Runouts		
		Up to 1.25"	1.5" to 2"	Over 2"
170-180	0.5	1.0	1.5	2.0
140-160	0.5	0.5	1.0	1.5
100-130	0.5	0.5	0.5	1.0

[1]Nominal iron pipe size and insulation thickness.

Table J4-15.
Lighting Power Budget[1]

Occupancy Group	Occupancy Description	Lighting Power Budget[2] (W/sq ft)
A-1	Assembly w/stage: occupancy of 1,000 or more	1.1
A-2	Assembly w/stage: occupancy of less than 1,000	1.1
A-2.1	Assembly w/o stage: occupancy of 300 or more other than B-2 and E	1.1
	Drinking and dining establishment	1.85
A-3	Assembly w/o stage: occupancy of less than 300 other than B-2 and E	1.1
	Drinking and dining establishments	1.85
A-4	Stadiums, reviewing stands, and amusement park structures not included in A or B-1, B-2 and B-3	1.1
B-1	Gasoline and service stations: includes the office, waiting room, and pump islands, plus five feet on each side of the island	2.0
	Storage Garages	0.3
B-2	Office buildings, wholesale stores, municipal police and fire stations	1.5
	Retail stores, state liquor stores, paint stores, w/o bulk handling, sales rooms for combustible goods	
	Class I (less than 1,000 sq ft)	1.5
	Class II (1,000 to 6,000 sq ft)	1.5
	Class III (6,000 to 20,000 sq ft)	1.5
	Class IV (20,000 to 40,000 sq ft)	1.5
	Class V (over 40,000 sq ft)	1.5
	Drinking and dining establishments: load of less than 50	1.85
	Work shops using material not highly flammable or combustible	2.0
	Storage and warehouses	0.7
B-3	Aircraft hangars	0.7
	Open parking garages	0.3
B-4	Ice plants, power plants, pumping plants, cold storage and creameries	1.0
	Factories and work shops	
	Less than 3,000 sq ft	2.0
	3,000 sq ft or greater	1.8
	Storage	0.7
	Sales rooms	2.0
	Shipyard structures	0.7

Table J4-15.
Lighting Power Budget[1] (Continued)

Occupancy Group	Occupancy Description	Lighting Power Budget[2] (W/sq ft)
E-1	Schools and daycare centers	
E-2	Less than 3,000 sq ft	2.0
E-3	3,000 sq ft or greater	1.8
H-1	Storage	0.7
	Handling	2.0
H-2	Storage	0.7
	Handling, dry cleaning plants, paint stores	2.0
	Paint shops and spray painting rooms	2.5
H-3	Warehouses	0.7
	Other	2.0
H-4	Auto repair and body shops	2.0
	Paint spray booths	5.0
H-5	Aircraft repair hangars	2.0
I-1 I-2 I-3	Institutions	2.0
R-1	Dwelling unit portions	Exempt
	Other than dwelling unit portions	Refer to appropriate occupancy
R-3	Dwelling unit portions	Exempt
	Other than dwelling unit portions	Refer to appropriate occupancy

[1]In the case of an occupancy not specifically mentioned above, the lighting power budget in watts per square foot shall be determined by the Building Official based upon the budget for the most comparable occupancy specified.

[2]Watts/sq ft of room may be increased by two percent per foot of height above 20 feet.

Chapter 5
Building Design by Energy Budgets Approach

Section 500. General

This chapter establishes design criteria in terms of total energy use by a building, including all of its systems. Sections 501 to 507 shall be used for all buildings except low-rise residential buildings of occupancy groups R-1 and R-3. Section 508 shall be used for low-rise residential buildings (R-1 and R-3 occupancy).

Section 501. Energy Analysis

Compliance with this section shall require the use of an approved (certified) calculation procedure which yields an annual energy budget expressed in Btu/sq ft/yr or in kWh/sq ft/yr.

A building designed in accordance with this chapter (the "alternative design building") shall comply with this Standard if the expected annual energy consumption is not greater than that of a building of similar design (a "standard design") whose enclosure elements and energy-consuming systems are designed in accordance with chapter 4.

"Building of similar design" shall mean a building using the same energy source(s) for the same functions and having equal floor area, environmental requirements, occupancy, climate data, and usage schedule. Inputs to the energy analysis relating to occupancy and usage shall correspond to the expected occupancy and usage of the building.

The alternative design shall incorporate the applicable provisions of Section 414 (mechanical system controls), Section 419 D (water temperature control), and Section 423 B (lighting switching).

Section 502. Design

The standard design, conforming to the criteria of chapter 4, and the proposed alternative design shall be designed on a common basis as specified herein.

The comparison of total energy usage shall be expressed in Btu input per square foot of gross floor area per year for the standard design and the alternative design. Comparison of similar elements, systems, or components shall be expressed in dimensions or terms accepted by standard engineering practice.

If the proposed alternative design results in an increase in consumption of one energy source and a decrease in another energy source, even though similar sources are used for similar purposes, the difference in each energy source shall be converted to equivalent energy units for purposes of comparing the total energy used.

Section 503. Analysis Procedure

The analysis of the annual energy usage of the standard design and the proposed alternative building and system design shall meet the following criteria:

A. General.

The building heating/cooling load calculation procedure used for annual energy consumption analysis shall be of sufficient detail to permit the evaluation of effect of factors specified in Section 504.

B. Detail.

The calculation procedure used to simulate the operation of the building and its service systems through a full-year operating period shall be of sufficient detail to permit the evaluation of the effect of system design, climatic factors, operational characteristics, and mechanical equipment on annual energy usage. Manufacturer's data or comparable field test data shall be used when available in the simulation of all systems and equipment. The calculation procedure must be certified by the Bonneville Power Administration, approved by the local Building Official, or be consistent with current engineering or analysis procedures and must represent a full 12 months of operation and use (typical month and year weather data from a recognized source). The calculation procedure shall separately identify the annual amounts of energy used by heating, cooling, ventilation, and,lighting. Further, any energy use not listed but consuming greater than 10 percent of the total energy budget shall be separately identified.

C. Data Identification.

The calculation procedure for the standard design and the proposed alternative design shall separately identify the energy input to each of the following systems: heating, cooling, ventilation, and lighting. The energy input to any other system using over 10 percent of of the total energy input shall also be separately identified. The energy use for the standard and alternative designs shall be calculated by summing the energy inputs assigned to each identified system and all other energy inputs not separately identified. The systems identified and, to the extent possible, the assumptions made in assigning energy inputs to each system, shall be the same for the standard design and the proposed alternative design.

EXCEPTION: Industrial processes are exempt from this requirement.

D. Heat Pumps.

When electrically driven heat pumps are employed to provide all or part of the heat for the alternative design, the standard design shall also, for the purposes of the analysis, assume that electrically driven heat pumps in conformance with Section 411, and having capacity at least as great as those used in the alternative design, are employed.

Section 504. Calculation Procedure

The calculation procedure shall cover the following items:

A. Design Requirements.

Design parameters required in chapter 3.

B. Climatic Data.

Sufficient coincident hourly data for temperatures, solar radiation, wind, and humidity of typical days to represent seasonal variation.

C. Building Data.

Orientation, size, shape, mass, air moisture, and heat transfer characteristics.

D. Operational Characteristics.

Control modes for temperature, humidity, ventilation, and illumination (including variations for occupied and unoccupied hours).

E. Mechanical Equipment.

Design capacity, part-load profile.

F. Internal Heat Generation.

Lighting equipment, number of people during occupied and unoccupied periods.

Section 505. Documentation

A proposed alternative design submitted under this chapter shall be accompanied by an energy analysis comparison report. The report shall provide sufficient technical detail on the two buildings and their systems, and on the data used in and resulting from the comparative analysis, to certify that both the analysis and the designs meet the criteria of this Standard.

When a non-certified analysis technique is used, documentation shall be submitted demonstrating that the analysis used is consistent with accepted techniques and procedures.

EXCEPTION: Proposed alternative designs for commercial and industrial structures having the indoor temperature controlled from a single point need not provide the energy usage analysis for a full year. A comparison of energy consumption between the alternative design and the standard design in a manner which follows approved engineering practices and standards, as approved by the Building Official, shall be provided.

Section 506. Buildings Using Non-depletable Energy

A. Exclusion of Non-depletable Energy Use.

Buildings using solar, geothermal, wind, or other non-depletable energy sources for all or part of its energy source shall meet the requirements of this chapter of this Standard, except such non-depletable energy may be excluded from the total annual energy consumption attributed to the alternative design building by this chapter.

B. Qualification Criteria.

To qualify for this exclusion, such non-depletable energy must be derived from a specific collection, storage, and distribution system.

> EXCEPTION: When the building glazing system is designed specifically to provide interior illumination through daylighting strategies, such glazing shall be exempted from the operable insulating requirements providing that such glazing meets the requirements of the following section.

C. Daylighting.

Daylighting can be used as part of the performance approach in lieu of the lighting budgets established in chapter 4, table J4-15, providing that the daylighting conditions meet the following criteria:

1. The zone in question shall be within 15 feet or less from a skylight or skylight well, and

2. All electric lighting within the zone shall be controlled by dimmers or switching capable of reducing the lighting power continuously or, in two or more steps, in one-third increments.

D. Nocturnal Cooling.

For the purposes of this section nocturnal cooling shall be treated as a non-depletable energy source.

> EXCEPTION: The energy consumed by mechancial systems, such as fans and control, shall be accounted for in the analysis. Evaporative cooling, high-capacitance thermal systems, thermal wheels, and other thermal recovery systems are applied to the requirements of this section.

E. Applicability of Component Standards.

All other criteria covered in this chapter and chapter 4 shall apply to the proposed designs utilizing non-depletable sources of energy.

Section 507. Documentation— Buildings Using Non-depletable Energy Sources

Proposed alternative designs, submitted as requests for exception to the standard design criteria, shall be accompanied by an energy analysis as specified in Section 503 of this chapter. The report shall provide sufficient technical detail on the alternative building and system designs, and on the data employed in and resulting from the comparative analysis, to verify that both the analysis and the designs meet the criteria of chapter 4 and this chapter.

The energy derived from non-depletable sources and the reduction in conventional energy requirements derived from nocturnal cooling, evaporative systems, and energy recovery systems shall be separately identified from the overall building energy use. Supporting documentation, on the basis of the performance estimates for the aforementioned non-depletable energy sources or nocturnal cooling means, must be submitted.

Energy usage must be calculated in accordance with the design conditions and methods specified in this Standard or certified by the Bonneville Power Administration.

Section 508. Energy Analysis Using Performance Approach for Occupancy Groups R-1 and R-3

This section applies only to low-rise residential buildings, occupancy groups R-1 and R-3.

A. Energy Budgets.

Buildings designed in accordance with this section shall be designed to use no more kilowatt-hours (kWh) of electric energy from depletable sources for space heating than that specified in table J5-1 for the appropriate climate zone and building type. New buildings shall also meet the applicable requirements of Sections 404, 414, 419, and 421.

B. Calculation of Energy Consumption.

The application for a building permit shall include documentation which demonstrates, using an approved calculation procedure, that a new building has been designed to not exceed the allowable space heating energy use in table J5-1 for the appropriate climate zone. The total calculated annual electricty consumption shall be shown in units of kWh/sq ft or Btu/sq ft of gross floor area.

C. Input Values.

The following input values shall be used in calculating annual space heating budgets:

Parameter	Value
Thermostat set point (average daily interior temperature)	65° F
Internal heat gain from lights, occupants, and appliances	2000 Btu/hr or 48,000 Btu/day
Minimum heat storage capacity	15 Btu/° F/sq ft of glazed area

Parameter values that may be varied by the building designer to model energy saving options include, but are not limited to, the following.

1. overall thermal transmittance value of building envelope or individual building components;
2. heat storage capacity of building;
3. glazing orientation and area;
4. heating system efficiency; and
5. infiltration levels.

Table J5-1.
Design Space Heating Energy Budgets for Low-Rise Residential Buildings
Occupancy Groups R-1 and R-2

	Climate Zone*					
	Zone 1		Zone 2		Zone 3	
Building Type	**kWh/sq ft/ Yr**	**Btu/sq ft/ Yr**	**kWh/sq ft/ Yr**	**Btu/sq ft/ Yr**	**kWh/sq ft/ Yr**	**Btu/sq ft/ Yr**
Single-Family (Occupancy Group R-3)	2.0	6,825	2.6	8,875	3.2	10,920
Multi-Family (Occupancy Group R-1)	1.2	4,095	2.3	7,850	2.8	9,555

*Climate Zones

1 = 4,000 to 6,000 degree days at 65 °F

2 = 6,001 to 8,000 degree days at 65 °F

3 = 8,001 + degree days at 65 °F

Chapter 6
Prescriptive Requirements Approach

Section 600. General

A. Purpose.

This chapter establishes design criteria in terms of prescribed requirements for building construction.

B. Scope.

The requirements contained in this chapter are applicable only to buildings less than 5,000 square feet in gross floor area or dwelling units of three stories or less in height including occupancy groups R-1 and R-3. Other methods may be used provided a satisfactory design is submitted showing compliance with the performance standards stated in table J5-1 of this Standard.

Section 601. Building Envelope Requirements

The building envelope requirement of this Standard may be met by installing one of the prescriptive component packages shown in table J6-1. Installed components shall meet the following requirements:

A. Insulation.

1. The minimum R value for insulation shall not be less than that shown in table J6-1 for each element of the building envelope specified as a package.

2. Blown or poured loose-fill insulation may be used in attic spaces where the slope of the roof is not less than 2-1/2 feet in 12 feet and there is at least 30 inches of clear distance from the top of the bottom chord of the truss or ceiling joist to the underside of the roof sheathing at the roof ridge. When eave vents are installed, baffling of the vent openings shall be provided so as to deflect the incoming air above the surface of the insulation. Baffles shall be in place at the time of framing inspection.

3. The minimum depth of concrete-slab floor perimeter insulation shall be 24 inches or the depth of the footing of the building, whichever is greater.

4. Floor insulation over unconditioned spaces, such as vented crawl spaces, garages, and overhangs may be omitted if the foundation walls are insulated to meet the wall insulation minimums shown in table J6-1, a vapor barrier is placed over the entire floor of the crawlspace, and the vents are fitted with operable louvers or plugs.

B. Glazing.

1. Glazing shall be installed which has equal or lower U values than shown in table J6-1. Permanently affixed insulated shutters or shades with a minimum R value of 5 may be used to achieve U values below .47.

2. Total glazing area shall not exceed the percentage of conditioned floor area specified in table J6-1.

3. No more than .25 percent of the conditioned floor area may be single-glazed for ornamental, architectural, or security purposes.

4. Effective solar glazing area shall not be less than the percentage of conditioned floor area specified in table J6-1. To qualify as effective solar glazing area, an area shall meet all of the following criteria:

(a.) The glazing area shall be oriented within 90 degrees of due south. Glazing area oriented between 31 degrees and 90 degrees east or west of due south shall be adjusted by multiplying by .6;

(b.) The glazing area, if mounted other than vertically, shall be tilted at least 30 degrees up from horizontal;

(c.) The glazing shall have a minimum transmittance factor of .88 at normal incidence for single pane;

(d.) The area oriented within 30 degrees of due south shall receive direct solar exposure for 50 percent of the hours between 9 a.m. and 3 p.m. on December 21;

(e.) The area oriented between 31 degrees and 90 degrees east of south shall receive direct solar exposure for 85 percent of the hours between 9 a.m. and 12 noon on March 21; and

(f.) The area oriented between 31 degrees and 90 degrees west of south shall receive direct solar exposure for 85 percent of the hours between 12 noon and 3 p.m. on March 21.

All other glazing area shall be considered non-solar.

5. Opaque wall area covered with glazing, such as mass- and water-walls which meet the criteria set forth in Section 601 B 4(A-F), shall be considered effective solar glazing.

6. All skylights shall have a maximum U value of .47.

C. Thermal Mass.

Thermal mass required in table J6-1 shall be installed to meet or exceed the minimum heat storage capacity shown in table J6-2. Qualifying thermal mass shall be distributed in floors, walls, and ceilings and be directly exposed to the conditioned space. Thermal mass includes hard-surface slab floors (excluding wood or carpet finishes), masonry walls, gypsum board and plaster walls and ceilings, water-walls, and other approved thermal storage materials. If the heat storage medium is not within the space containing the qualifying glazing, an acceptable natural or mechanical means of transferring the heat to the heat storage medium shall be provided.

Heat storage capacity shall be calculated as specified in Equation 6 in chapter 4.

D. Air Leakage.

The minimum air infiltration control measures taken shall be those specified for the applicable prescriptive package shown in table J6-1 and described in table J6-3.

EXCEPTION: Required fire doors with a fire-resistance rating over one hour, and fire windows are exempt from this section.

E. Insulation and Vapor Barriers.

Insulation and Vapor Barriers shall be installed in accordance with Section 302.

Section 602. Building Mechanical Systems

All HVAC devices, components, and their elements shall conform to the requirements of this section.

A. Heating and Mechanical Cooling Devices.

1. All heating and mechanical cooling devices shall meet the required efficiency factor specified herein or in tables J4-4, J4-5, J4-6, J4-7, and J4-8 for the specific type of device.

EXCEPTION: Air-to-air, ground-to-air, or water-to-air heat pumps installed to comply with a prescriptive package set forth in table J6-1 shall meet the required seasonal-of-performance factor as determined using Equation 7.

2. Calculation of Heating and Cooling Loads. Heating and cooling design loads for the purpose of sizing HVAC systems are required and shall be calculated in accordance with accepted analysis practices. The design parameters specified in chapter 3 shall apply for all computations.

HVAC equipment for low-rise residential buildings shall be sized no greater than 125 percent of the design load as calculated above.

All associated duct work shall be sized to meet air flow requirements as determined by the load calculation.

B. Temperature Control.

Each heating system shall be provided with at least one thermostat for the regulation of temperature. Each thermostat shall be capable of being set as follows:

Where used to control heating only: 55-75° F;
Where used to control cooling only: 70-85° F;
Where used to control both heating and cooling, it shall conform to the requirements of Section 414.

C. Zoning for Temperature Control.

1. Detached One- and Two-Family Dwellings (R-3 Occupancies). At least one thermostat for regulation of space temperature shall be provided for each separate HVAC system. In addition, a readily accessible manual or automatic means shall be provided to partially restrict or shut off the heating and/or cooling input to each space, floor, or zone not controlled by a thermostat. Spaces other than dwelling units shall meet the requirements of paragraph 3 of this subsection.

2. Other Dwellings (R-1 Occupancy). For other dwellings, each individual dwelling unit shall have at least one thermostat for regulation of space temperature. A readily accessible manual or automatic means shall be provided to partically restrict or shut off the heating and/or cooling input to each room. Spaces other than dwelling units shall meet the requirements of paragraph 3 of this subsection.

3. All Other Types of Buildings or Occupancies. At least one thermostat for regulation of space temperature shall be provided for:

(a.) Each separate system;

(b.) Each separate zone as defined in Section 223. As a minimum, each floor of a building shall be considered as a separate zone. In a multi-story building where the perimeter system offsets only the transmission losses of the exterior wall, an entire side of uniform exposure may be zoned separately. A readily accessible manual or automatic means shall be provided to restrict partially or shut off the heating and/or cooling input (for the exposure) to each floor.

4. Control Setback and Shutoff.

(a.) Residential Occupancy Groups (R-1 and R-3 Occupancies). The thermostat required in paragraphs 1 and 2 of this subsection or an alternate means, such as a switch or clock, shall provide a readily accessible manual or automatic means for reducing the energy required for heating and cooling during periods of nonuse or reduced need such as, but not limited to, unoccupied periods and sleeping hours. Lowering the thermostat set-points to reduce energy consumption of heating systems shall not cause energy to be expended to reach the reduced setting.

(b.) Other Buildings and Occupancies. Each system shall be equipped with a readily accessible automatic means of shutting off or reducing the energy used during periods of nonuse or alternate uses of the building spaces or zones served by the system. Acceptable means include, but are not limited to:

(i.) manually adjustable automatic timing devices, or

(ii.) automatic control systems.

D. Insulation.

1. Duct Insulation. All ducts, plenums, and enclosures installed in buildings shall be thermally insulated in accordance with table 4-12 and constructed and erected in accordance with the Mechanical Code.

2. Pipe Insulation. All piping installed to serve buildings or within buildings shall be thermally insulated in accordance with tables 4-13 and 4-14.

EXCEPTION: For service water heating systems, see Section 603.

Section 603. Service Water Heating

Water heating storage tanks, boilers, and piping for all water heating systems shall be installed in accordance with the following:

A. Temperature Controls.

Service water heating systems shall be equipped with automatic temperature controls capable of adjustment from the lowest to the highest acceptable temperature settings for the intended use.

B. Shutdown.

A separate switch shall be provided to permit turning off the energy supplied to electric service water heating systems. A separate valve shall be provided to permit turning off the energy supplied to the main burner(s) of all other types of service water heating systems.

C. Swimming Pools.

Heated swimming pools shall be equipped with:

1. Controls which allow water temperature to be regulated from the maximum design temperature down to 65° F;

2. An on/off switch for the pool heater, mounted for easy access, to allow shutting off the operation of the heater without adjusting the thermostat setting and to allow restarting without relighting a pilot light; and

3. A pool cover at the surface of the water, or

4. A solar pool water heating system or heat pump pool heater.

D. Pump Operation.

Circulating hot water systems shall be arranged so that the circulating pump(s) can be conveniently turned off, automatically or manually, when the hot water system is not in operation.

E. Insulation.

For recirculating systems, piping heat loss shall be limited to a maximum of 17.5 Btu/h per linear foot of pipe in accordance with table J4-13, which is based on design external temperature no lower than 65° F. Other design temperatures must be calculated.

EXCEPTION: Piping insulation is not required when the heat loss of the piping, without insulation, does not increase the annual energy requirements of the building.

Other hot water piping systems shall be insulated in accordance with table J4-12.

F. Showers.

Showers used for other than safety reasons shall be equipped with flow-control devices to limit total flow to a maximum of 2.75 gpm per shower head.

G. Water Heaters, Storage Tanks, and Boilers.

Water heaters, storage tanks, and boilers shall meet the requirements of Section 419.

Section 604. Electric Power and Lighting

The electric power distribution and lighting systems shall conform to the requirements of Sections 423 and 424.

EXCEPTION: One- and two-family detached dwellings and the dwelling portion of multi-family buildings are exempt from the requirements of this section.

Table J6-1a.
Alternative Component Packages for Climate Zone 1—4,000 to 6,000 Heating Degree Days at 65 °F
Single-Family Dwellings (R-3 Occupancy)

	Package				
Component	**A Well Insulated**	**B Low Infiltration**	**C Sun Tempered**	**D Passive Solar**	**E Heat Pump**
Building Envelope					
Insulation Minimums					
Ceiling	R-38	R-38	R-38	R-30	R-30
Wall	R-27	R-19	R-25	R-19	R-19
Slab Floor Perimeter	R-10	R-10	R-10	R-10	R-6.35
Floor Over Unconditioned Space	R-19	R-30	R-19	R-19	R-19
Exterior Doors (DISI No.)	2.0	2.0	2.0	2.0	6.5
(EDII No.)	—	—	—	—	6.5
Glazing					
Maximum U Value	.37	.37	.47	.47	.47
Maximum Total Area[1]	15%	15%	15%	No Requirement	No Requirement
Minimum Effective Solar Glazing Area[2]	No Requirement	No Requirement	8%	10%	No Requirement
Thermal Mass[3]	Not Required	Not Required	Not Required	Required	Not Required
Space Conditioning System					
Heating System Type	No Special Requirement	No Special Requirement	No Special Requirement	No Special Requirement	High-Performance Heat Pump (S.P.F. = 2.0)[4]
Infiltration Control Package					
(See table J6-3)	A	A	A	B	A

[1]Percent of conditioned floor area. [3]See Section 601C for calculation.

[2]See Section 601B for calculation. [4]See Equation 7 for calculation.

Table J6-1b.
Alternative Component Packages for Climate Zone 2—6,001 to 8,000 Heating Degree Days at 65 °F
Single-Family Dwellings (R-3 Occupancy)

	Package			
Component	**A Well Insulated**	**B Sun Tempered**	**C Passive Solar**	**D Heat Pump**
Building Envelope				
Insulation Minimums				
Ceiling	R-38	R-38	R-38	R-38
Wall	R-31	R-25	R-25	R-19
Slab Floor Perimeter	R-12	R-12	R-12	R-12
Floor Over Unconditioned Space	R-30	R-30	R-19	R-19
Exterior Doors (DISI No.)	2.0	2.0	2.0	6.5
(EDII No.)	—	—	—	6.5
Glazing				
Maximum U Value	.37	.37	.37	.47
Maximum Total Area[1]	15%	15%	15%	No Requirement
Minimum Effective Solar Glazing Area[2]	No Requirement	8%	10%	No Requirement
Thermal Mass[3]	Not Required	Not Required	Required	Not Required
Space Conditioning System				
Heating System Type	No Special Requirement	No Special Requirement	No Special Requirement	High-Performance Heat Pump (S.P.F. = 2.0)[4]
Infiltration Control Package				
(See table J6-3)	B	B	B	A

[1]Percent of conditioned floor area. [3]See Section 601C for calculation.

[2]See Section 601B for calculation. [4]See Equation 7 for calculation.

Table J6-1c.
Alternative Component Packages for Climate Zone 3—Over 8,000 Heating Degree Days at 65 ° F Single-Family Dwellings (R-3 Occupancy)

	Package			
Component	**A** **Well Insulated**	**B** **Sun Tempered**	**C** **Passive Solar**	**D** **Heat Pump**
Building Envelope				
Insulation Minimums				
Ceiling	R-38	R-38	R-38	R-38
Wall	R-31	R-25	R-25	R-19
Slab Floor Perimeter	R-15	R-15	R-15	R-15
Floor Over Unconditioned Space	R-30	R-30	R-19	R-19
Exterior Doors (DISI No.)	2.0	2.0	2.0	6.5
(EDII No.)	—	—	—	6.5
Glazing				
Maximum U Value	.37	.37	.37	.47
Maximum Total Area[1]	15%	15%	No Requirement	No Requirement
Minimum Effective Solar Glazing Area[2]	No Requirement	8%	10%	No Requirement
Thermal Mass[3]	Not Required	Not Required	Required	Not Required
Space Conditioning System				
Heating System Type	No Special Requirement	No Special Requirement	No Special Requirement	High-Performance Heat Pump (S.P.F. = 2.0)[4]
Infiltration Control Package				
(See table J6-3)	B	B	B	A

[1]Percent of conditioned floor area. [2]See Section 601B for calculation. [3]See Section 601C for calculation. [4]See Equation 7 for calculation.

Table J6-1d.
Alternative Component Packages for Multi-Family (R-1 Occupancy) Dwellings and Other Occupancies up to 5,000 Square Feet

	Climate Zones		
	1	**2**	**3**
Component	**4,000-6,000 Heating Degree Days**	**6,001-8,000 Heating Degree Days**	**Over 8,000 Heating Degree Days**
Building Envelope			
Insulation Minimums			
Ceiling	R-30	R-30	R-30
Wall	R-19	R-25	R-25
Slab Floor Perimeter	R-10	R-15	R-15
Floor Over Unconditioned Space	R-19	R-30	R-30
Exterior Doors (DISI No.)	2.0	2.0	2.0
Glazing			
Maximum U Value	.47	.47	.47
Maximum Total Area[1]	15%	15%	15%
Infiltration Control Package			
(See table J6-3)	B	B	B

[1]Percent of conditioned floor area.

Table J6-2.
Minimum Thermal Mass Requirements

Solar Glazing as a Percent of Conditioned Floor Area	**Minimum Heat Storage Capacity Requirements Btu/° F/sq ft of Solar Glazing[1]**
0-8	No Requirement
9-14	30
Over 15	45

[1]Calculated using Equation 6, chapter 4.

Table J6-3. Infiltration Control Packages

Package A

Nominal Standard—.4 Air Changes per hour (AC/HR)

Required Measures

1. **Window and Doors.** All windows and doors shall conform to air infiltration requirements specified in table J4-3. Site-built and millwork shop-made wooden sash are exempt from testing but shall be made tightly fitting. Fixed lights shall have glass retained by stops with sealant or caulking all around. Operating sash shall have weatherstripping working against overlapping trim, and a closer/latch which will hold the sash closed. The window frame to framing crack shall be made tight with caulking, overlapping membrane, or other approved technique.
2. **Caulking and Sealing.** The following openings in the building shall be caulked or otherwise sealed to limit infiltration:
   a. Exterior joints and between double studs in window and door frames, between wall soleplates and floors, and between exterior wall panels;
   b. Openings for plumbing, electricity, and gas lines in walls, ceilings, and floors;
   c. Openings in the attic floor (such as where ceiling panels meet interior and exterior walls and masonry fireplaces);
   d. Sill plate in addition to the normal sill sealer;
   e. Partition wall base moldings; and
   f. All other such openings in the building envelope.
3. **Electric Outlet Plate Gaskets.** Electric outlet plate gaskets shall be installed on all receptacle, switch, or other electric boxes in exterior and interior walls.
4. **Vapor Barrier.** A vapor barrier shall be installed on the warm side (in winter) of all insulation as specified in Section 302.
5. **Heating Ducts.** If not enclosed within the conditioned envelope, heating ducts shall be sealed at all joints and corners and shall be insulated to the levels specified in table J4-12.
6. **Masonry and factory-built fireplaces shall have the following:**
   a. Tight fitting, closeable metal or glass doors covering the entire opening of the firebox (this requirement may be omitted if such doors would interfere with devices permanently installed in the fireplace which are designed to increase the circulation of heat);
   b. A combustion air intake to draw air from outside of the building directly into the firebox, which is at least six square inches in area and is equipped with a readily accessible, operable, and tight fitting damper; and
   c. Tight fitting flue damper with a readily accessible control.

EXCEPTION: Dampers in fireplaces with gas-burning equipment shall have a minimum position stop on the fireplace damper.

7. **Exhaust Systems.**
   a. Fan or other exhaust systems exhausting air from the building to the outside shall be provided with backdraft dampers or automatic dampers to prevent air leakage.
   b. Bathrooms shall have exhuast fans with positive closure damper vented to outside or through a heat exchanger to the outside. Timed switches or humidistats shall be installed to prevent unnecessary operation. Exhaust fan capacity shall be at least 50 cfm.
8. **Humidity Control.** Dehumidifier(s) shall be provided capable of maintaining a relative humidity no higher than 60% (at 68°F) throughout the building. The dehumidifier shall be centrally located, free of restrictions, such as filters, unless it is a direct component of the furnace system or the dehumidifier control is connected to the furnace fan. If the designer anticipates that the relative humidity may at times during the heating season fall below 30%, a humidifier should be considered.

Package B

Low Infiltration with Supplemental Mechanical Ventilation as Required

1. **Windows.** All windows shall be of a sealed type or casement or awning.
2. **Continuous Infiltration Barrier.** A continuous infiltration barrier shall be installed over the inside face of framing in celings and floors and over the outside face framing in exterior walls. Where ceilings are plank and beam construction exposed to the conditioned space, the barrier shall be placed on top of the planking, and the wall/ceiling joints shall be sealed with caulking or sealant. All openings in the continuous infiltration barrier, including spaces around plumbing, electric conduits and boxes, flues, and other elements which penetrate the infiltration barrier, shall be sealed with permanent tape or sealant. A continuous exterior infiltration control barrier may be substituted for interior barriers provided it is permeable to water vapor.
3. **Air-to-Air Heat Exchange.** Supplemental mechanical ventilation via air-to-air heat exchanger shall be installed if the home does not meet the Bonneville Power Administration's exemption criteria for air tightening measures. The air-to-air heat exchanger required shall be capable of ventilating the dwelling unit at a rate equal to at least 0.7 times the volume of the conditioned space per hour. An air-to-air heat exchanger is a device which will reduce the heat losses or gains which occur when a building is mechanically ventilated, by transferring heat between the conditioned air being exhausted and the unconditioned air being supplied.

   This requirement may be met by a central mechanical ventilation system with an integral air-to-air heat exchanger or by one or more single-package room mechanical ventilators with an integral air-to-air heat exchanger.

   If an air-to-air heat exchanger is installed a dehumidifier (Measure 8 in package A) is no longer required.

Appendix K
Conservation Assessment Methodology and Assumptions

This appendix provides an overview of the procedures and major assumptions used to derive the Council's conservation estimates. While identical procedures were followed for each of the Council's forecasts, only the Council's high growth forecast is illustrated. Citations are provided following each sector's discussion to the specific technical studies which served as the basis for the Council's conservation estimates. These reports are available for review at the Council's Portland office and at the Council office in each state.

As described in Appendix F, the Council's evaluation of a conservation measure's cost-effectiveness requires calculation of its levelized cost. This appendix and/or the technical exhibits listed at the end of the discussion of each sector provide the capital cost data, energy savings, and measure life used by the ouncil to determine each conservation measure's levelized cost. All costs are shown in 1980 dollars. Bonneville is expected to use comparable assumptions and procedures in its determination of regional cost-effectiveness. Bonneville may use alternative capital cost, energy savings, and measure life assumptions if, after consultation, the Council determines that an alternative value is more accurate.

Levelized costs are to be calculated as follows:

$$LC = \frac{K \times CRF}{EA}$$

Where:

LC = levelized cost (cents per kilowatt-hour)

K = conservation measure's installed cost in 1980 dollars

CRF = capital recovery factor as determined by

$$\frac{i\,(1+i)^N}{(1+i)^N - 1}$$

Where: N = conservation measure's useful life (years)
i = real discount rate (3 percent)

EA = annual savings of electricity (kilowatt-hour)

Residential Sector Assessment

Space Heat Conservation in Existing Buildings

The Council's assessment of conservation potential available through improving the thermal efficiency of existing dwellings involved seven steps. These steps were to:

1. Identify the thermal efficiency levels, house size, thermostat set points, and other characteristics affecting electric space heating use in existing dwellings;

2. Estimate the cost and potential savings available from the thermal efficiency of existing electrically heated dwellings;

3. Develop preliminary conservation supply functions;

4. Compare projected cost and savings estimates with historically observed cost and savings data;

5. Calibrate projected savings estimates and demand forecasting model inputs assumptions;

6. Develop final conservation supply functions; and

7. Estimate realizable conservation potential.

The basic assumptions used in each of these steps are detailed below. Where appropriate, illustrative calculations are shown.

Step 1. Identify Characteristics Affecting Electric Space Heating Used in Existing Dwellings. The basic source used to obtain dwelling characteristics and occupant behaviors (e.g., thermostat setting) was the Pacific Northwest Residential Energy Survey. This study was conducted for Bonneville and PNUCC by Elrick and Lavidge in 1979. It is the most recent regionwide assessment of the conservation measures extant in residential buildings.

The results of this survey were used to develop three prototypical residential buildings. It was also used to identify the level of thermal efficiency present in the region's existing electrically heated housing stock. Tables K-1, K-2, and K-3 summarize the number of units in each building category that were assumed to have specific insulation levels in 1979. Due to the limited data contained in the Residential Energy Survey on mobile homes and multi-family insulation characteristics, the values shown in tables K-2 and K-3, except for glazing, are based on professional judgment.

Table K-1.
Number of Single-Family Electrically Heated Units with Given Nominal R-Values Existing in 1979—By Climate Zone (thousands)

Component	R-Value	Zone 1	Zone 2	Zone 3	Total
Roof	0	64.6	19.0	1.7	85.3
	7	41.3	12.2	1.7	55.2
	11	147.7	57.8	10.7	216.2
	19	84.1	81.3	12.5	177.9
	24	87.9	84.3	19.6	191.8
	30	21.9	36.7	11.9	70.5
	38	16.6	32.3	10.7	59.6
	49	11.0	16.4	7.2	34.6
Infiltration	0.6 ach	475.0	340.0	76.0	891.0
Floors	0	361.0	262.5	56.6	680.1
	7	23.8	0.0	1.1	24.9
	11	67.9	26.9	9.6	104.3
	19	22.3	50.7	8.7	81.7
Glass	1 pane	335.8	167.5	15.4	518.7
	2 panes	139.2	172.5	60.6	372.3
Walls	0	107.4	43.2	4.2	154.8
	11	367.6	296.8	71.8	736.2
Doors	2	475.0	340.0	76.0	891.0

Table K-2.
Number of Electrically Heated Multi-Family Units with Given Nominal R-Values Existing in 1979—By Climate Zone (thousands)

Component	R-Value	Zone 1	Zone 2	Zone 3
Roof	0	172	52	12
Floors	0	172	52	12
Glass	1	144	30	3
	2	28	22	9
Walls	0	172	52	12
Doors	2	172	52	12
Infiltration	.6 ach	172	52	12

Table K-3.
Number of Electrically Heated Mobile Home Units with Given Nominal R-Values Existing in 1979—By Climate Zone (thousands)

Component	R-Value	Zone 1	Zone 2	Zone 3	Total
Roof	19	66	74	16	
Floor	11	66	74	16	
Glass	1	20	11	2	
	2	46	63	14	
Walls	0	66	74	16	
Doors	2	66	74	16	
Infiltration	.6 ach	66	74	16	

Step 2. Estimate Cost and Savings Available from Efficiency Improvements. A list of conservation measures that could be applied to improve the thermal efficiency of existing buildings was developed. The effect of each measure on the annual space heating energy use of the building prototypes was then simulated. Savings were estimated for each of the region's major climate zones. The cost of installing these measures was obtained from contractors. These cost and savings estimates are shown in tables K-4 through K-6. Some measures (e.g., Insulate Glass 2-3) are listed twice with different costs. This difference is due to the fixed cost of installing each measure. For example, the cost of achieving triple-pane windows shown in table K-4 can be either $756, if one simply adds a storm window to an existing double-pane window, or $1,012 to add a double-pane storm window to an existing single-pane unit. The cost of adding the third pane could either be $256 ($1,012 - $756 = $256) or $756, with the difference attributed to a contractor's fixed cost.

Table K-4.
Estimated Energy Conservation Cost and Savings for Existing Single-Family Buildings

Resource Description	Unit Cost 1980$	Life Years	Zone 1 Energy (kWh/unit)	Zone 2 Energy (kWh/unit)	Zone 3 Energy (kWh/unit)
Insulate Roof					
R0 to R19	396	30	10,747	15,536	17,767
R7 to R19	315	30	2,045	2,960	3,417
R19 to R30	128	30	787	1,141	1,335
R11 to R30	396	30	1,764	2,555	2,967
R30 to R38	93	30	254	382	441
R19 to R38	396	30	1,041	1,523	1,776
R24 to R38	338	30	683	1,004	1,169
R38 to R49	128	30	211	319	371
R30 to R49	396	30	465	701	812
R38 to R49	303	30	211	319	371
Infiltration					
.60-.48	279	30	676	1,017	1,722
.48-.44	166	30	217	327	383
Insulate Floors					
R0 to R11	446	30	2,342	3,416	3,991
R11 to R19	149	30	466	685	798
R19 to R30	244	30	377	568	663
R7 to R19	446	30	1,317	1,927	2,249
R19 to R30	217	30	377	568	663
R11 to R30	595	30	843	1,253	1,461
R19 to R30	446	30	377	568	663
Insulate Glass					
1-2	756	30	2,013	2,982	3,455
2-3	1,012	30	600	910	1,072
3-4	872	30	273	413	489
2-3	756	30	600	910	1,072
3-4	1,278	30	273	413	489
Insulate Walls					
R0 to R11	573	30	4,142	5,983	6,967
R11 to R23	3,553	30	979	1,474	1,762
Doors					
R2 to R15	424	30	449	674	794

Table K-5.
Estimated Energy Conservation Cost and Savings for Existing Multi-Family Buildings

Resource Description	Unit Cost 1980$	Life Years	Zone 1 Energy (kWh/unit)	Zone 2 Energy (kWh/unit)	Zone 3 Energy (kWh/unit)
Insulate Roof					
R0 to R38	472	30	2,537	3,715	4,334
Infiltration					
.60-.48	210	30	501	764	881
.48-.44	125	30	152	238	276
Insulate Floors					
R0 to R38	472	30	1,584	2,370	2,740
Insulate Glass					
1-2	724	30	1,195	1,841	2,135
2-3	696	30	359	569	665
3-4	734	30	159	251	298
2-3	696	30	359	569	665
3-4	724	30	159	251	298
Insulate Walls					
R0 to R11	258	30	2,295	3,354	3,873
Doors					
R2 to R15	111	30	122	191	222

Table K-6.
Estimated Energy Conservation Cost and Savings for Existing Mobile Homes

Resource Description	Unit Cost 1980$	Life Years	Zone 1 Energy (kWh/unit)	Zone 2 Energy (kWh/unit)	Zone 3 Energy (kWh/unit)
Insulate Roof					
R0 to R38	310	15	871	1,281	1,490
Infiltration					
.60-.48	279	15	523	776	899
.48-.44	166	15	163	245	288
Insulate Floors					
R0 to R38	115	15	535	791	918
Insulate Glass					
1-2	953	15	1,695	2,547	2,942
2-3	953	15	580	876	1,030
Doors					
R2 to R15	379	15	408	615	718

Step 3. Develop Preliminary Conservation Supply Functions. Supply functions are a traditional economic concept. They show how many units of a commodity can be produced at a given price. With respect to conservation, they show how much energy can be saved at a given unit cost.

The Council's supply function for conservation in existing residential buildings was developed for the year 2002. 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 also constrained by the need for additional energy supplies. Third, some houses currently in existence will be torn down by the turn of the century. As a result, the conservation savings from existing buildings diminishes with time. By developing its retrofit supply function for the year 2002, the Council was able to account for demolitions and set deployment schedules based on the need for additional supplies.

Table K-7 shows the preliminary supply function that was developed for conservation in existing residential buildings. This curve was developed by multiplying the savings per measure shown in tables K-4 through K-6 by the number of buildings to which these measures could be applied in the year 2002. This procedure assumes that no retrofit activity takes place between 1979 (the date of the survey) and 2002.

The number of buildings that could be retrofitted was determined by applying an annual demolition rate of .5 percent of total stock for single-family and multi-family buildings, and 1.0 percent of total stock for mobile homes. In the Council's high growth forecast, this implies that the average life of single-and multi-family buildings is approximately 62 years. Mobile homes would typically last 39 years under this same forecast. Table K-8 presents the number of existing (1983) electrically heated buildings expected to survive through the year 2002 for each building type and climate zone. Buildings added between 1980 and 1983 are assumed to be built to current codes. Consequently, they represent potential candidates for only a limited set of retrofit measures.

Table K-7. Preliminary Conservation Supply Function for Existing Residential Buildings

Levelized Cost (Cents/kWh)	Cumulative Savings (Technical Potential) (MW)
1	666
2	1,067
3	1,192
4	1,275
5	1,335
6	1,359
7	1,375
8	1,376
9	1,396
10	1,410

Table K-8. Existing* Electrically Heated Residential Stock Surviving in Year 2002 (Thousands of Units)

	Climate Zone			
Dwelling Type	1	2	3	**Total**
Single-Family	490	351	82	923
Multi-Family	182	55	12	249
Mobile Home	39	44	12	95
Total	711	450	106	1,267

*As of 1983.

Step 4. Compare Projected Cost and Savings Estimates With Observed Cost and Savings. The Council compared its estimates of projected energy savings and cost with those observed in current utility weatherization programs. Figure K-1 shows the relative space heating energy use of homes before and after they have been retrofitted. It also shows the amount of money spent to achieve those savings. The solid line on this graph plots the predicted savings and cost used by the Council. The other points depict utility program experience. The Council's cost and savings estimates appear to be in reasonable agreement with existing utility program experience.

The principal assumption made in plotting the observed bill changes is that pre-weatherization use represents the actual thermal efficiency of the house. In other words, it was assumed that those houses weatherized under the Seattle City Light (SCL) program and by Puget Sound Power and Light Company (Puget) had invested less than $100 in efficiency improvements prior to weatherization. Similarly, it was assumed that houses weatherized by Pacific Power and Light (PP&L) and Portland General Electric (PGE) had invested approximately $750-800 in thermal integrity improvements prior to weatherization. These expenditures may have been made at the time the house was constructed.

An alternative approach would have been to assume that differences in the observed use prior to weatherization was due to occupant behavior, such as temperature setbacks, room closures, and wood heat use. Since survey data reveal significant use of wood heat and room closures, this assumption would appear to be appropriate. However, this assumption was rejected. Assuming that observed use represents the actual thermal efficiency of buildings reduces the available technical potential for conservation. It implies that some conservation measures have already been installed which, indeed, may not be in place. Rather than include this technical potential in its assessment of retrofit savings, the Council assumed that consumers who now operate their unweatherized houses at reduced temperatures would raise thermostat settings following weatherization. Subsequently, the actual bill changes (i.e., savings) that are expected by the Council assume that consumers will discontinue their use of wood, re-open closed-off rooms, and increase thermostat settings. This was done as a conservatism.

Step 5. Calibrate Projected Savings Estimates and Demand Forecasting Model Inputs Assumptions. The next step in the Council's conservation assessment process was to make the projected technical potential for energy savings and forecasting model inputs consistent. The Council's residential demand fore- casting model requires input on the *average* level of efficiency of existing stock for both public and private utilities. The Council's conservation assessment was based on a measure-by-measure analysis. Therefore, it was necessary to translate the savings from individual measures to average savings per building. This was done as follows. First, estimates of the total regional space heating demand were developed assuming the thermal integrity levels shown in tables K-1 through K-3. Each prototype building space heating use was simulated with and without individual conservation measures. The "savings" shown in tables K-4 through K-6 were multiplied times the number of buildings that already had them installed. These savings were subtracted from the total load that would be created had none of the measures been installed. For example, there were an estimated 64,600 single-family units in Climate Zone 1 with uninsulated ceilings in 1979. Had these ceilings been insulated to R-19, they would have saved 10,747 kilowatt-hours per year. Therefore, 79 megawatts (64,600 units x 10,747 kWh/yr/unit + 8,760 x 1000) would have been subtracted from the regional demand estimate.

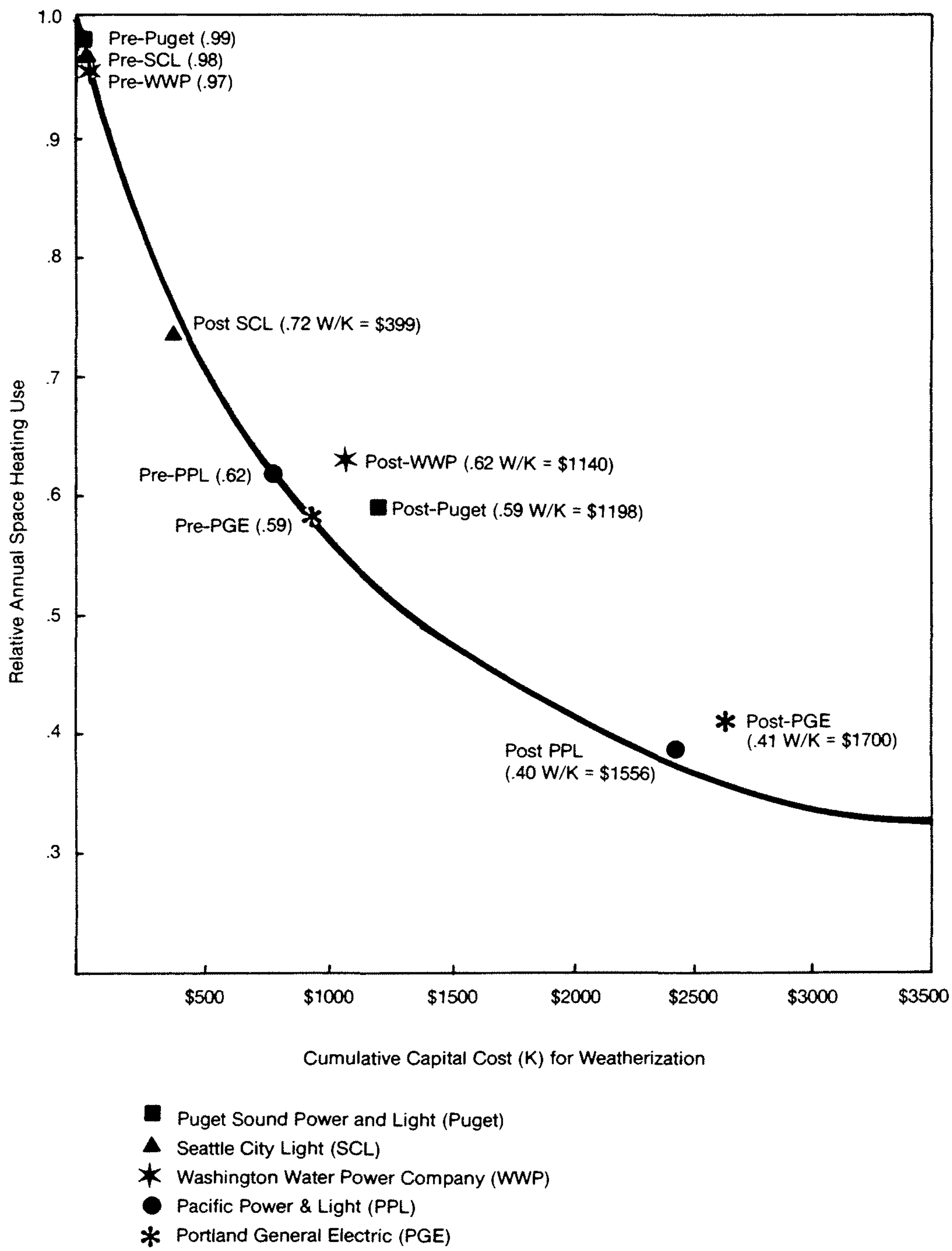


Figure K-1.
Comparison of Regional Thermal Integrity Curve
Estimated Cost and Savings With Observed Bill Changes In Existing Utility Weatherization Programs

Once this engineering estimate of the total region's space heating demand was developed, it was divided by the number of electrically heated buildings in the region to determine the average use per building. Tables K-9 and K-10 show the estimated total average annual consumption and average annual consumption per square foot of floor area for existing buildings in 1979 resulting from this process.

Table K-9.
Estimated Annual Space Heat for Units Existing In 1979 Before Retrofit
(kilowatt-hours per unit)

Housing Type	Zone 1	Zone 2	Zone 3	Average
Single-Family	13,566	17,951	17,783	15,599
Multi-Family	9,865	14,985	16,784	11.345
Mobile Home	7,370	11,759	13,967	10,129
Average	12,100	1,637	17,081	14,150

Table K-10.
Estimated Annual Space Heat for Units Existing In 1979 Before Retrofit
(kilowatt-hours per square foot)

Housing Type	Zone 1	Zone 2	Zone 3	Average
Single-Family	10.05	13.30	14.60	11.55
Multi-Family	11.74	17.84	19.98	13.51
Mobile Home	7.09	11.31	13.43	9.74
Average	9.93	13.66	14.02	11.62

Table K-11 compares the space heat use estimates derived via the above method with those assumed in the Council's residential forecasting model for the same year (1979). There are several reasons for the differences. First, insulation levels are not reported in the Pacific Northwest Energy Survey for mobile homes and multi-family units. It appears that the assumptions regarding the thermal integrity of these units in the engineering analysis were too pessimistic. According to utility retrofit program records and existing building codes at least some of these buildings are insulated. Secondly, the engineering estimates of consumption assumed no use of wood heat or zone control (i.e., room closures) by occupants. According to surveys conducted by Puget Sound Power and Light, the use of wood heating devices can reduce an electric space heating customer's consumption by 25 to 33 percent. Third, Puget also found that houses heated with electric furnaces (which are difficult to zone control) consumed 34 percent more than houses with individual room baseboard heaters. Fourth, one prototype was used to represent each building category. The single-family category, for example, includes buildings (duplex, triplex, and fourplex) with common walls and ceilings. However, it was represented by a single-family detached building. All of these factors would tend to over-estimate average consumption per unit. However, as shown in figure K-1 the building energy use simulation appears to give an accurate measure of the savings that could be expected from individual measures.

Table K-11.
Estimated Annual Space Heating Use In Existing Buildings—1979

	Annual Use (kilowatt-hours per year)				
		Forecasting Model			
Building Type	Engineering Estimate	Public Utility	Private Utility	Weighted Average	Model Estimate as Percent of Engineering
Single-Family	15,600	14,140	12,580	13,425	86%
Multi-Family	11,345	6,070	5,400	5,655	50%
Mobile Home	10,130	8,490	7,555	7,905	78%
Weighted Average	14,150	13,230	9,440	11,060	78%

Given the above factors, the Council adjusted the engineering estimates of use to those assumed in the forecasting model. This reduced the conservation potential available in existing residential buildings by 488 megawatts. This adjustment was made as follows:

Given

1,267,000 existing housing units (564,000 in public utility service areas and 703,000 in private utility service areas)

14,150 kWh/yr/unit = Engineering estimate of annual use

13,230 kWh/yr/unit = Econometric estimate of annual use for space heat by public utility customer

9,440 kWh/yr/unit = Econometric estimate of annual use for space heat by private utility customer

Then

Total use projected by engineering estimates of individual unit use

$$= \frac{14{,}150 \text{ kWh/yr} \times 1{,}267{,}000}{8{,}760 \times 1{,}000}$$

= 2,047 MW

Total use projected by econometric estimates of individual use

$$= \frac{13{,}230 \text{ kWh/yr} \times 564{,}000 + 9{,}440 \text{ kWh/yr} \times 703{,}000}{8{,}760 \times 1{,}000}$$

= 1,609 MW

Adjustment

2,047 MW - 1,609 MW = 438 MW

In addition to the adjustment required to calibrate the base year (1979) consumption in the forecasting model with the conservation supply, a second adjustment was made to account for weatherization that occurred between 1979 and 1983. This was done by entering an estimate of the number of retrofits that have occurred since 1979 in the forecasting model. The model was also run to incorporate consumer price responses between 1979 and 1983.

As a result of this retrofit activity ,the average annual space heating consumption for public utility customers was reduced from 13,230 kilowatt-hours per unit in 1979 to 10,135 kilowatt-hours per unit in 1983. Private utility space heat consumption decreased from 9,440 kilowatt-hours per unit to 8,425 kilowatt-hours per unit. The effect of these retrofits reduced the technical potential for conservation in existing buildings by 296 megawatts.

Given

Estimated 1979 consumption for space heating = 1,609 megawatts

Annual use of space heating in 1983

= 10,330 kilowatt-hours per unit in public utility service areas

= 8,915 kilowatt-hours per unit in private utility service areas

Number of existing electric space heat customers

= 564,000 public utility customers

= 703,000 private utility customers

Then

Estimated 1983 consumption for space heat

$$= \frac{10{,}330 \text{ kWh/unit} \times 564{,}000 + 8{,}915 \text{ kWh/unit} \times 703{,}000}{8{,}760 \times 1{,}000}$$

= 1,381 MW

Adjustment

1,609 MW - 1,381 MW = 228 MW

Step 6. Develop Final Conservation Supply Functions. The combined effect of calibrating the engineering estimates of conservation potential to the Council's forecasting model reduced the technical potential for existing space heat conservation by 666 megawatts.

This reduction was prorated across the savings available between 1.0 and 3.0 cents per kilowatt-hour as follows:

Given

Proportion of technical potential between 1.0 and 3.0 cents per kilowatt-hour

0-1.0¢ = 56%
1.1-2.0¢ = 34%
2.1-3.0¢ = 10%

Initial estimate of technical potential between 1.0 and 3.0 cents per kilowatt-hour

0-1.0¢ = 666 MW
1.1-2.0¢ = 401 MW
2.1-3.0¢ = 125 MW

Then

Prorating the 666 megawatts across the initial savings estimates for

0-1.0¢/kWh = 666 - (666 x .56) = 293 MW
1.1-2.0¢/kWh = 401 - (666 x .34) = 175 MW
2.1-3.0¢/kWh = 125 - (666 x .10) = 58 MW

The adjusted conservation supply function for residential space heat conservation in existing buildings is shown in table K-12.

Table K-12.
Final Conservation Supply Function—Existing Residential Space Heat

Levelized Cost (Cents/kWh)	Technical Potential (Cumulative MW)
1.0	293
2.0	468
3.0	526
4.0	616
5.0	686
6.0	706
7.0	726
8.0	731
9.0	756
10.0	766

Step 7. Estimate Realizable Conservation Potential. The final step in the Council's assessment of retrofit potential was to develop and estimate the share of the 766 megawatts that could realistically be achieved over the next 20 years. To accomplish this the Council used current utility experience and its engineering assessment. Table K-13 shows the capital and marginal cost of achieving space heating savings in existing residential buildings. This table indicates that for a marginal cost of less than 4.0 cents per kilowatt-hour, relative space heating use can be reduced by approximately 60 percent. However, current estimated consumption for space heating for public utility customers is already 73 percent of 1979 use. Private utility customers' space heat use is estimated to be 63 percent of its 1979 level. Thus, as was discussed earlier, some 666 megawatts of technical potential (as estimated by an engineering model) have already been realized. Therefore, the remaining realizable potential available at a cost below 4.0 cents per kilowatt-hour is the savings that can be achieved between 73 percent and 40 percent for public utility customers and between 63 percent and 40 percent for private utility customers. This was calculated as follows:

Given

Estimated space heating use in existing buildings in 1983 of

10,330 kWh/yr for public utility customers

8,915 kWh/yr for private utility customers

564,000 existing housing units in public utility service areas

703,000 existing housing units in private utility service areas

Estimated space heating use per customer after weatherization using measures costing 4.0¢/kWh or less = 5,660 kWh/yr (14,150 x .4 = 5,660)

Then

Remaining technical potential at less than 4.0¢/kWh on a unit basis

Public

$$= \frac{10{,}330 \text{ kWh/yr/unit} - 5{,}660 \text{ kWh/yr/unit} \times 564{,}000 \text{ units}}{8{,}760 \text{ hrs/yr} \times 1{,}000}$$

= 301 MW

Private

$$= \frac{8{,}915 \text{ kWh/yr/unit} - 5{,}660 \text{ kWh/yr/unit} \times 703{,}000 \text{ units}}{8{,}760 \text{ hrs/yr} \times 1{,}000}$$

= 261 MW

Total

301 + 261 = 562 MW

Comparing the 562 megawatts derived above for average savings per unit with the savings estimated to be technically available on a measure-by-measure basis in table K-12 reveals approximately a 10 percent difference.

This 562 megawatts of technically available conservation potential was then reduced by 15 percent to account for less than complete market penetration, unanticipated building barriers, and quality control. Thus, the amount of energy savings contained in the Council's plan under its highgrowth forecast is 478 megawatts (562 x .85).

Table K-13.
Relative Supply Function for Space Heat in the Year 2002 (1980$)

Marginal Cost (¢/kWh)	Cumulative Capital Cost ($/unit)	Cumulative Capital Cost ($/sq ft)	Annual Space Heat Use (kWh/sq ft)	Relative Space Heat Use
Base	526	.43	11.62	1.000
1.0	1,285	1.06	5.91	.509
2.0	1,285	1.06	5.91	.509
3.0	1,698	1.39	5.11	.440
4.0	2,161	1.79	4.51	.388
5.0	2,535	2.08	4.14	.356
6.0	2,707	2.22	4.00	.344
7.0	2,825	2.32	3.93	.335
8.0	2,859	2.35	3.89	.335
9.0	3,283	2.70	3.67	.316
10.0	3,283	2.70	3.67	.316
15.0	3,549	3.73	3.22	.277

Space Heat Conservation in New Buildings

The Council's assessment of conservation potential available through improving the thermal efficiency of new dwellings involved many of the same steps used to estimate retrofit potential for existing buildings. The Council's assessment required five steps. These were to:

1. Identify the thermal efficiency levels in new housing;
2. Estimate the cost and potential savings for thermal efficiency improvements in new dwellings;
3. Compare projected cost and energy savings with observed cost and savings in new energy-efficient buildings;
4. Develop conservation supply functions for technical potential; and
5. Estimate realizable conservation potential.

The basic assumptions used in each of these steps are detailed below. Where appropriate, illustrative calculations are shown.

Step 1. Identify Thermal Efficiency Levels in New Housing. The Council assumed that new residential buildings were being constructed in compliance with current building codes. In those areas which have not adopted mandatory energy conservation codes for new buildings, the Council attempted to identify "current practice." The principal data sources for this latter procedure were discussions with home builders and an annual survey of new housing characteristics conducted for Bonneville. Table K-14 summarizes the Council's assumptions regarding the level of thermal efficiency present in new residential buildings.

Table K-14.
New Residential Construction Base Case Efficiency Levels and Annual Space Heating Use Assumptions

	Climate Zone						
	1		2		3		
Building Type	Insulation Level	Annual Use (kWh/sq ft)	Insulation Level	Annual Use (kWh/sq ft)	Insulation Level	Annual Use (kWh/sq ft)	Weighted Average Use (kWh/sq ft)
Single-Family		5.5		8.9		9.0	6.8
Ceiling/Roof	R-30		R-30		R-38		
Walls	R-11		R-11		R-11		
Underfloor	R-11/19		R-11/19		R-11/19		
Windows	Double glazed*		Double glazed*		Double glazed		
Multi-Family		3.4		6.0		7.2	4.3
Ceiling/Roof	R-30		R-30		R-30		
Walls	R-11		R-11		R-11		
Underfloor	R-11/19		R-11/19		R-11/19		
Windows	Double glazed		Double glazed		Dougle glazed		
Mobile Homes		6.5		10.0		13.0	8.6
Ceiling/Roof	R-19		R-19		R-19		
Walls	R-11		R-11		R-11		
Underfloor	R-11		R-11		R-11		
Windows	Double glazed*		Double glazed*		Double glazed		

Step 2. Estimate Cost and Potential Savings for Thermal Efficiencylmprovements In New Dwellings. Tables K-15 through K-17 show the Council's estimate of the cost and savings available through improved thermal efficiency in new residential buildings on a measure-by-measure basis. The cost estimates are given in 1980 dollars. The savings estimates are based on the Sunday computer simulation of the annual space heating energy use of new dwellings assuming no wood heating and an average 24-hour per day thermostat setting of 65° F. Waste heat given off by lights, appliances, and occupants was assumed to provide 5,133 kWh/year of "free heat."

Step 3. Compare Projected Cost and Energy Savings with Observed Cost and Savings In New Energy-Efficient Buildings. The Council compared the simulated energy use for new buildings to metered energy use in energy-efficient houses in the Northwest. For a sample of 39 energy-efficient houses, the Council's projected annual use for space heating was 2.7 kilowatt-hours per square foot per year. The average actual use of this sample was 2.8 kilowatts per square foot per year — a difference of less than 4 percent.

Step 4. Develop Conservation Supply Functions. The potential for conservation in new dwellings is directly related to the number of new dwellings built. Under the Council's high economic and demographic forecast, it is projected that approximately 2.327 million new electrically heated housing units will be built between 1986 and 2002. Of these, 71 percent (1.666 million) are expected to be single-family units, 17 percent (393,000) multi-family units, and 12 percent (268,000) mobile homes. To estimate the technical potential for conservation in new dwelling units the Council multiplied the savings shown in tables K-15 through K-17 per unit for individual measure times number of those units projected to be built. Table K-18 summarizes the results of this process.

Step 5. Estimate Realizable Conservation Potential. The Council's estimate of realizable potential for conservation savings in new residential buildings is based on the implementation of its proposed model efficiency standard. The adoption of this standard would reduce the projected regional average energy use per unit in the 2002 from an estimated 6,896 kilowatt-hours per unit to 2,967 kilowatt-hours per unit. If 100 percent of the 2.327 million electrically heated buildings built between 1986 and 2002 complied with this standard, the region would save 1,044 megawatts (2.327 million units x 6,896 kWh/unit - 2,967 kWh/unit + 8,760 x 1,000). The Council's plan anticipates that 90 percent of the new units built will comply with its proposed standard. Therefore, the projected 1,044 megawatts of savings from this standard were "discounted" for less than complete compliance, reducing the expected savings to 940 megawatts. The Council's plan captures 880 megawatts of these savings as a resource. The remaining 60 megawatts are assumed to be "retained" by consumers in the form of increased amenity levels (e.g., warmer houses). The distribution of the savings expected from the Council model standard for new dwellings by state is approximately as follows: Washington - 420 megawatts, Oregon - 300 megawatts, Idaho -130 megawatts, and Western Montana - 30 megawatts.

Table K-15.
Technical Potential for Energy Conservation In New Single-Family Buildings

Resource Description	Unit Cost 1980$	Life Years	Climate Zone 1 Energy (kWh/unit)	Climate Zone 2 Energy (kWh/unit)	Climate Zone 3 Energy (kWh/unit)
Insulate Roof					
R19 to R30	176	30	729	1,097	1,266
R30 to R38	137	30	239	363	427
R38 to R49	176	30	156	262	313
R49 to R60	176	30	106	179	215
Infiltration					
.6-.4	381	30	1,096	1,650	1,927
.4-.2	635	30	941	1,471	1,745
Insulate Floors					
R11 to R19	200	30	422	637	750
R19 to R30	301	30	290	480	571
R30 to R42	652	30	171	312	380
Insulate Glass					
1-2	302	30	2,046	3,005	3,499
2-3	346	30	584	875	1,046
3-4	495	30	200	347	419
2-3 (Casement/awnings)	631	30	584	875	1,046
Insulate Walls					
R11 to R19	396	30	860	1,284	1,480
R19 to R27	382	30	365	554	653
R27 to R31	150	30	127	190	229
R31 to R38	569	30	72	136	168
Doors					
R2 to R13	87	30	474	702	814

Table K-16.
Technical Potential for Energy Conservation in New Multi-Family Buildings

Resource Description	Unit Cost 1980$	Life Years	Climate Zone 1 Energy (kWh/unit)	Climate Zone 2 Energy (kWh/unit)	Climate Zone 3 Energy (kWh/unit)
Insulate Roof					
R19 to R30	42	30	108	167	194
R30 to R38	30	30	32	54	64
Infiltration					
.6-.4	340	30	751	1,178	1,372
Insulate Floors					
R11 to R19	47	30	184	282	327
R19 to R30	71	30	82	138	164
R30 to R38	189	30	30	51	60
Insulate Glass					
1-2	196	30	1,252	1,907	2,199
2-3	225	30	336	538	639
3-4	724	30	131	233	276
Insulate Walls					
R11 to R19	91	30	331	510	592
R19 to R27	95	30	157	248	293
R27 to R38	290	30	80	139	165
Doors					
R2 to R13	23	30	131	201	232

Table K-17.
Technical Potential for Energy Conservation in New Mobile Homes

Resource Description	Unit Cost 1980$	Life Years	Climate Zone 1 Energy (kWh/unit)	Climate Zone 2 Energy (kWh/unit)	Climate Zone 3 Energy (kWh/unit)
Insulate Roof					
R19 to R33	340	15	696	1,049	1,225
R33 to R38	147	15	109	163	196
Infiltration					
.6-.48	279	15	476	721	849
.48-.44	166	15	155	232	277
Insulate Floors					
R11 to R19	203	15	512	774	893
Insulate Glass					
2-3	333	15	583	878	1,033
Insulate Walls					
R11 to R19	382	15	1,062	1,591	1,834
Doors					
R2 to R15	339	15	384	582	686

Table K-18.
Conservation Supply Function for Space Heating—
New Residential Buildings

Levelized Cost (Cents/kWh)	Cumulative Potential (MW)
1.0	270
2.0	760
3.0	1,008
4.0	1,190
5.0	1,205
6.0	1,245
7.0	1,260
8.0	1,270
9.0	1,290
10.0	1,290

Water Heat Conservation

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

1. Estimate the cost and savings potential available from improved water heating efficiency;

2. Develop conservation supply functions for technical potential; and

3. Estimate realizable conservation potential for new and retrofit applications.

The basic assumptions used in each of these steps are detailed below. Where appropriate, illustrative calculations are shown.

Step 1. Estimate Cost and Savings Potential Available from Improved Water Heating Efficiency. Table K-19 shows the Council's estimate of the incremental capital cost (1980$) and energy savings available through improved tank insulation, pipe wraps, etc., and the use of heat pump water heaters. The incremental cost of heat pump water heaters assumes they are selected to replace standard electric resistance water heaters of comparable life. These savings estimates are based on the assumption that the annual water heater standby losses are 1,610 kilowatt-hours per year and that each occupant in a building contributes 1,310 kilowatt-hours per year to the water heater demand. These assumptions are based on an analysis by the Council's contractor of metered water heater use in 120 Northwest houses and field and laboratory tests by Seattle City Light, Portland General Electric, Lawrence Berkeley Laboratories, and Bonneville. This survey data is summarized in table K-20 and figure K-2. The water heater heat pump savings shown assume 980 kilowatt-hours per year of standby loss reduction measures have been taken. (This excludes temperature setback.) They also assume an annual heat pump COP of 1.8.

Table K-19.
Estimated Cost and Savings for Water Heater Conservation Measures

Measure	Capital Costs (1980$)	Life of Measure (Years)	Annual Energy Savings (kWh/yr)
Reduced Standby Losses:			
Efficient (R-10) Tank	$ 16.90	12	460
Setback Temperature to 130° F	16.90	12	200
R-10 Wrap	37.10	12	200
R-10 Bottom Board	13.50	12	140
Thermal Trap	27.40	12	180
TOTAL			1,180
Install Heat Pump In:			
1 Occupant Household	$856.00	12	736
2 Occupant Household	856.00	12	1,260
3 Occupant Household	856.00	12	1,784
4 Occupant Household	856.00	12	2,308
5 Occupant Household	856.00	12	2,832
6 Occupant Household	856.00	12	3,356

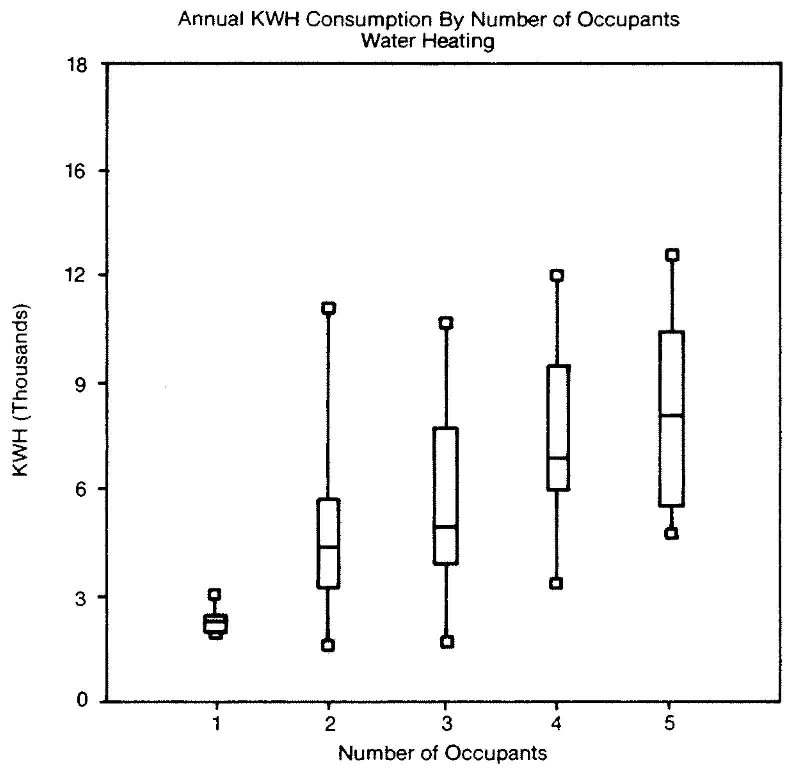
Table K-20.
Statistical Summary—Sub-Metered Hot Water Data

Sample	**Size**	**Mean (kWh/yr)**	**Standard Deviation (kWh/yr)**	**Comments**
Eugene Energy Efficient	10	6,504.00	2,154.00	All in heated spaces; no jackets
Eugene Conventional	12	6,475.25	1,891.14	All in unheated spaces; no jackets
Portland PURPA	19	4,422.00	1,576.00	Random
BPA Midway	17	8,605.25	2,876.95	All in unheated spaces; no jackets
Portland EPRI	10	6,113.00	2,375.00	Random
Portland WHIP	18	5,654.00	2,223.07	All jackets?
Tacoma	8	3,553.38	2,066.27	R-11 jackets, temp. setbacks
Seattle City Light	26	7,455.00	2,691.50	All in unheated spaces, no setbacks
All Samples	120	6,318.10	2,695.96	
1 occupant	5	2,374.20	411.11	
2 occupants	22	4,840.67	2,187.81	
3 occupants	21	5,590.00	2,407.82	
4 occupants	28	7,504.29	2,407.82	
5 occupants	12	8,069.83	2,771.30	

Variable	**Seattle**	**EPRI**	**WHIP**	**Tacoma**
# houses	23	10	24	8
# occupants	84	36	78	22
# occ./home	3.65	3.60	3.25	2.75
daily gallons	2,033.00	673.20	1,398.00	272.80
gallons/home	88.40	67.32	58.25	34.10
daily gal./occ.	24.20	18.70	17.90	12.40
daily H_2O kWh	469.80	167.50	315.10	77.90
daily kWh/occ.	5.59	4.65	4.04	3.54
gallons/kWh	4.33	4.02	4.44	3.50

Data Contacts

Eugene Data: Bob Lorenzen, Eugene Water and Electric Board, Eugene, Oregon (503) 484-2411. *Portland PURPA Data; Portland EPRI Data; Portland WHIP Data:* George Perrault, Portland General Electric Company, Portland, Oregon (503) 226-8626. *BPA Midway Data:* Jim Lynch, Bonneville Power Administration, Portland, Oregon (503) 230-3818. *Tacoma Data:* Richard Crenshaw, Lawrence Berkely Laboratory, Berkeley, California (415) 486-4000. *Seattle City Light Data:* Harry Wall, Seattle City Light, Seattle, Washington (206) 625-3760.



1 occupant	Sample Size: 5
2 occupants	Sample Size: 22
3 occupants	Sample Size: 21
4 occupants	Sample Size: 28
5 occupants	Sample Size: 12

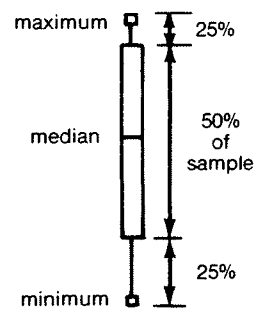


Figure K-2.
Average Water Heat Consumption by Household Size

Step 2. Develop Conservation Supply Functions. The Council's assessment of the regional technical potential for water heating conservation makes the following assumptions:

- 70 percent of the existing buildings can install heat pump water heaters (this assumption is based on a Bonneville study);
- 85 percent of existing and 100 percent of new residential buildings can install more efficient tanks and other standby loss reduction measures;
- 100 percent of new buildings could be designed to accommodate water heater heat pumps;
- 100 percent of the water heaters now in existence will be replaced between 1983 and 2002;
- 85 percent of the 6.166 million residential buildings existing in 2002 will use electric water heaters (assumes Council's high forecast); and
- The proportion of households with a given number of occupants is as shown in table K-21.

Given the above assumptions, the Council estimated the technical potential for water heat conservation in new and existing buildings in 2002 as approximately 1,800 megawatts. Table K-22 shows this potential at a cost between 1.0 and 10.0 cents per kilowatt-hour.

Table K-21.
Average Number of Occupants and Water Heater Consumption of Electricity by Housing Type

Number Occupants	Percent of Units With Given Number of Occupants		
	Single-Family	**Multi-Family**	**Mobile Home**
1	13.0	39.9	22.7
2	36.0	36.8	37.0
3	18.0	14.5	15.6
4	18.7	6.2	16.7
5	9.0	1.5	4.7
6 plus	6.0	1.1	3.3
Weighted Average	2.92	1.96	2.54
Percent of Units with 3 or more occupants	51	23.3	40.3
Estimated Average Energy Use of Water Heating in 1979			
Use 1979	5,435 kWh	4,178 kWh	4,937 kWh

Weighted average use for all housing types (2.7 occupants) = 5,147 kWh/yr

Table K-22.
Residential Water Heat Conservation Supply Function Technical Potential in Year 2002

Levelized Cost (Cents/kWh)	Cumulative Potential (MW)
1.0	166
2.0	376
3.0	904
4.0	1,114
5.0	1,114
6.0	1,429
7.0	1,429
8.0	1,429
9.0	1,429
10.0	1,521

Step 3. Estimate Realizable Conservation Potential. The Council's estimate of the realizable potential for water heat conservation is based on the following assumptions:

- Average use per occupant - 1,310 kWh/year;
- Average number of occupants/household in 2002 = 2.2;
- Average standby loss for tanks installed pre-1981 = 1,610 kWh/year;
- Average standby loss for tanks installed post-1981 = 1,150 kWh/year. (This assumes all new tanks currently have at least R-10 insulation.);
- All water heaters now in existence will be replaced by 2002;
- 90 percent of new and existing houses with electric water heaters will install the equivalent of R-20 tanks (either by installing R-10 wraps on R-10 tanks or by installing tanks with R-20 insulation integral with the tanks), R-10 bottom boards, and thermal traps;
- 50 percent of the electric water heaters in new and existing houses will have their temperature set at 130° F; and
- 34 percent of the new single-family units constructed after 1986 will be occupied by four or more people. Of these, 90 percent will install heat pump water heaters (or solar water heaters) which operate with a coefficient of performance (COP) of 1.8.

The following calculations illustrate how these assumptions were used to estimate the realizable conservation potential for water heat savings:

Given

6.166 million residential units in the 2002

0.847% electric water heater saturation in 2002

Average savings per unit of 620 kWh/year comprised of:

200 kWh/year from adding R-10 wraps to tanks with R-10 insulation or purchasing R-20 tanks

140 kWh/year from adding on R-10 insulating board beneath the water tank

180 kWh/year from installing anti-thermosiphoning devices (e.g., "thermal traps" to pipes when tanks are replaced or installed)

100 kWh/year from temperature setbacks from 140° F to 130° F (actual savings are 200 kWh/year/unit on 50% of units)

Then

Tank Efficiency Improvement Savings

$$= \frac{6.166 \times 10^6 \times .847 \times 620 \text{ kWh/unit} \times .9 \text{ penetration}}{8{,}760 \times 1{,}000}$$

= 333 MW

Given

2.294 million new single-family units added between 1986 and 2002

84.7% electric water heater saturation in 2002

34% of new single-family houses are occupied by four or more individuals

Weighted average savings from the use of heat pump water heaters for households with 4-6 occupants = 2,633 kWh/year/unit

90% market penetration of heat pumps in single-family houses with four or more occupants

Then

Heat Pump Savings

$$= \frac{2.294 \times 10^6 \times .847 \times .34 \times 2{,}633 \text{ kWh/year} \times .9}{8{,}760 \times 1{,}000}$$

= 179 MW

179 MW

Total Realizable Potential for Water Heat Conservation

333 + 179 = 512 MW

Appliance Efficiency Potential

The Council's assessment of the potentially available savings from improved appliance efficiency involved four steps. These were to:

1. Identify current regional average consumption for major residential appliances;
2. Identify the most efficient appliances now commercially available;
3. Estimate the technical potential for conservation, assuming that all consumers purchased the most efficient appliances now available; and
4. Estimate the realizable conservation potential, taking into account less-than-complete market penetration efficient appliances and the interaction between space heating needs and more efficient appliances.

The major assumptions used in each of these steps are detailed below. Where appropriate, illustrative calculations are shown for the Council's high forecast.

Step 1. Identify Current Regional Average Use per Appliance. Table K-23 shows the estimated average consumption for the major appliances modeled separately in the Council's residential forecasting model. These estimates are based on statistical analysis of customer use and appliance saturation data carried out by Bonneville, the Oregon Department of Energy, and others. Their derivation is discussed in the Technical Exhibits.

Step 2. Identify Most Efficient Appliances Now Commercially Available. Table K-23 shows, for each appliance, the annual consumption for the most efficient model presently manufactured in the United States.

Table K-23.
Appliance Efficiency Savings

	Current (1983) Regional Average Use (kWh/yr)	Most Efficient Model Available (kWh/yr)	Savings/Unit (kWh/yr)
Refrigerator	1,350	745	605
Freezers	840	800	40
Cooking			
Single-Family/ Mobile Home	975	880	90
Multi-Family	615	527	70
Lighting	800	600	200
Other Appliances (Washer/Dryers, Dishwashers, Waterbeds, Well Pumps)	3,650		400

Step 3. Estimate Technical Potential for Conservation. To estimate the technical potential for conservation available through improved appliance efficiency, the Council assumed that complete market penetration of the most efficient appliances now on the market could be achieved by the year 2002.

The savings were calculated as follows:

Given

Savings per appliance shown in table K-23

5.741 million households in 2002

Appliance saturations in 2002 of

13 percent for air conditioning
116.5 percent for refrigerators
52.8 percent for freezers
94 percent for electric ovens and ranges
100 percent for electric lighting
100 percent for other appliances

Then

The technical potential for each appliance

$$= \frac{\text{Savings/unit x Total Households x Saturation}}{\text{8,760 hrs/yr x 1,000}}$$

Air conditioners - No savings estimated

Refrigerators

$$= \frac{\text{605 kWh/yr x 6.166 million x 1.165}}{\text{8,760 hrs x 1,000}}$$

= 496 MW

Freezers

$$= \frac{\text{40 kWh/yr x 6.166 million x .52.8}}{\text{8,760 hrs/yr x 1,000}}$$

= 15 MW

Cooking

$$= \frac{\text{90 kWh/yr x 6.166 million x .94}}{\text{8,760 hrs x 1,000}}$$

= 60 MW

Lighting

= 200 kWh/yr x 6.166 million x 1.0

= 141 MW

Other appliances

= 400 kWh/yr x 6.166 million x 1.0

= 282 MW

Total Technical Potential

496 + 15 + 60 + 141 + 282 = 994 MW

Step 4. Estimate Realizable Conservation Potential. To estimate the realizable potential the Council made the following assumptions:

- 50 percent of the 3.303 million new residential units added between 1986 and 2002 would install the most efficient refrigerator presently available (605 kWh x 3.303 x 10^6 x .5 ÷ 8,760 x 1,000 = 114 MW);
- 35 percent of the 3.459 million existing (in 1983) refrigerators would be replaced with the most efficient model now available by 2002 (605 kWh/yr x 3.459 x 10^6 x .35 ÷ 8,760 x 1,000 = 84 MW);
- 35 percent of the 3.303 million new residential units added between 1986 and 2002 would purchase the most efficient freezer currently available (40 kWh/unit x 3.303 x 10^6 x .35 ÷ 8,760 x 1,000 = 5 MW);
- 20 percent of the 1.540 million existing (in 1983) freezers would be replaced with the most efficient model presently available by 2002 (40 kWh/unit x 1.540 x 10^6 x .20 ÷ 8,760 x 1,000 = 1 MW);
- 75 percent of the 3.105 (3.303 x .91) million residential units built between 1986 and 2002 which use electric ovens and ranges would install the most efficient models now available (90 kWh/unit x 3.105 x 10^6 x .75 ÷ 8,760 x 1,000 = 24 MW);
- No existing residential units would replace their cooking appliances with more efficient ones;
- 75 percent of 6.166 million residential units in 2002 will have installed more efficient lights (200 kWh/yr x 6.166 x 10^6 x .75 ÷ 8,760 x 1,000 = 106 MW); and
- Other appliances, including clothes washers, dryers, dishwashers, waterbeds, and well pumps, will improve their efficiency by 5 percent (400 kWh/yr x 6.166 x 10^6 x .75 ÷ 8,760 x 1,000 = 211 MW).

Total Realizable Potential:

Air conditioning	0	0
Refrigerators		
New dwellings	114	
Existing dwellings	84	
	198	198
Freezers		
New dwellings	5	
Existing dwellings	1	
	6	6
Cooking		
New dwellings	24	
Existing dwellings	0	
	24	24
Lighting	106	106
Other Appliances	211	211
		545

The use of more efficient residential appliances reduces the amount of "waste heat" provided to a house's interior. This waste heat, or internal gains, makes a major contribution to the space heating in insulated homes. Therefore, reduction in the amount of internal gains can lead to an increased requirement for space heating.

In its analysis of the space heating needs of residential buildings, the Council assumed that internal gains contributed 5,133 kWh/year (or 2,000 BTU/hour) to the building. Table K-24 summarizes the sources of these gains. Table K-24 also shows the amount of internal gains that would be provided to this same house if it contained all of the most efficient appliances assumed in the Council's conservation assessment. In both cases, the total internal gains provided by occupants and appliances exceeds that used to estimate the space heating requirement of new and retrofitted houses. While the Council did not discount appliance energy savings, further improvements in appliance efficiency will increase space heating requirements.

PRINCIPAL DATA SOURCES

Palmiter, Larry and Baylon, David. *Assessment of Electric Power Conservation in the Pacific Northwest. Volume 1 Residential Building Conservation.* June 1982. (Draft) Submitted to Battelle Pacific Northwest Laboratories by Ecotope Group.

Palmiter, Larry and Kennedy, Mike. *Assessment of Electric Power Conservation and Supply Resources in the Pacific Northwest. Volume 1: Supplement A - Heat Pumps in Residential Buildings.* January 1983. (Draft) Submitted to Battelle Pacific Northwest Laboratories by Ecotope Group.

Palmiter, Larry and Kennedy, Mike. *Assessment of Electric Power Conservation and Supply Resources in the Pacific Northwest. Volume 1: Supplement B - Passive Solar, Internal Gains and Monthly Loads of Residential Buildings.* February 1983. (Draft) Submitted to Battelle Pacific Northwest Laboratories by Ecotope Group 1.

Geller, Howard S. *Efficient Residential Appliances: Overview of Performance and Policy Issues.* American Council for an Energy Efficient Economy. January 1983. (Draft).

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Charles River Associates. *Data and Program Documentation, Volume 2.* Draft Final Report. September 7, 1982.

Commercial Sector Assessment

The Council assessment of the potential for electric energy conservation in new and existing commercial buildings involved four steps. These were to:

1. Identify the current regional average consumption for typical existing commercial building categories and typical new commercial buildings;
2. Prepare engineering estimates of the cost and technical potential for energy conservation in new and existing commercial buildings;
3. Çompare the engineering estimates with observed energy conservation cost and savings in commercial buildings; and
4. Develop estimates of realizable potential for conservation in new and existing commercial buildings.

The major assumptions used in each of these steps are detailed below. Where appropriate, illustrative calculations are shown.

Step 1. Identify Current Regional Average Consumption for Typical Commercial Building Categories. The Council's commercial sector forecasting model contains representations of 10 building categories. The annual energy use for all-electric commercial buildings in this model assumed is shown in table K-25. Also shown are the Council's estimates of the annual energy use for new commercial buildings built to current practice and constructed under the region's most stringent energy code.

To verify the reasonableness of these estimates, the Council reviewed several recent analyses of commercial building consumption. Table K-25 summarizes the principal data the Council used to check its estimates of energy use in new and existing commercial buildings.

In comparing the data shown in tables K-25 and K-26, three factors should be kept in mind. First, the buildings shown in table K-26 were not selected to be statistically representative of the average. Secondly, several building categories have extremely small samples or are known to be biased. For example, the restaurant category represents only one "chain" and thus cannot be considered a cross sectional sample. Finally, the annual use figures shown in table K-25 are for "all-electric" buildings. The consumption figures shown in table K-26, although given in kilowatt-hours, represent each building's total energy use. Since many of these buildings are known to use natural gas or fuel oil, the conversion efficiencies of these fuels should be taken into account prior to drawing strict comparisons. Table K-27 compares the estimated annual use in the Council's forecasting model for all fuels by different commercial building categories, and the sample means from table K-26 for existing buildings.

Table K-24.
Internal Gain Changes From More Efficient Appliances

Appliance/Source	Saturation	Energy Use Per Unit (kWh/yr) @ Current Efficiencies	Energy Use Per Unit (kWh/yr) @ Forecast Efficiencies	Percent Indoors	Internal Gains Provided @ Current Efficiencies (kWh/yr)	Internal Gains Provided @ Forecast Efficiencies (kWh/yr)
Lighting[a]	1.00	880	660	90	792	594
Refrigerator[b]	1.0825	1,350	745	86	1,257	694
Range/Cooking	1.00	975	880	100	975	880
Freezer	.53	840	800	50	223	212
Water Heater[c]	1.00	1,150	530	50	575	265
Television	2,000 set/ hr/yr	200	200	100	200	200
Clothes Dryer	.7	950	900	10	67	63
Dishwashers, Clotheswashers, & Misc. Appliances	—	2,500	2,100	630	750	630
People[d]	2.7/2.2	1,970	1,710	100	1,970	1,710
Total					6,809	5,308

[a] Assumes 1,350 sq ft home. For other floor areas, lighting loads should be scaled by floor area.

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

[c] Assumes water tank has R-10 for current efficiencies, and R-20, with R-10 bottom board, and temperature setting of 130° F on 50% of tanks. Waste heat from water use is included with contribution from people.

[d] Contribution from people includes 290 kWh/yr/occupant as sensible heat and 230 kWh/yr/occupant as latent heat. Also included is 565 kWh/yr of latent heat provided to the house from the use of warm water for cooking and bathing.

Table K-25.
Commercial Sector—All Electric Building Energy Use

Building Category	Estimated Annual Use (kWh/sq ft) Average of Existing Stock	Average New Stock	New Stock Under Region's Most Stringent Energy Code
Office	36	30	18
Retail	34	30	18
College/University	30	25	22
Schools	22	19	14
Hotel/Motel	33	28	25
Health Care	45	32	27
Warehouses	16	16	10
Restaurants	83	74	50
Groceries	56	50	34
Other	18	17	11

Table K-26.
Summary of Annual Energy Use for New and Existing Commercial Buildings—Located in Region

Building Type & Sample Size (N)	Annual Energy Use (kWh/sq ft/yr) High	Low	Mean	Standard Deviation
Office (Large 50,000 sq ft)				
Existing (N-12)	72	15	38	16
New (N-8)	40	16	22	8
Office (Small 50,000 sq ft)				
Existing (N-87)	70	11	42	17
New (0)	n.a.	n.a.	n.a.	n.a.
Retail				
Existing (N-20)	38	28	32	4
New (0)				
College/University				
Existing (N-3)	38	28	32	4
New (0)				
Schools				
Existing (N-60)	59	11	22	9
New (0)	n.a.	n.a.	n.a.	n.a.
Hotel/Motel				
Existing (0)	n.a.	n.a.	n.a.	n.a.
New (0)	50	18	35	13
Health Care				
Existing (N-35)	92	28	55	19
New (0)	n.a.	n.a.	n.a.	n.a.
Warehouses				
Existing (N-8)	69	8	28	n.a.
New (0)	n.a.	n.a.	n.a.	n.a.
Restaurant				
Existing (N-10)	247	25	156	n.a.
New (0)	n.a.	n.a.	n.a.	n.a.
Groceries				
Existing (N-300)	86	50	61	9
New (N-24)	70	29	52	10

n.a.—not available

The sample data made available to the Council on actual energy use per square foot in existing buildings tend to support the Council's estimates. For example, large buildings in Seattle and Tacoma use roughly 29 and 28 kWh/sq ft, respectively; this compares with the plan's estimates of 30 kilowatt-hours for stock constructed under current code, and 36 kWh/sq ft for the average of existing all-electric stock. Data from Energard Corporation show total energy consumption for office buildings of 40 kWh/sq ft and when this number is adjusted to reflect the conversion efficiencies of buildings that use gas as well as electricity, the 40 kilowatt-hour figure dips into the mid-thirties — within the Council's range.

In a similar manner, the Council's estimate of 34 kWh/sq ft for retail space (again, after adjusting for other fuels) is supported by the sample data made available to the Council. Retail use in Tacoma is estimated at 33 kWh/sq ft and the Energard data show a 28 kWh/sq ft estimate.

The Seattle Building Owners and Managers Association survey (table K-31) also shows an average pre-construction use of 33.8 kWh/sq ft, which closely approximates the Council's estimates.

Table K-27.
Commercial Sector Forecasting Model
Assumed Energy Use Versus Sample Building Energy Use

	Annual Use			
	Forecasting Model		Sample Mean	
Building Type	**Btu/sq ft/yr**	**(kWh/sq ft/yr)**	**Btu/sq ft/yr**	**(kWh/sq ft/yr)**
Office	136,000	(40)	136,520	(40)
Retail	142,000	(42)	105,800	(31)
College/University	157,000	(46)	109,220	(32)
Schools	95,500	(28)	75,100	(22)
Hotel/Motel	137,400	(51)	187,700	(55)
Warehouses	41,200	(12)	95,600	(28)
Restaurants	335,200	(98)	532,400	(156)
Groceries	196,900	(58)	208,200	(61)

Step 2. Prepare Engineering Estimates of Cost and Technical Potential in New and Existing Commercial Buildings. Table K-28 summarizes the results of the study prepared for the Council on the cost and technically achievable energy conservation potential in new and existing commercial buildings. The data shown are based on computer simulations of prototype building energy use and installation cost estimates prepared by architect/engineers. For existing buildings, it appears that economically achievable savings available at or below a cost of 4.0 cents per kilowatt-hour range from 11 percent to 62 percent of estimated 1974 use levels. The technical potential in new commercial buildings ranges from a low of 22 percent in new small office buildings to 78 percent in new retail buildings, at a cost below 4.0 cents per kilowatt-hour.

Table K-28.
Summary of Commercial Prototype Use and Potential Savings

	1974 Practice Base Case Use (kWh/sq ft/yr)	**Annual Use with Less than 4.0¢/kWh Conservation (kWh/sq ft/yr)**	**Percent Savings Over Base Case**
Existing Large Office	51	20	60
New Large Office	23	13	43
Existing Small Office	42	16	62
New Small Office	25	19.6	22
Existing Hotels	42	17	60
New Hotels	18.6	12	35
Existing Motels	22.4	11.6	11
New Motels	15.3	9.5	38
Existing Retail	60	25.5	58
New Retail	43	17	60
New Elementary Schools	10.7	5.4	50

Table K-29 compares the technical potential estimates of savings with the annual use assumed in the Council's commercial sector model. Savings over the model's assumed use range from 38 percent in existing retail buildings to over 70 percent in existing hotels and motels. For new buildings the savings available range from a low of 60 percent in new retail buildings to 80 percent in new elementary schools.

Table K-29.
Commercial Sector Forecasting Model
Assumed Energy Use Versus Protypical Building Energy Use

	Annual Use (kWh/sq ft)		
Building Type	**Forecasting Model @ 1983 Efficiency**	**Prototype with 4.0¢/kWh Conservation**	**Percent Savings Over 1983 Efficiency**
Office	40		
Existing		20	50
New		13	68
Retail	43		
Existing		26	38
New		17	60
College/University	46	n.a.	n.a.
Schools	28		
Existing		n.a.	n.a.
New		5.4	80
Motel/Hotel	43		
Existing (Motel)		12	70
New (Motel		10	77
Existing (Hotel)		17	60
New (Hotel)		12	72
Health Care	51	n.a.	n.a.
Warehouse	12	n.a.	n.a.
Restaurants	98	n.a.	n.a.
Groceries	58	n.a.	n.a.

n.a.—not available

Step 3. Compare Engineering Estimates with Observed Cost and Savings in Commercial Buildings. To verify the reasonableness of its engineering savings estimates, the Council compared them with several surveys f commercial retrofit experience. These are summarized in tables K-30 through K-32. Tables K-30 and K-32 present data on retrofit savings from Puget Power, the Seattle Building Owners and Managers Association (BOMA), and the U.S. Department of Energy (DOE). The DOE estimates do not reflect the customers who failed to participate in the program. If these customers are included, then the savings figures would be 15 percent rather than 20 percent. The Council's proposed program includes measures up to 40 mills. The savings cited above are the result of significantly less attractive financing packages. This is particularly the case in the DOE survey, which found that pay-backs of less than three years were most common and that few long-term investments in capital improvements were made. Since the BOMA buildings were also improved without financial assistance, it is reasonable to assume that most savings were achieved through very low-cost, short pay-back measures. The Council's review of the experience depicted in these tables lead it to conclude that, in general, a 30 percent savings can be realistically expected in commercial retrofit programs. Moreover, both engineering estimates and actual utility experience appear to indicate that 90 to 95 percent of these savings can be realized at a levelized cost below 3.0 cents per kilowatt-hour.

Table K-30.
Summary of Puget Power Commercial Sector Retrofit Conservation Savings

Sample Size—2.128 million square feet

Pre-retrofit average electricity use = 19.3 kilowatt hours per square foot

Post-retrofit electricity use (projected based on audit) = 13.5 kilowatt-hours per square foot

Average savings of electricity = 30%

Average retrofit cost (based on contractor bids) = $1.04 square foot

Average cost = 9 to 10 mills per kilowatt-hour
(Levelized at 3% for 30 years)

Distribution of Savings by Cost

Levelized Cost (Mills/kWh)	Percent of Savings
0-5	32
0-10	58
0-15	73
0-20	86
0-25	94
0-30	100

Table K-31.
Commercial Building Survey
Seattle Building Owners and Managers Association
April 1, 1981

TOTAL SQUARE FOOTAGE SURVEYED	4,969,100 sq ft
Conservation Programs Implemented	
Lighting Reduction	4,969,100 sq ft
HVAC Modification	3,855,893 sq ft
Insulation	1,935,000 sq ft
Hot Water System Modification	761,581 sq ft
Reduction in Operating Hours	585,000 sq ft
Publication of Energy Newsletter	253,842 sq ft
Energy Consumption*	
Electric—4,340,557 sq ft	
Present	kWh 98.1 x 10^6 (22.6 kWh/sq ft)
Prior to Conservation Program	kWh 146.7 x 10^6 (33.8 kWh/sq ft)
Savings	33%
Steam—3,101,985 sq ft	
Present	MLBS 735,374
Prior to Conservation Program	MLBS 2,519,959
Savings	70%

*551,544 square feet under new programs: savings not available.

Seattle City Light estimates that it services approximately 71 million square feet of office and retail space. The BOMA survey covered approximately 7 percent of this space.

Table K-32.
Commercial Sector—Retrofit Savings

SOURCE

D.O.E. survey of the actual energy use in 223 commercial buildings across the United States.

FINDINGS

- 89% of retrofitted structures achieved simple pay-backs of less than 3 years
- 9% failed to save, largely due to improper maintenance
- Average savings of electricity for sample was 20%
- Average cost was $.62 per square foot

Savings by Building Type

Building Category	**Average Savings**	**Sample Size**
Elementary Schools	24	72
Secondary Schools	30	38
Large Office	23	37
Hospital	21	13
Community Center	56	3
Hotel	25	4
Corrections	7	4
Small Office	33	4
Shopping Center	11	1
Multi-Family Apartment	44	1
		174

The technical potential for conservation in new commercial buildings was verified by comparing the engineering estimates of use with new buildings recently constructed in Seattle. Table K-33 provides the projected annual use of several new large commercial buildings. These buildings were designed to comply with Seattle's energy code. The Council's proposed model standard for new non-residential structures closely approximates Seattle's code.

Table K-33.
Projected Annual Energy Consumption of Major Commercial Buildings In Downtown Seattle—Constructed Between 1979 - 1983

Building	Total Floor Area	Projected Annual Consumption (kWh/sq ft/hr)	(kWh/yr)
Daon Building	261,636	24.0	6,286,010
1111 Third Avenue	560,250	16.1	9,028,348
One Union Square	795,629	16.1	12,821,446
PEMCO	166,600	39.6	6,589,804
Blanchard Plaza	259,000	14.9	3,881,575
Metropolitan Park	329,000	26.6	8,757,974
Seattle First Plaza	986,000	17.6	17,333,724
Columbia Center	1,500,000	17.9	26,809,259
Holiday Inn	338,000	49.8	16,835,628
Madison Hotel	457,750	18.1	8,288,588
	5,653,865		116,632,360

Average Consumption = $\frac{116{,}632{,}360 \text{ kWh/yr}}{5{,}653{,}865 \text{ sq ft}}$

= 20.63 kWh/sq ft/yr
= (70,410 Btu/sq ft/yr)

Median Consumption = 18 kWh/sq ft/yr
= (61,434 Btu/sq ft/yr)

Step 4. Develop Estimates of Realizable Conservation Potential in New and Existing Commercial Buildings. The Council's estimates of the technical potential for conservation in new and existing commercial buildings were developed on the assumption that the efficiency of these buildings could be improved by 30 percent. The total regional savings available from this average level of improvement were estimated using the Council's commercial sector forecasting models.

First, this sector's demand was forecast without further improvements in efficiency. Demand was forecast separately for new and existing buildings. Then a 30 percent efficiency improvement over current efficiencies was imposed on the model, and demand re-estimated. The difference between projected demand at current efficiencies and demand with a 30 percent improvement represented the total technical conservation potential. In the Council's high forecast this was 882 megawatts for existing commercial buildings and 712 megawatts for new (post-1983) commercial buildings.

In order to estimate how much of the technical potential was available at a given cost, the Council combined data from its own studies with the experience of Puget Sound Power and Light. Table K-34 shows the distribution of total technically achievable savings by cost level for new and existing buildings used by the Council. It also depicts the distribution estimated by engineering estimates as well as that experienced by Puget. The Council judgmentally adjusted its engineering estimates of savings for cost below 3.0 cents per kilowatt-hour using Puget's experience. To estimate realizable potential the Council's estimate of technically available potential at 3.0 cents per kilowatt-hour was multiplied by a 90 percent market penetration rate. Table K-35 shows the realizable potential for the Council's high forecast.

The distribution of the savings from the model standard for new commercial buildings by state is approximately as follows: Washington - 320 megawatts, Oregon - 220 megawatts, Idaho - 60 megawatts, and Western Montana - 15 megawatts.

Table K-34.
Commercial Sector Conservation Supply Function
(Distribution of Savings by Cost Level)

Marginal Cost (Cents/kWh)	(Percent Savings)				
	Council		Engineering Estimate		Puget Power*
	Existing	New	Existing	New	Existing
1	50	55	84	81	58
2	80	85	94	86	86
3	90	95	98	90	100
4	91	96	98	96	—
5	92	96	98	97	—
6	93	97	99	98	—
7	94	97	99	99	—
8	95	98	99	99	—
9	96	98	99	99	—
10	97	99	99	99	—
10+	3	1	1	1	—

*Puget only finances those measures costing less than 3.0 cents per kilowatt-hour.

Table K-35.
Technically Potential Versus Realistically Achievable
Commercial Sector Conservation

Marginal Cost (Cents/kWh)	Technical Potential		Realistically Achievable	
	Existing	New	Existing	New
1	440	356	396	320
2	705	605	635	545
3	794	676	715	608
4	803	684	722	615
5	816	684	729	615
6	820	691	738	622
7	829	691	746	622
8	838	698	754	628
9	847	698	762	628
10	856	705	770	635
10+	882	712	794	641

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Irrigated Agriculture

The Council's assessment of the potential energy savings available from efficiency improvements in irrigated agriculture involved four steps. These were to:

1. Estimate the efficiency of conventional and energy-conserving irrigation systems;
2. Estimate the potential acreage that could technically adopt more efficient irrigation technologies;
3. Estimate the cost of improving irrigation efficiency; and
4. Develop irrigated agriculture conservation supply functions and estimate realizable potential.

The major assumptions used in each of these steps are described below. Where appropriate, illustrative calculations are shown.

Step 1. Estimate Efficiency of Conventional and Energy Conserving Irrigation Systems. The operating parameters for the conventional and energy-conserving application systems and pumping plants are presented in tables K-36 and K-37. The other parameters used for estimating the energy use of the various irrigation systems are the power unit efficiency (PUE) and the decrease in water pumped (V) when improved scheduling methods are used in conjunction with sprinkler irrigation systems. The PUE for electric motors was assumed to be 90 percent, based on manufacturer's estimates, and the V forimproved scheduling of sprinkler irrigations was taken to be 24 percent, based on empirical results generated by testing of paired irrigation fields in California.

Table K-36.
Operating Parameters for Irrigation Applications Systems[a]

	Application Head	
Conventional Systems	**(ft)**	**(psi)**
Gravity Flow	5	2.2
Hand-Move	155	67
Sideroll	160	69
Center-Pivot	190	82
Energy-Conserving Systems		
Reduced Pressure Center-Pivot	70	30
LEPA	25[b]	11

a Sources: Parameters for conventional systems were obtained from Manufacturer's estimates. Parameters for energy-conserving systems were obtained from those developed by Gilley (1980) and Lyle (1980).

b Field tests performed with LEPA (Lyle 1980) indicate that LEPA will also reduce water use in row crop irrigation by 18%.

Table K-37.
Operating Parameters for Pumping Plants

Conventional Pumps	Groundwater Pump Efficiency (%)	Surface-Water Pump Efficiency (%)
New Pumps[a]	70	72
Existing Pumps[b]	54	58
Energy-Conserving Pumps		
Redesigned Pump Impeller and Housing[c]	75	NA
Modifications to Existing Pumps[d]	64	68

a Based on Manufacturer's estimates. The efficiency for surface-water pumps is assumed to be slightly higher because these are generally larger pumps.

b Based on field pump testing results performed by the Bonneville Power Administration (1981). Efficiencies for 31 to 74 hp pumps were taken to be representative of most groundwater pumps and efficiencies for pumps larger than 75 hp were assumed for surface-water pumps.

c This estimate was taken from the tests of the system developer (Hamrick 1980). The system is only appropriate for groundwater pumping.

d Taken from Bonneville's pump target efficiencies (Bonneville Power Administration 1981). It is assumed that the modifications under study will be able to raise existing pump efficiencies to these levels.

Because pumping head (Hp) and volume of water pumped (V) vary significantly between different irrigated areas in the Northwest, it was necessary to divide the Northwest region into 15 subregions for purposes of analysis. These subregions are shown in figure K-3. The subregions defined in figure K-3 are basically the same as those defined in the Pacific Northwest Electric Power Planning and Conservation Act, except that an additional region is added for Western Montana. Data on average surface water and groundwater pumping lifts ($H_p + H_w$) and volume of water applied by conventional gravity flow and sprinkler irrigation systems were obtained from a 1975 survey of irrigation operations. This data, by subregion, is presented in table K-38.

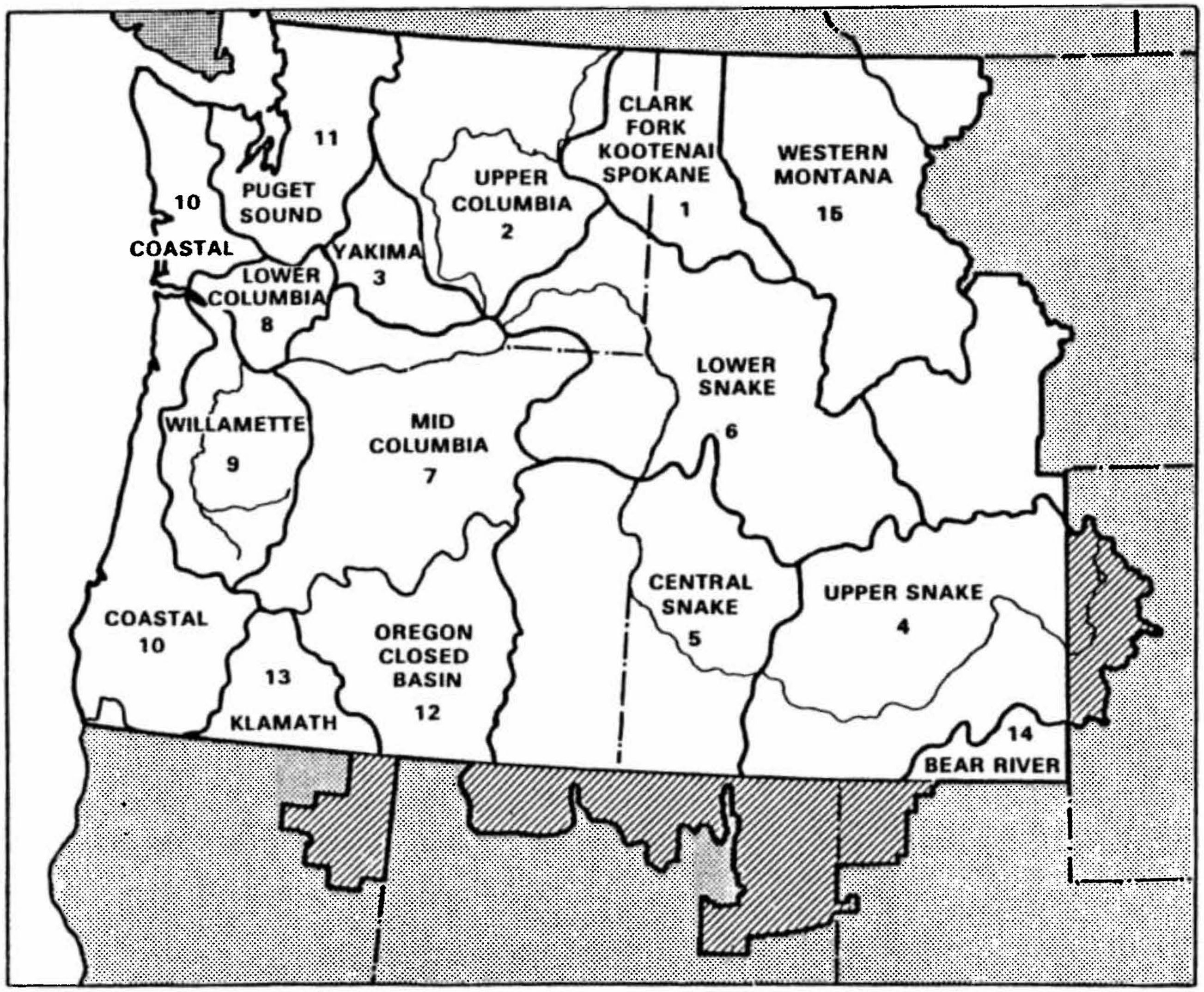

Figure K-4. Pacific Northwest Irrigation Subregions
(Striped areas are defined under the Pacific Northwest Electric Power Planning and Conservation Act but are not analyzed)

Table K-38.
Irrigation Pumping Lifts and Volume of Water Pumped for Northwest Subregions[a]

Number	Pumping Lift (ft) Groundwater	Water	Volume of Water Pumped (acre/ft) Gravity Flow	Sprinkler
1	157	48	3.74	2.10
2	340	16	5.90	3.19
3	350	10	5.40	3.64
4	262	9	3.50	2.44
5	268	14	4.20	2.77
6	129	27	3.30	2.43
7	130	118	4.50	2.89
8	75	32	2.40	2.04
9	72	20	2.40	1.59
10	20	33	4.10	2.16
11	50	25	1.00	2.35
12	34	11	3.70	2.35
13	89	10	3.30	2.37
14	250	10	3.20	2.19
15	157	48	3.74	2.10

aSources: Data for subregions 1 to 14 was obtained from *Supplemental Report: Energy and Water Consumption of Pacific Northwest Irrigation Systems,* King et al. August 1978. Data for subregion 15 was assumed to be the same as that for subregion 1 because no data on pumping lifts or water application amounts for the Montana subregion could be located.

Step 2. Estimate Potential Acreage That Could Technically Adopt More Efficient Irrigation Technologies. For purposes of estimating total regional energy savings for each of the energy-saving irrigation technologies, it was necessary to obtain forecasts of the acreage of conventional irrigation systems that could potentially be replaced or improved by energy-conserving irrigation measures in each subregion. These conventional systems were identified as gravity flow, hand-move, sideroll, and center-pivot systems. The forecasts of irrigated acreages used by the Council were developed from a U.S. Department of Energy study using a linear programming model. Forecasts were developed in the DOE study using three alternative scenarios concerning the future economic growth of the Pacific Northwest region — no growth, moderate growth, and high growth. Forecast acreages under the moderate growth scenario were used by the Council.

Forecast acreages for Western Montana were developed by using current acreages and assuming that the rate of growth in Western Montana would be the same as the rate of growth inherent in the linear programming forecasts for Subregion 1 which borders Western Montana.

To facilitate comparisons with other acreage forecasts, the total regional forecast acreages used by the Council in its conservation assessment are shown in table K-39. Based on the sum of current irrigated acreages in Oregon, Idaho, Washington, and Western Montana, the forecast acreages presented in table K-38 represent an annual growth rate of .84 percent in irrigated acreage to the year 2002.

Because the energy savings and the cost per kilowatt-hour saved from using energy-conserving irrigation systems vary significantly between surface and groundwater sources, forecast acreages by system and water source were needed. The forecast acreages in the DOE study were not developed by water source; consequently, the relative percentage of groundwater and surface-water irrigation that occurred in 1975 in each subregion for each irrigation system was multiplied by the forecast acreages by system under the assumption that the relative percentages of surface water and groundwater irrigation will remain constant in the future.

Table K-39.
Total Forecast Acreage by Irrigation System[a]

	Year			
System	**1985**	**1990**	**1995**	**2002**
Gravity Flow	4,569,947	4,668,538	4,771,674	4,941,152
Center-pivot	909,917	1,097,907	1,291,584	1,479,570
Other Sprinkler[b]	2,933,948	3,169,230	3,314,707	3,457,077
Total	8,413,812	8,935,675	9,377,965	9,877,729

[a]Sources: *Projected Energy and Water Consumption of Pacific Northwest Irrigation Systems.* (King et al. 1977) and private telephone conversation (Smith 1982).

[b]Includes hand-move, sideroll, and solid set systems.

Mathematically, the process of determining the forecast acreage in each subregion can be described as:

$$FA_{ijkm} = F_{ijm} \times P_{ikm}$$

Where:

FA_{ijkm} = Forecast acreage for conventional irrigation system i, in forecasting year j, for water source k, in subregion m

FA_{ijm} = DOE study model forecasts of forecast acreage for conventional irrigation system i, in forecasting year j, for subregion m

P_{ikm} = Percentage of 1975 acreage for conventional irrigation system i, using water source k, in subregion m

i = gravity flow, sideroll, hand-move, or center-pivot irrigation system

j = 1985, 1990, 1995, or 2002 forecasting period

k = Surface water or groundwater source

m = Subregions 1, 2, . . ., 15

The method of aggregating subregional results to obtain weighted average regional estimates was as follows:

- For new energy-conserving application systems, generic system cost, and energy savings estimates for each subregion were multiplied by new acreages in each subregion obtained from the acreage forecasts developed by King et al. (1978). The resulting products were then summed over all 15 subregions and the cost estimates were divided by the regionwide sum of the new acreages to obtain average unit costs. For LEPA, only row crop acreages were used.

- For conversion of existing conventional systems, generic subregional cost and energy savings estimates were multiplied by "base acreage" figures from each subregion. The "base acreage" figures represent current acreages minus any decreases in acreage forecast by King et al. (1978). The resulting products were then summed over all 15 subregions, and the cost estimates were divided by the regionwide sum of the base acreages to obtain average unit costs. For LEPA, only row crop acreages were used.

- For the redesigned pump housing and impeller, generic subregional cost and energy savings estimates were multiplied by forecast new groundwater acreages. The resulting products were then summed over the 15 subregions and divided by sum of the new groundwater acreages to obtain average unit costs.

- For general improvements in pump efficiency and for scheduling improvements, generic subregional cost and energy savings estimates were multiplied by total forecast acreages from each subregion. The resulting products were then summed over the 15 subregions, and the cost estimates were divided by the regionwide sum of total forecast acreages to obtain average unit costs. For scheduling improvements, estimates were developed for sprinkler irrigation only, because improved scheduling was not assumed to be effective when used in conjunction with gravity flow systems.

Step 3. Estimate Cost of Improving Irrigation System Efficiency. The incremental costs of investing in an energy-conserving irrigation system depends on the nature of investment being considered. The incremental costs for a new energy-conserving irrigation system compared to a new conventional system will be different from the incremental costs of converting an existing conventional system into an energy-conserving system.

Alternative Water Application System Costs

The alternative water application system conservation investments considered by the Council included the following:

1. New conventional gravity flow, sideroll, and hand-move systems versus new reduced pressure center-pivot systems;
2. New conventional gravity flow, sideroll, and hand-move systems versus new LEPA systems;
3. New reduced pressure center-pivot systems versus new LEPA systems;
4. Conversion of conventional gravity flow, sideroll, hand-move, and center-pivot systems to reduced pressure center-pivot systems; and
5. Conversion of conventional gravity flow, sideroll, hand-move, and center-pivot systems to LEPA systems.

Note that the comparison of new high-pressure conventional center-pivot to the energy-conserving systems was not included among the alternatives. The Council has assumed that almost no new conventional center-pivots will be purchased in the future, given that the initial costs for new reduced pressure center-pivots are almost identical to those of new conventional center-pivots.

The capital and operating and maintenance costs for each of the systems included in these alternatives are presented in table K-40. The conversion system capital and operating and maintenance costs in table K-40 represent the *incremental* costs of converting an existing system into an energy-conserving system. The capital costs for conversion from an existing gravity flow system are the same as if the energy-conserving system was purchased new because no components of the gravity flow system can be used in the conversion and these components are assumed to have no salvage value.

Table K-40.
Estimated Capital and Operating and Maintenance Costs for Conventional and Energy-Conserving Irrigation Systems

New Systems Costs	**Capital Cost ($/acre)[a]**	**Operating and Maintenance Cost (a/Acre)[b]**
Gravity Flow	67	33
Sideroll	150	21
Hand-move	81	68
Reduced Pressure Center-pivot	292	19
LEPA	346	23
Conversion System Incremental Costs[c]		
Conversion to Reduced Pressure Center-Pivot:		
Gravity Flow	292	-14
Sideroll	232	- 2
Hand-move	260	-49
Conversion to LEPA:		
Gravity Flow	346	-10
Sideroll	286	2
Hand-move	314	-45
Center-pivot	56	4

[a]Based on manufacturer's estimates for sideroll and hand-move, estimates developed by Willet (1982) for garvity flow, and estimates by Gilley (1980) and Lyle (1980) for reduced pressure center-pivot and LEPA systems.

[b]Includes labor and repair costs. Labor requirements for each sytem were determined from the Irrigation Planning Guide by Fairbanks-Morse (1981). Annual labor costs were calculated assuming a cost of $4.50 per hour. Repair costs were assumed to be negligible for gravity flow and hand-move systems, 3 percent per year of the original purchase price for sideroll, and 5 percent of the original purchase price for center-pivot and LEPA.

[c]Conversion is assumed to take place when the existing system is ten years old, and it is assumed that the existing system can be sold for its depreciated value.

The capital costs for conversion from a sideroll system are the capital costs of the energy-conserving system minus the revenue from the sale of the sideroll system at an assumed market value equal to its depreciated value at the time of sale. The capital costs for conversion from an existing center-pivot shown in table K-40 represent the costs incurred in replacing existing high-pressure sprinkler heads with either low-pressure sprinkler heads (in the case of reduced pressure center-pivots) or with drop tubes and emitters (in the case of LEPA). The cost of pressure regulating devices are also included in the center-pivot conversion costs.

When existing application systems are converted into energy-conserving systems, modifications to the existing pumping plan are usually necessary to take full advantage of the potential energy savings of changes in operating parameters. The exact modifications, however, vary substantially depending upon the nature of the existing pumping plant. The pumping plant modifications assumed to be necessary for the conversions analyzed by the Council, and the cost of each of these modifications, are shown in table K-41. It should be emphasized that the modifications shown in table K-41 are only estimates by knowledgable experts of some common modifications, and these modifications may or may not be applicable in a specific situation.

Table K-41.
Necessary Pump Modifications and Costs for Conversion of Conventional Application Systems

	Cost	
Necessary Modifications	**Surface Water ($/acre)**	**Groundwater ($/acre)**
1. Pump Pulling[a]	3	23 if Hp[b] ≤ 30 ft 31 if 30 < Hp ≤ 120 ft 38 if Hp > 120 ft
2. Bowl Modification[c]	Not Applicable	13 if Hp ≤ 30 ft 14 if 30 < Hp ≤ 120 ft 20 if Hp > 120 ft
3. Impeller Trimming[a]	4	4
4. Pump Flow Rate Adjustment[c]	2	2

[a]Based on data gathered in telephone conversations with pump repair company experts (Sheppe 1982; Lusk 1982).

[b]Hp = Pumping head.

[c]Based on data on bowl modification and pump adjustment developed by Gilley and Supalla (Gilly and Supalla 1981).

Pumping System Costs

The pumping plant alternatives analyzed by the Council are the following:

1. New conventional groundwater turbine pumps versus new groundwater turbine pumps with a redesigned housing and impeller, and

2. Pumping plant modifications which will raise existing groundwater and surface-water pump efficiencies to Bonneville's target level pump efficiencies.

The system developer of the redesigned turbine pump indicates that the incremental capital costs of the redesigned pump are minimal compared to a conventional turbine pump. The pump packer cost would largely be offset by a reduction in line and pipe costs, and the modified impeller cost is all research and development costs with no additional costs to the farmer. Thus, the capital costs for the redesigned pump were assumed to be only $2 an acre greater than those of a conventional turbine pump.

It is commonly accepted that farmers can raise their existing pump efficiencies to Bonneville's target level pump efficiencies (an average increase of 10 percentage points), but the actions necessary to achieve these increases in pump efficiencies and the costs of these actions are not well known.

The estimated cost per acre for the pump modifications being considered by the Council is shown in table K-42. It should be emphasized that these costs are only estimates, and that costs vary substantially depending upon the condition and type of the pump being modified.

Table K-42.
Estimated Costs of Modifications to Existing Pumping Plants to Improve Pump Efficiency

Necessary Modifications	Cost: Surface Water ($/acre)	Cost: Groundwater ($/acre)
1. Pump Pulling[a]	3	23 if Hp[b] ≤ 30 ft 31 if 30 < Hp ≤ 120 ft 38 if Hp < 120 ft
2. Impeller Replacement[a]	4	4 if Hp ≤ 30 ft 5 if 30 < Hp ≤ 120 ft 6 if Hp < 120 ft
3. Pump Flow Rate Adjustment[c]	2	2
4. Modified Pipe Mainline and Fittings[b]	5	5
5. Improved Pump Maintenance[a]	1	1

[a]Based on data gathered in telephone conversations with pump repair company experts (Sheppe 1982; Lusk 1982).

[b]Hp = Pumping head.

[c]Based on data on pump adjustment costs developed by Gilley and Supalla (1981).

[d]Based on data gathered in a telephone conversation with an Oregon State Extension Agricultural Engineer (Schearer 1982).

Scheduling Costs

The costs of improved methods of irrigation scheduling depend on the level of the scheduling services being provided. The costs to the farmer for compiling and publishing general evapotransportation data will be much lower than those associated with "full service" scheduling programs where data is collected for individual fields and precise recommendations on when and how much water to apply is provided. The "full service" scheduling program offered in California, from which the percentage reduction in water use from improved scheduling, cost an average of $5 an acre per year in 1980. This cost was used to represent the cost of improved scheduling methods.

Step 4. Develop Irrigated Agriculture Conservation Supply Functions and Estimate Realizable Potential. The maximum technical potential energy savings for a generic energy-conserving irrigation system, and the cost per kilowatt- hour of electricity saved, were estimated for each of the 15 specified subregions. The results shown are estimates of the weighted average regional energy savings and cost per kilowatt-hour saved for each energy-conserving option.

The technically feasible regional energy savings, cost per kilowatt-hour saved, and the range in cost per kilowatt-hour saved among the 15 subregions for the energy-conserving irrigation systems for 2002 are presented in tables K-43 and K-44. All energy savings are cumulative to 2002.

Table K-43.
Energy Conserving Application Systems: Maximum Potential Energy Savings, Costs per Kilowatt-Hour Saved, and Range in Cost per Kilowatt-Hour Saved in 2002

	Technical Energy Savings (Average MW)		Cost Per kWh Saved (1980 Mills)		Range in Cost per kWh Saved (1980 Mills)	
Energy Conservation Measure	**Ground-water**	**Surface Water**	**Ground-water**	**Surface Water**	**Ground-water**	**Surface Water**
New System						
Reduced Pressure Center-pivot vs. Gravity Flow	0.89	0[b]	20	∞	11 to 21	∞
LEPA[c] vs. Gravity Flow	0.71	0.49	16	171	11 to 46	31 to 381
Reduced Pressure Center-pivot vs. Sideroll Sprinkler	3.00	20.13	19	19	12 to 34	13 to 37
LEPA vs. Sideroll	2.66	—[d]	18	20	10 to 33	15 to 39
LEPA vs. Reduced Pressure Center-pivot	14.55	8.96	10	20	8 to 25	18 to 29
Converted Systems						
Reduced Pressure Center-pivot vs. Gravity Flow	5.14	0	73	∞	19 to 75	∞
LEPA vs. Gravity Flow	4.16	0.03	30	559	13 to 88	250 to 588
Reduced Pressure Center-pivot Sideroll Sprinkler	11.61	25.07	48	36	30 to 78	30 to 71
LEPA vs. Sideroll	10.40	17.84	30	29	17 to 55	22 to 57
Reduced Pressure Center Conventional Center-pivot	11.89	17.18	10	4	7 to 12	2 to 5
LEPA vs. Conventional	15.20	—[d]	9	7	6 to 12	4 to 9

[a]Range represents low and high among 15 subregions.

Reduced pressure center-pivots will not produce any energy savings compared to gravity flow systems using surface water. Thus, cost per kilowatt-hour saved is equa1 to

[c]LEPA assumed to be used only on row crop fields.

[d]Reduced pressure center-pivot costs are less than LEPAs in this application. Thus, it is assumed that LEPA would not penetrate.

Table K-44.
Redesigned Turbine Pump, Pump Efficiency Improvements, Irrigation Scheduling Improvements: Maximum Potential Energy Savings, Cost per Kilowatt-Hour Saved and Range[a] in Cost per Kilowatt-Hour Saved in 2002

	Technical Potential Energy Savings (Average MW)		Cost Per kWh Saved (1980 Mills)		Range in Cost per kWh Saved (1980 Mills)	
Energy Saving Option	**Ground-water**	**Surface Water**	**Ground-water**	**Surface Water**	**Ground-water**	**Surface Water**
Redesigned Pump with						
Gravity Flow	0.80	—	4	—	1 to 26	—
Reduced Pressure Center	6.68	—	3	—	2 to 11	—
Other Sprinkler	3.36	—	4	—	1 to 7	—
Pump Efficiency Improvement on						
Gravity Flow	9.88	15.30	27	113	13 to 163	14 to 165
Center-pivot	13.62	18.49	18	11	13 to 40	9 to 17
Other Sprinkler	35.58	37.84	30	17	13 to 57	10 to 28
Scheduling Improvements on						
Center-pivot	59.78	30.18	5	11	4 to 13	9 to 16
Other Sprinkler	65.05	61.76	9	16	4 to 19	9 to 26

[a]Range represents low and high among 15 subregions.

The total potential energy savings from all of the energy conservation options analyzed by the Council are not equal to the sum of the energy savings for each of the individual options. Two of the systems under study, reduced pressure center-pivots and LEPA, have overlapping applications. Conventional center-pivots can be converted to either reduced pressure center-pivots or to LEPA, but not to both. To avoid double counting of energy savings, the Council's analysis used a decision rule for selecting between similar options based on the cost per kilowatt-hour saved. This rule assumed that the option with the lowest cost per kilowatt-hour will be used.

All energy savings estimates for reduced pressure center-pivots and LEPA shown in table K-43 have been adjusted according to this decision rule. For example, because LEPA cost less than reduced pressure center-pivots when compared to conventional gravity flow systems using groundwater, it was assumed LEPA would replace gravity flow systems using groundwater on all row crop acreages.

A summary of the estimated technically feasible aggregate energy savings which could result from using energy conservation options as selected by the decision rule are shown in table K-45. The total energy savings increase over time because new acreage on which the energy savings options can be used are being brought into production. The Council's plan assumes that all of the technically achievable potential costing less than 4.0 cents per kilowatt-hour could be realized.

Table K-45.
Total Technical Feasible Energy Savings From Using Irrigation Conservation Options

Option	1985	1990	1995	2002
Reduced Pressure Center-pivots[a]	82	86	86	95
LEPA[b]	59	62	71	75
Pump Improvements[c]	121	126	133	141
Scheduling Improvements[d]	169	181	202	217
Total	431	455	492	528

[a]Calculated as the sum of savings for reduced pressure center-pivot systems on existing and new acreages of gravity flow, sideroll sprinkler, and center-pivot systems. Where the cost per kilowatt-hour for LEPA is less than that for reduced pressure center-pivots, only non-row crop acreages are used in calculating reduced pressure center-pivot savings.

[b]Calculated as the sum of savings for LEPA on existing and new row crop acreages of gravity flow, sideroll sprinkler and center-pivot systems.

[c]Calculated as the sum of the savings for all pump efficiency improvements on new and existing acreages of gravity flow, center-pivot, and all other sprinkler systems.

[d]Calculated as the sum of the savings for irrigation scheduling improvements on center-pivot, and all other sprinkler systems.

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Industrial Sector Assessment

The Council's assessment of the conservation potential available in the industrial sector initially involved an evaluation based on a typical plant in each industry. After discussions with industry representatives, this approach was abandoned in favor of an approach which the Council asked industry to conduct - a self-assessment. The Council asked each major electricity consuming industry, including the Direct Service Industries of Bonneville, to estimate the amount of conservation savings they could identify at given cost levels. Specifically, industrial firms were asked to estimate the amount of electric savings that might be expected if they were offered an "up-front" cash payment of between $1,000 and $3,000 per average kilowatt saved. Table K-46 summarizes the response received by major industrial class.

Table K-46.
Industrial Sector Conservation

	Industrial Category Cumulative Savings (MW)				
Capital Cost/kW	**Pulp & Paper**	**DSI Aluminum**	**Plywood**	**Other**	**Total**
$1,000	44	57	—	3.0	104
$2,000	81	100	—	19.4	200.4
$3,000	95	376	17	58.3	546.3

All respondents indicated that these data should be used with caution in estimating the realizable potential for industrial conservation. The Council decided that, since these savings represent less than 10 percent of the region's current industrial demand for electricity that they were a reasonable conservation goal for the industrial sector.

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Conservation on the Existing Power System

The Council has not done a detailed analysis of the potential for conservation in this area, but has been informed over the last year and in testimony received during the public hearings that there is considerable potential. Both Bonneville and the Corps of Engineers have programs underway to improve efficiency of the existing system.

Bonneville has estimated the loss on their customers' distribution systems to be as high as 900 average megawatts, and on their own transmission systems to be as high as 300 average megawatts. Measures such as changing system configuration, adding more efficient capacitors, changing conductors to reduce resistance, and replacing transformers, could be cost-effective in the near-term. Bonneville is also considering raising the voltage levels and additional parallel feeders. The potential for saving electricity is significant. Additionally, Bonneville has estimated that efficiency improvements to existing Kaplan turbines at dam sites in the region could result in up to 200 average megawatts of savings.

The Corps of Engineers has estimated that efficiency improvements at their dams could result in savings of 100 to 150 average megawatts in addition to Bonneville's turbine efficiency improvements.

The Council believes that there may be other opportunities to improve system efficiency and will work toward identifying those opportunities in the next two years and beyond. The Council feels that it is conservative planning to assume that with existing and yet to be identified programs, 270 average megawatts can be achieved through efficiency improvements over the twenty-year plan.

Appendix L
Efficiency Standards for Conversion to Electric Space Conditioning

1.0 Efficiency Standard for Conversion to Electric Space Conditioning

1.1 Residential Buildings: Single-Family, Duplex (Group R — Division 3) and Multi-Family (Group R — Division 1)

1.1.1 General

Before the utility will connect a new or enlarged electric service for electric space heat in any residential building for which a building permit was granted on or before December 31, 1985, the customer shall:

a. make any changes or installations necessary to comply with the efficiency standards listed in Section 1.3, 1.4, or 1.5 (below), and

b. schedule and permit an inspection of the premises by a utility or local building code field representative.

Before the utility will connect new or enlarged electric service for electric space heat in any residential building which receives a building permit on or after January 1, 1986, it shall comply with the Northwest Power Planning Council's Model Standard for Energy Conservation in New Buildings.

1.1.2 Exemptions

Buildings which are designated as historical landmarks are exempt from this subsection only to the extent necessary to preserve those features necessary for their historical appearance or function.

1.2 Service for Purposes Other Than Electric Heat

For new or enlarged electric services of over 125 amperes in single-family or duplex buildings, which are requested for purposes other than electric space heat, the customer shall:

a. submit to the servicing utility or local government a notorized statement which states that the new or enlarged service will not be used for electric space heat; and

b. comply with existing efficiency requirements at such time as electric space heat is added.

If consumption records indicate the presence of electric space heat in the future, the servicing utility or local government will require inspection of the premises by a utility or local building code field representative. If the inspection reveals electric space heat, compliance with Section 1.1 of this standard will be required.

1.3 Efficiency Standards

a. **Ceilings**. Ceilings over the top floor shall be insulated to a thermal resistance of no less than 38 (R-38). If there are architectural barriers to R-38, ceilings must be insulated to the maximum extent possible.

b. **Walls and Windows**. The customer must do the following:

  1. Insulate all exterior walls to R-11 unless the walls have previously been insulated, and

  2. A. install double-glazed windows (two panes of glass installed in a single sash with at least 1/2-inch air space between them), or

     B. fit windows with sealed rigid-frame storm windows.

c. **Floors**. All floors over unheated spaces shall be insulated to a thermal resistance of no less than 0 (R-30) unless the insulation requires major alteration of the existing building or unless installation with a thermal resistance of 19 (R-19) has previously been installed. If the existing building precludes insulating to R-30, insulation shall be installed to the maximum extent possible. All earth under the building shall be covered with vapor barrier that is 6-mill thick black polyethylene or equivalent.

d. **Electric Water Heaters**. Electric water heaters shall be insulated with a thermal resistance of no less than 20 (R-20) where space allows. Additional insulation shall not be required if the water heater has been certified by the manufacturer to have a standby loss no greater than 2.8 Watts per square foot of external area. Water heaters shall also have anti-thermal siphoning devices (thermal traps) installed on inlet and outlet pipes. Where space permits, an insulating board with a thermal resistance no less than 10 (R-10) shall be installed beneath the water heater, unless the water heater is presently located on a surface with a thermal resistance of 19 (R-19) or greater.

   NOTE: Adding insulation above ceilings and under floors may increase moisture condensation in those areas unless adequate ventilation is provided. Adequate ventilation will prevent possible moisture damage and preserve the integrity of the insulation.

   The ventilation standards below are provided for reference.

Attics: Ventilation. Where determined necessary by the utility or building official due to atmospheric or climatic conditions, enclosed attics and enclosed rafter spaces formed where ceilings are applied direct to the underside of roof rafters shall have cross ventilation for each separate space by ventilating openings protected against the entrance of rain and snow. The net free ventilating area shall be not less than 1/150 of the area of the space ventilated, except that the area may be 1/300 provided at least 50 percent of the required ventilating area is provided by ventilators located in the upper portion of the space to be ventilated at least 3 feet above eave or cornice vents and with the balance of the required ventilation provided by eave or cornice vents.

Underflooring: Foundation ventilation. Underfloor areas shall be ventilated by an approved mechanical means or by openings in exterior foundation walls. Such openings shall have a net area of not less than 1 square foot for each 150 square feet of underfloor area. Openings shall be located as close to corners as practicable and shall provide cross ventilation. The required area of such openings shall be approximately equally distributed along the length of at least two opposite sides. They shall be covered with corrosion-resistant wire mesh not less than 1/4 inch or more than 1/2 inch in any dimension. Where moisture due to climate and groundwater conditions is not considered excessive, the Building Official may allow operable louvers and may allow the required net area of vent opening to be reduced to 10 percent of the above, provided the underfloor ground surface area is covered with an approved vapor barrier.

1.4 Heat Pump Standard

A heat pump is a device that uses a refrigerant to transfer heat from a cooler area (ground, water, or air) to a warmer one.

A customer requesting a new or enlarged electric service who already has or intends to install a heat pump must comply with all of Section 1.3, *except* he/she shall not be required to insulate ceilings over the top floor in excess of a thermal resistance of 30 (R-30) and floors over unheated spaces in excess of a thermal resistance of 19 (R-19), *provided* that the heat pump has a seasonal performance factor (SPF) of at least 2.0.

1.5 Alternate Efficiency Standards

Compliance with Section 1.1 may also be shown by providing a detailed analysis which demonstrates compliance with either the heat loss efficiency standards or the annual energy budget standard described below.

a. **Heat Loss Standard.** To show compliance with Section 1.1 of these efficiency requirements, the customer shall provide a detailed analysis of the building using a standard heat loss methodology (such as that of the American Society of Heating, Refrigeration and Air Conditioning Engineers) to show that the building is at least as efficient as it would be if Section 1.3 were followed. The component performance approach described in Section 1.6.A is an acceptable method for this analysis. Heat loss calculations demonstrating compliance with the heat loss standard must be supplied in writing by the customer to the servicing utility or local building code official and approved in writing.

b. **Annual Energy Budget Standard.** To show compliance with Section 1.1 under the Annual Energy Budget tandard, the customer shall provide a detailed analysis to show that the annual consumption of electricity will be no greater than the annual consumption of the building with conventional electric space heat if Section 1.3 were followed. The system analysis approach described in Section 1.6.B must be used for this analysis.

1.6 Calculation Procedures for Performance Alternatives

a. **Heat Loss Standard — Component Performance Approach**

General. This section establishes design criteria in terms of thermal performance of various components of a building. A residential building that is being converted to electric space heat shall meet the overall thermal performance requirements of this section.

Overall Thermal Performance (U_O)

1. The stated U_O of any one element of a building, such as roof/ ceiling, wall, or floor may be increased and the U_O value for other components decreased provided that the overall heat gain or loss for the entire building envelope does not exceed the total resulting from state U_O values.

2. Where return air ceiling plenums are employed, the roof ceiling assembly shall (a) for thermal transmittance purposes, not include the ceiling proper nor the plenum as part of the assembly, and (b) for gross area purposes, be based on the interior face of the upper plenum surface.

3. General insulation and vapor barriers (where physically feasible) shall be installed in accordance with sound building practice.

4. General Requirements.

   A. Walls. For any low-rise residential building that is heated and/or mechanically cooled, the overall thermal transmittance value (U_O) of the gross wall area of exterior walls shall not exceed the value given in table L-1. Equations 1 and 2 shall be used to determine acceptable combinations to meet this requirement. For glazing, the R value of operable window insulation may be installed in the U_O calculations, but shall be multiplied by .5 for calculation purposes.

Table L-1.
Thermal Performance Criteria for Low-Rise Residential Buildings Converting to Electric Heat

Element	**Group R-Division 3 Detached One- and Two-Family Dwellings (U_o Value)**	**Group R-Division 1 All Other Residential Buildings Three Stories or Less (U_o Value)**
Walls	.20	.24
Roof/Ceiling	.028	.035
Floors Over Unconditioned Spaces Exposed to Outside Air	.035	.05
All Others	.08	.08
Slab-on-Grade Floors		
Unheated (R value)	5.0	5.0
Heated (R value)	8.0	8.0

B. Roof/Ceiling. For any low-rise residential building that is heated and/or mechanically cooled, the overall combined thermal transmittance value (U_o) for the gross roof/ceiling area of the roof/ceiling assembly shall not exceed the value given in table L-1. Equations 1 and 3 shall be used to determine acceptable combinations to meet this requirement.

C. Floors Over Unconditioned Spaces. For any low-rise residential building that is heated with electricity, the overall thermal transmittance value (U_o) for floors exposed to outside air, such as floors over vented crawl spaces, garages, or overhangs, shall not exceed the value given in table L-1. For any other low-rise residential building that is electrically heated and/or mechanically cooled, the overall thermal transmittance value (U_o) for all other floors over unconditioned spaces shall not exceed the value given in table L-1.

D. Slab-On-Grade Floors. For slab-on-grade floors in low-rise residential buildings, the thermal resistance value (R) of the insulation around the perimeter of the floor shall not be less than the value given in table L-1. The insulation shall extend downward from the top of the slab for a minimum distance of 24 inches downward.

5. Exemption for Passive Solar Features. Subject to the following limitations, glazing area or mass-, or water-wall areas in residential spaces which qualify by meeting *all* of the criteria below may be exempted from the U_o calculations:

A. The glazing shall be double glazing. Single glazing will be permitted where the glazing is separated from the conditioned space by a mass wall with a heat storage capacity of at least 15 Btu/° F/ft^2 or a water-wall with a heat storage capacity of at least 30 Btu/° F/ft^2. Solid concrete walls 8 inches thick or equivalent mass-walls and water-walls 6 inches thick are examples of wall that shall be deemed to comply with these requirements;

B. The glazing area shall be oriented within 30 degrees of due south.;

C. Glazing shall be tilted at least 30 degrees up from horizontal;

D. The glazing shall be clear (transmission coefficient numerically greater than or equal to .80 for each light of the glazing);

E. The glazing area shall receive direct solar exposure for 50 percent of the hours between 9:00 a.m. and 3:00 p.m. on December 21;

F. The glazing area shall receive direct solar exposure for 85 percent of the hours between 9:00 a.m. and 3:00 p.m. on March 31;

G. The building shall contain heat storage capacity equivalent to 15 Btu/° F/ft^2 for each square foot of qualifying area between 8 and 15 percent of the total wall area and 20 Btu/° F/ft^2 for each square foot of qualitying area in excess of 15 percent of the total wall area for light-frame construction, and 30 Btu/° F/ft^2 for other than light-frame construction located inside the insulated shell of the building and not covered with insulation materials, such as carpet, yielding an R value of 1.0 or greater. If the heat storage medium is not within the conditioned space containing the qualifying glazing, an acceptable natural or mechanical means of transferring the heat to the heat storage mechanism shall be provided.

Mass- or water-walls which meet the requirements of Section 1.6.5(A) above shall be deemed to comply with this requirement. Heat storage capacity shall be calculated by the following procedure:

$$HS = \frac{(WM)(SH)}{A}$$

Where:

HS = heat storage capacity for each square foot of solar glazing and for one degree F change in temperature expressed in Btu/° F/ft^2

WM = the weight of materials (lbs) inside the insulated shell of the building to a depth of 1 (R-1), except in the case of slab floors where only the slab itself is credited

SH = specific heat of those materials expressed in Btu/lbs/° F

A = area of passive solar glazing in square feet

The following will allow a quick method of calculation of mass needed for each square foot of exempted glazing.

15 square feet of interior stud partition wall (2" x 4" @ 16" o.c. with 1/2" gypsum two sides)

30 square feet of exterior stud wall or ceiling (2" x 4" @ 16" o.c. with 1/2" gypsum inside and insulation and various exterior wall treatments)

5 square feet of 8" lightweight concrete block masonry exterior wall insulated externally, cores filled for structural support only

4 square feet of concrete slab floor provided with a steel trowel finish, exposed aggregate, tile terrazo, or hardboard parquet not greater than 1/2" thick

6. Equations

A. Equation 1 — Assembly Thermal Transmittance

$$U = \frac{1}{1/F_o + R_1 + R_2 + \dots R_n + 1/f_i}$$

Where:

U = the thermal transmittance of the assembly

F_o = outside air film conductance, $1/F_o = 0.17$ for all exterior surfaces

f_i = inside air film conductance, $1/f_i = 0.60$

$1/f_i = 0.60$ for interior horizontal surfaces

$1/f_i = 0.68$ for interior vertical surfaces

R = 1/C = X/K = measure of the resistance to the passage of heat for each element

C = conductance, the heat flow through a specific material of specific thickness

K = insulation value of a material

X = the thickness of the material

B. Equation 2 — Gross Wall Area Overall Thermal Transmittance

$$U_o = \frac{U_w A_w + U_g A_g + U_d A_d \cdots}{A_o}$$

Where:

U_o = the overall thermal transmittance of the gross wall area

A_o = the gross wall area of exterior walls

U_w = the thermal transmittance of all elements of the opaque wall area

A_w = the area of the opaque wall

U_g = the thermal transmittance of the glazing area

A_g = the glazing area, including sash

U_d = the thermal transmittance of the door

A_d = the door area

NOTE: Where more than one type of wall, window, and/or door is used, the U and A terms for those items shall be expanded into subelements, as:

$Uw_1Aw_1 + Uw_2Aw_2 + Uw_3Aw_3 + \ldots$ etc.

Calculations shall include the effects of all heat flow paths, such as framing members. Framing as a percent of opaque wall area is typically:

17 percent for 2-inch studs @ 12" o.c.
15 percent for 2-inch studs @ 16" o.c.
12 percent for 2-inch studs @ 24" o.c.
20 percent for 3-inch studs @ 16" o.c.

C. Equation 3 — Gross Roof/Ceiling Area Overall Thermal Transmittance

$$U_o = \frac{U_r \times A_r + U_s \times A_s}{A_o}$$

Where:

U_o = the overall thermal transmittance of the gross roof/ceiling area

A_o = the gross roof/ceiling area of a roof/ceiling assembly

U_r = the thermal transmittance of all elements of the opaque roof/ceiling area

A_r = roof/ceiling area

U_s = the thermal transmittance of all skylight elements on the roof/ceiling assembly

A_s = skylight area, including frame

NOTE: Where more than one type of roof/ceiling and/or skylight is used, the U x A term for that exposure shall be expanded into its subelements, as:

$(U_{r_1} \times A_{r_1}) + (U_{r_2} \times A_{r_2}) + (U_{r_3} \times A_{r_3}) \ldots$ etc.

Calculations shall include the effects of all heat flow paths, such as framing members. Framing as a percent of opaque floor and roof/ceiling area is typically:

13 percent for 2-inch joist @ 12" o.c.
10 percent for 2-inch joist @ 16" o.c.
6 percent for 2-inch joist @ 24" o.c.

b. **Systems Analysis Approach.**

1. **General**. This section establishes design criteria in terms of total space heating energy use by a residential building. A residential building that is being converted to electric space heat shall demonstrate compliance if the expected annual heating consumption is not greater than that of a building of similar design whose enclosure elements and electric-energy-consuming systems are designed in accordance with Section 1.6.a.

   "Building of similar design" shall mean a building using the same energy source(s) for the same functions and having equal floor area, environmental requirements, occupancy, climate data, and usage schedule. Inputs to the energy analysis relating to occupancy and usage shall correspond to the expected occupancy and usage of the building.

2. **Analysis Procedure**. The analysis of the expected annual space heating usage of the standard design and the proposed alternative building system design shall meet the following criteria:

   A. The building heating load calculation procedure used for annual energy consumption analysis shall be of sufficient detail to permit the evaluation of effect of factors specified in Section 1.6.b(3);

   B. The calculation procedure used to simulate the operation of the building and its space heating service systems through a full-year operating period shall be of sufficient detail to permit evaluation climatic factors, operational characteristics, and mechanical equipment on annual energy use. Manufacturers' data or comparable field test data shall be used when available in the simulation of all systems and equipment. The calculation procedure must be certified by the Bonneville Power Administration, approved by the local Building Official, or be consistent with current engineering or analysis procedures and must represent a full 12 months of operation and use typical month and year data from a recognized source. The calculation procedure shall separately identify the annual amounts of energy used by heating, cooling, and ventilation. Further, any energy use not listed but consuming greater than 10 percent of the total energy budget shall be separately identified;

   C. The calculation procedure for the standard design and the proposed alternative design shall separately identify the energy input for heating and cooling; and

   D. When electrically driven heat pumps, except those which have a waste heat or renewable energy source, are employed to provide all or part of the heat for the alternative design, the standard design shall also, for the purposes of the analysis, assume that an electrically driven heat pump having at least the same capacity as that used in the alternative design is employed.

3. **Calculation Procedure**. The calculation procedure shall cover the following items:

   A. Design requirements. The following design parameters shall be used for calculation required under this standard:

      1. Outdoor design temperature (as specified by ASHRAE in the .6 percent column for winter or .5 percent column for summer for nearest location with comparable climate);

      2. Degrees days heating as specified by ASHRAE at 65° F;

      3. Indoor design temperature 68° F for heating and 78° F for cooling; and

      4. Indoor design relative humidity shall not exceed 30 percent.

   B. Climatic Data. Sufficient coincident hourly data for temperatures, solar radiation, wind, and humidity of typical days to represent seasonal variation.

   C. Building data. Orientation, size, shape, mass, air, moisture, and heat transfer characteristics.

   D. Operational characteristics. Control modes for temperature, humidity, ventilation, and illumination (including variations for occupied and non-occupied hours).

   E. Mechanical equipment. Design capacity, part load profile.

   F. Internal heat generation. Lighting, equipment, and number of people during occupied and non-occupied periods.

4. **Documentation**. When a non-certified analysis technique is used, documentation shall be submitted demonstrating that the analysis used is consistent with accepted techniques or procedures.

1.7 Inspection

A utility or local building code field representative will inspect the building for compliance with the efficiency standards prior to permanent electric service connection. The field representative will approve the requested service for connection if the building complies with the standards. If not, the customer must make necessary corrections and schedule another inspection to determine compliance.

1.8 Customer Assistance

A customer may contact the servicing utility or local building code office for advice in completing his/her own heat loss calculation or annual energy budget analysis and filling out the appropriate forms.

1.9 Effective Date

The effective date of this Standard is January 1, 1986.

2.0 Non-residential Customers

2.1 Scope

a. **Application**. This subsection applies, except as noted below, to all non-residential customers who request new or enlarged electric service connections and it applies *only* to that portion of the premises which is either owned, rented, or leased by the customer.

b. **Exemptions**.

   1. Temporary services, construction services, and replacement services which do not increase the amperage capacity of the incoming service are exempt from this subsection.
   2. Buildings which are designated as historical landmarks are exempt from this subsection only to the extent necessary to preserve those features necessary for their historical appearance or function.

2.2 General

Before the utility will *permanently* connect a new or enlarged service for a building for which a building permit was granted on or before December 31, 1985, and to which this subsection applies, the customer shall:

a. make all changes or installations necessary to comply with the efficiency standards set out in subsections 2.3, 2.4, and 2.5;

b. schedule and permit an inspection of the premises by a utility or local building code field representative;

c. submit Lighting Power Budget forms as required below;

d. conduct an Electric Energy Analysis in accordance with the requirements of subsection 2.6; and

e. submit the results to the utility or local building code official on Electric Energy Analysis forms provided by the utility or local building code official.

Before the utility will *permanently* connect a new or enlarged service for a building which receives a building permit on or after January 1, 1986, the customer shall comply with the Northwest Power Planning Council's Model Standard for Energy Conservation in New Buildings.

2.3 Lighting Efficiency Standard

The Lighting Power Budget is the upper limit of electric power that is allowed to be used for permanently installed lighting. The Lighting Power Budget for a premises shall be the sum of the wattage limits computed for all lighted interior and exterior spaces. The lighting wattage in the premises shall not exceed the budget level calculated in this section. Lighting wattage includes lamp and ballast wattage.

a. The exterior Lighting Power Budget shall be calculated by multiplying the building perimeter in feet by 7.5 Watts per foot. The total installed exterior lighting shall not exceed this calculation. An allowance for outdoor parking lighting may be added at 0.05 Watts per square foot of parking area. Electric outdoor signs are exempt from this subsection.

b. The interior Lighting Power Budget is to be calculated as follows:

   1. Determine the lighting power index for each occupancy, using the accompanying Lighting Power Budget Index (table L-2).

Table L-2.
Lighting Power Budget Index

Occupancy Type	**Lighting Power Budget (Watts/sq ft)**
Auditoriums, theaters, public assembly	1.1
Hospitals	2.0
Indoor parking	0.3
Libraries	2.0
Offices	2.0
Restaurants	1.85
Retail stores and museums	2.0
Schools and day care centers	2.0
Warehouses	0.7
Gasoline and service stations (includes the office, wating rooms, and pump islands plus five feet on side of island)	2.0
Storage garages	0.3
Boat moorages	0.3
Paint shops and spray painting rooms	2.5
Auto repair and body shops	2.0

Note: In the case of an occupancy type not specifically mentioned above, the lighting power budget in Watts per square foot shall be based upon the budget for the most comparable occupancy type specified.

2. Multiply the power budget index (in Watts per square foot) by the gross floor area (in square feet) to arrive at the Lighting Power Budget (in Watts). The gross floor area shall be computed by summing the areas of the premises including basement, mezzanine, and intermediate-floored tiers and penthouses of headroom height, measuring from the centerline of walls separating buildings provided that covered walkways, open roofed-over areas, porches, and similar spaces and features, such as pipe trenches, exterior terraces or steps, chimneys, roof overhang, etc., are excluded.

3: Total the wattage for all lighting fixtures installed in the establishment, including lamps and ballasts. The total wattage for lighting must not exceed the allowable Lighting Power Budget calculated in steps 2 and 3.

4. The calculations of Lighting Power Budgets shall be determined for each specific occupancy of the building or portion of a building. When a building is 90 percent or more of one occupancy classification as given in the Lighting Power Budget Index, then that occupancy may be considered the primary occupancy for the entire building. Therefore, when a secondary occupancy is less than 10 percent of the primary occupancy, the secondary occupancy may be included in the calculation of the Lighting Power Budget at the Watts-per-square-foot level of the primary occupancy.

5. Each Lighting Power Budget calculation shall include the necessary areas that directly serve the occupancy to be calculated. The accessory areas shall include, but not be limited to:

   A. restroom facilities;

   B. janitor closets and service rooms;

   C. stairways;

   D. mechanical rooms;

   E. ticket booths;

   F. coat rooms; and

   G. indoor circulation areas immediately adjacent to the occupancy under consideration.

6. If the installed lighting wattage exceeds the allowable Lighting Power Budget, make the necessary changes to comply with the standard.

7. Exemptions. Lighting for the following applications shall be exempted from inclusion in the calculation of the Lighting Power Budget:

   A. stage lighting, entertainment, or audiovisual presentations where the lighting is an essential technical element for the functions performed;

   B. lighting for medical and dental tasks;

   C. lighting in areas specifically designed for visually handicapped people;

   D. for restaurant occupancies, lighting for kitchens and food preparation areas;

   E. power required for trickle-charging for battery-powered emergency lighting; and

   F. portable task lighting for special tasks which require additional lighting level such as drafting, machine work, and other detailed work.

8. For Class I, II, and III retail occupancies (as defined in the Lighting Power Index Budget), lighting for highlighting applications may be included in addition to the power budget up to the following limits:

   Class I - 3.0 W/sq ft (less than 1,000 sq ft)
   Class II - 2.0 W/sq ft (100 to 6,000 sq ft)
   Class III - 1.0 W/sq ft (6,001 sq ft and above)

2.4 Water Heat Efficiency Standard

a. **Electric Water Heaters**. Electric water heaters and associated storage tanks shall be insulated to a thermal resistance of 20 (R-20) where space allows. Where walls or other barriers prevent installation of insulating wrap of R-20, insulate to the maximum extent possible. Additional insulation shall not be required if the water heater has been certified by the manufacturer to have a standby loss of no greater than 2.8 Watts per square foot of external area.

b. **Piping Insulation for Electric Water Heat Hot Water Pipes**. All exposed and readily accessible electrically heated hot water piping installed to serve buildings and within buildings shall be thermally insulated in accordance with table L-3, except as stated herein.

Table L-3.
Minimum Pipe Insulation[1]

Piping System Types	Fluid Temp Range (°F)	Insulation Thickness In Inches for Pipe Sizes[2]					
		Run-Outs 2"	1" and Less	1.25" to 2"	2.5" to 4"	5" to 6"	8" and Larger
Heating Systems **Steam and Hot Water**							
High-Pressure/Temp	306-450	1.5	2.5	2.5	3.0	3.5	3.5
Med-Pressure/Temp	251-305	1.5	2.0	2.5	2.5	3.0	3.0
Low-Pressure/Temp	201-250	1.0	1.5	1.5	2.0	2.0	2.0
Low Temperature	120-200	0.5	1.0	1.0	1.5	1.5	1.5
Steam Condensate (for Feed Water)	Any	1.0	1.0	1.5	2.0	2.0	2.0
Cooling Systems							
Chilled Water	40- 55	0.5	0.5	0.75	1.0	1.0	1.0
Refrigerant or Brine	Below 40	1.0	1.0	1.5	1.5	1.5	1.5

[1]For Piping exposed to ambient temperatures, increase thickness by 0.5 in.

[2]Pipe sizes are nominal dimensions.

[3]Runouts to Individual Terminal Units (not exceeding 12 ft in length).

Exception: Piping insulation is not required in any of the following cases:

1. piping installed within HVAC equipment;

2. piping at fluid temperatures between 55° F and 100° F; or

3. when the heat loss and/or heat gain of the piping without insulation does not increase energy requirements of the building.

c. **Other Insulation Thicknesses**. Insulation thicknesses in table L-3 are based on insulation having thermal resistivity in the range of 4.0 to 4.6 ft° /h° F/Btu per inch of thickness on a flat surface at a mean temperature of 75° F. Minimum insulation thickness shall be increased for materials having R values less than 4.0 or may be reduced for materials having R values greater than 4.6 as follows:

1. for materials with thermal resistivity greater than 4.6, the minimum insulation thickness may be reduced as follows:

$$\frac{4.6 \times \text{Table L-4 Thickness}}{\text{Actual R}} - \text{New Minimum Thickness}$$

2. for materials with thermal resistivity less than 4.0, the minimum insulation thickness shall be increased as follows:

$$\frac{4.0 \times \text{Table L-4 Thickness}}{\text{Actual R}} - \text{New Minimum Thickness}$$

d. Additional insulation and vapor barriers shall be provided to prevent condensation where required.

Table L-4.
Insulation of Ducts[1]

Duct Location	**Mechanically Cooled**	**Heated**
On roof or exterior of building	C, V, and W	B and W
Attics, garages, and crawl spaces	B and V	B
In walls, within floor/ceiling spaces[3]	B and V	B
Within the conditioned space or in basements	None required	None required
Cement slab or within ground	None required	None required

[1]Where ducts are used for both heating and cooling, the minimum insulation shall be as required for the most restrictive condition.

[2]Insulation types:

B 2 inch 0.60 lb/cu ft mineral fiber blanket
1 inch 1.5 to 3 lb/cu ft mineral fiber board or equivalent to provide an installed thermal conductance = 0.24

C 3 inch 0.60 lb/cu ft mineral fiber blanket
1 inch 1.5 to 3 lb/cu ft mineral blanket (duct liner)
1 inch 3 to 10 lb/cu ft mineral fiber board or equivalent to provide an installed thermal conductance = 0.16

V Vapor barrier, with perm rating not greater than 0.05 perms, all joints sealed

W Approved weatherproof barrier

[3]Insulation may be omitted on that portion of a duct which is located within a wall or a floor/ceiling space where both sides of this space are exposed to conditioned air and where the space is not ventilated or otherwise exposed to unconditioned air.

e. **Hot Water Tank Thermostats**. Domestic hot water thermostats (temperture control devices) on electric hot water tanks and storage tanks shall be set no higher than 130° F. Exemptions shall be allowed:

1. for combination domestic water heating/space heating boilers;

2. when health department regulations require a higher temperature for dishwashing or such other purposes;

3. for those domestic hot water heating systems capable of using heat that otherwise would be wasted; and

4. for those commercial processes requiring hot water temperatures in excess of 130° F.

2.5 Heat Duct Insulation

All ducts, plenums, and enclosures installed in or on buildings shall be thermally insulated to meet the requirements of table L-4.

Exception: Duct insulation (except where required to prevent condensation) is not required in any of the following cases:

1. when the heat gain or loss of the ducts, without insulation, will not increase the energy requirements of the building;
2. within HVAC equipment; or
3. exhaust air ducts.

2.6 Piping Insulation

All piping installed to serve buildings and within buildings shall be thermally insulated in accordance with table L-3, except as stated herein.

2.7 Electric Energy Analysis (Audit)

Those customers whose new or enlarged service connection is for purposes other than electric space conditioning shall be exempt from this subsection.

Those customers whose new or enlarged service connection is for the purpose of a heat pump shall also be exempt from this subsection *provided that* the heat pump complies with the applicable minimum performance specifications set forth in the Northwest Power Planning Council's Model Standard for Energy Conservation in New Buildings. A heat pump is an assembly which normally includes an indoor conditioning coil, compressor(s), and outdoor coil or refrigerant-to-water heat exchanger, including means to provide both heating and cooling functions. It is designed to provide the functions of air circulating, air cleaning, cooling, and heating with controlled temperature and dehumidifying, and may optionally include the function of humidifying. This definition includes unitary and packaged terminal heat pumps.

The electric energy analysis required shall follow Bonneville's minimum requirements for commercial energy audits, and shall consist of an analysis of existing consumption of electricity, an analysis of modifications which will result in electric energy savings, and an economic analysis of those modifications which illustrate the pay-back period for each modification as follows:

a. The analysis of existing electricity consumption shall provide detailed information to establish an estimate of annual consumption of electricity. The information shall include, but is not limited to:

    1. wattage and approximate number of hours of annual operation for all permanently installed electric systems including lighting, heating, air conditioning, ventilation, refrigeration, water, and process heating;

    2. wattage and approximate number of hours of annual operation for all electric equipment which is not permanently installed and for which the connected electric load is or would be 5 kilowatts or greater;

    3. survey of construction details of the building which affect thermal performance including, but not limited to, insulation levels (R value), double glazing, infiltration, transmission; and

    4. an estimate of the actual annual heating and/or cooling electric energy consumption of the building.

b. The analysis of modifications which will result in electric energy savings shall include, but is not limited to:

    1. Tune-up, operations, and maintenance modifications such as:

        A. establishment of routine, preventive maintenance program including, but not limited to, schedules for the following activities:

            equipment lubrication

            checking operation of all mechanical system controls

            changing filters

            cleaning all heat exchange surfaces; and

            cleaning all lighting fixtures;

B. repair and replacement of existing insulation as required;

C. timing the operation of all electric systems;

D. shutoff of heating, ventilation, and air conditioning systems during unoccupied hours, as consistent with the nature of the building and the activities conducted on the premises; and

E. removing lamps and disconnecting ballasts (in ballasted systems) in areas where lighting can be reduced beyond the values required by the Lighting Power Budget.

2. Other modifications, such as:

A. replacement of existing lamps or fixtures with more efficient lamps or fixtures;

B. installation of a new and more efficient heating, ventilation, and air conditioning system and/or boiler controls;

C. installation of an economizer cycle (an economizer cycle is a controlled sequence of an air supply system that modulates the quality of outdoor air supplied for the purpose of space conditioning in order to reduce or eliminate the use of refrigeration energy for cooling);

D. for those buildings installing electric space conditioning, and improvement of building shell including insulation, weatherstripping, caulking, and double-glazing; and

E. any other appropriate modifications which result in electric energy savings.

3. Economic Analysis.

A. The economic analysis of the electric energy-saving modification shall show a pay-back period for each modification calculated by dividing the cost of the modification by the annual benefits. The costs shall include an estimated, itemized cost of the modification, applicable taxes, and design and installation costs. The benefits shall include the monetary value of the annual kilowatt-hour savings, reduction in demand charges, and any other identified benefits resulting from the modifications. The cost per kilowatt-hour and per kilowatt for computation purposes shall reflect all applicable costs and charges in the applicable electric rate schedule at the time of the computation.

NOTE: The above pay-back methodology does not take into consideration potential future rate increases, inflationary trends, interest rates, or other pertinent economic considerations. It is offered as a simple method for calculating how quickly the customer will retrieve his/her financial investment. An alternative economic analysis (such as those mentioned in B below) will provide the customer with a more accurate, representative analysis of costs and benefits.

B. **Alternative economic analysis.** Alternative economic analyses, such as life-cycle costing or net present value, may be used provided that the above pay-back computation appears.

2.8 Confidentiality

Data obtained as a result of subsection 2.2 will not be reported in a fashion which identifies an individual customer, except with that customer's permission.

2.9 Inspection

a. A utility or local building code official field representative will inspect the building for compliance with the lighting and water heat and heating duct efficiency standards prior to permanent electrical service connection. For those customers required to comply with the electric energy analysis (audit) subsection, a utility or code official field representative may inspect the building to determine whether the electric energy analysis submitted by the customer complies with the requirements of the subsection prior to permanent electric service connection. The field representative will approve the requested service for connection if the building complies with the efficiency standards and if the electric energy analysis complies with the subsection requirements. If not, the customer shall make the necessary corrections and schedule another inspection to determine compliance.

2.10 Customer Assistance

Customers may contact the servicing utility or local building code office for advice in completing their own Electric Energy Analysis form and any other appropriate forms.

2.11 Effective Date

The effective date of this standard is January 1, 1986.