VIRTUAL SPACE HEATING LOADS AND ENERGY CONSERVATION: LESSONS FROM THE NORTHWEST

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ABSTRACT

The WPPSS crisis in the Pacific Northwest (PNW) illustrated the true economic ramifications of the enormous uncertainty inherent in future predictions of energy use. In response to the crisis, regional institutions designed two regionally cost-effective energy programs for electrically heated homes: the Model Conservation Standards (MCS) code, and a regional weatherization program. These two programs significantly reduce regional planning uncertainty, yet no calculation of cost-effectiveness has included the value of reduced uncertainty.

Much of the uncertainty in PNW forecasts lies in residential electric space heating. Current energy consumption for these homes is below what any engineering model or survey analysis over the last ten years had predicted. Most of the discrepancy between predicted and actual use can be traced to lifestyle changes rather than improvements in the building stock, indicating that large take-backs are possible during times of flat or declining real energy prices.

We introduce the concept of the "virtual" space heating load (VHL) as the upper bound of demand that could be put on the system under plausible use assumptions: full-home heating to 65 degrees and no secondary fuel use. We use the Northwest Power Planning Council's (Council) 1983 engineering model estimates as the VHL proxy for buildings built before 1980. The VHL for new buildings is derived from engineering calculations from the Council's model. We use a recent utility estimate as the lower bound of consumption.

In the "High Case" scenario we develop, the two Council progams reduce uncertainty by approximately 375 aMW over a ten-year planning horizon. Our methodology for calculating the economic worth of this reduction shows that generating capacity costing almost $990 million could be avoided if the Council's path were followed instead of continuing current practice. This regional saving is pro-rated over MCS and weatherized houses. Reduced uncertainty adds up to $960 in value to each MCS and weatherized home, though the most likely value is somewhat lower.

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INTRODUCTION

Over the last decade, space heating energy consumption in the average Northwest home has declined substantially.[1] Most of this reduction reflects lifestyle changes and curtailment rather than efficiency improvements.[2] Existing household heating energy consumption was estimated to be between 13,000 and 14,000 kilowatt hours per year in the late seventies and early eighties.[3] Forecasts of 1985 consumption were around 11,000 to 12,000 kWh/yr. The low end of the plausible range of estimated space heating values is as low as 6,228 kWh/year. [4] (See Table 1 for a summary of the different space heating predictions made over the last 8 years.)

The upper level of space heating use is the "virtual" space heating load, which we define as the demand from space heating that could be placed on the system under plausible use assumptions. We show that the Model Conservation Standards (MCS) and an effective regional weatherization program have the ability to reduce substantially the uncertainty facing energy planners. The wide range of space heating consumption figures for single family homes under different growth scenarios could lead to a planning uncertainty in the Northwest of 1100 average megawatts (aMW) over a ten year planning horizon. Scenarios we construct which include regional implementation of the MCS and regional weatherzation program, show demand uncertainty reduced to 725 aMW, a net reduction of 375 aMW.

So far, no quantitative work has explicitly included the uncertainty reducing value of conservation in analysis of the cost-effectiveness of these two programs.[5] The economic value of this uncertainty reduction can be deduced from the amount of generation capacity that would have to be constructed to cover the additional uncertainty. The economic value can then be applied to the capital cost of the conservation measures in buildings constructed or retrofitted under these programs.

Table I. Various estimates of regionally-weighted average space heat use for existing and future Northwest electrically heated homes.

Estimate or Forecast Year Published- End Year	Average Space Heat UEC-kWh/yr. (Base Year)	Mid-point UEC- if available-kWh/yr (yr.)	End of Forecast UEC-kWh/yr. (yr.)
BPA 1981-1999	13,636 ('79)	11,814 ('85)	9,494 ('99)
BPA 1982-1999	13,380 ('80)	11,150 ('85)	8,600 ('00)
BPA 1983-2000	13,924 ('80)		
BPA 1984-2000	11,233 ('80)		8,890 ('00)
BPA 1985-2005	13,620 ('79)	10,900 ('85)	10,385 ('05)
LBL 1983	11,696 ('80)		
NCAC 1982	13,160 ('80)		
NPPC 1983-2005	13,425 ('79)	Forecast Model	
NPPC 1983-2005	15,599 ('79)	Engineering Model*	
NPPC 1985-2005	10,285 ('80)	9,990 ('85)	8,316 ('05)
PNUCC 1978-1999	12,600 ('76)	12,600 ('85)	12,600 ('99)
PNUCC 1979-1999	12,840 ('77)	12,840 ('85)	12,840 ('99)
PNUCC 1980-1999	13,860 ('78)	11,720 ('80)	
Virtual Load 1985	13,974 ('85)		

* = Pre-1980 Virtual Load

Other measurements or estimates of space heat use

Source	Space Heat Use Estimate (Base yr.)
1983 ORNL Report on BPA RWP	14,924 ('80)
1985 analysis PNGC Residential Survey	6,228 ('83)
NPPC interpretation of PNGC 1983 Data	6,228-9,756 ('83)
NPPC interpretation of PNGC 1981 Data	10,704-11,509 ('81)

Source: Notes 3, 4

I. THE PROBLEM: CHANGED NORTHWEST SPACE HEATING PRACTICES

At the beginning of the decade, many projections of average space heating electricity use in electrically heated homes showed consumption remaining flat, or declining slightly. As can be seen from Table I, energy planners at that time were reasonably consistent in their estimates of 1985 household consumption; the average was around 13,500 kWh/yr.

These early forecasts of 1985 average space heating use were also within about 1,000 kWh of each other. However, little was known about the lower bound of space heat consumption or how much people could save by burning wood and/or closing off rooms and turning down the thermostat.

The problem energy planners currently face is not very different from the one they faced at the beginning of the decade. Analysis done by the Pacific Northwest Generating Company (PNGC) suggests that average regional space heating use could be as low as 6,228 kWh/yr[6] falls below any previous projection or estimate of the possible range of values, even under scenarios including heavy weatherization.[7] While there is now a lower boundary of average space heating consumption is more clearly defined, enormous uncertainty still exists.

While substantial, the level of retrofit activity in the Northwest has not been sufficient to affect the range of average space heat use to the degree that is being estimated by PNGC.[8] We did a rough estimate of the amount of weatherization that would have to have occurred between 1980 and 1985 in order to reduce the average space heat value from estimates of 1980 use of 13,500 kWh/yr[9] to a present-day average of 6,228 kWh/yr. Over one million homes would have to have been retrofitted to 6,100 kWh/yr (about 7,400 kWh savings) in order to bring average space heat use down that much. Clearly, this level of weatherization has not occurred on this scale, which indicates that other forms of "conservation" are happening.

This "conservation" took the form of curtailment and lifestyle changes and was precipitated by unprecedented "rate-shock" as the full economic impact of the "Whoops" debacle hit.

II. BACKGROUND: A CRISIS OF PLANNING

In the early 1970s, Northwest power planners saw no end in sight to robust postwar demand growth. Plans under Bonneville Power Administration's Hydro-Thermal Power Program in the early seventies called for 27 large-scale coal or nuclear plants to be built by 1993.[10] By 1974, sixteen of these plants were in various stages of planning or construction.[11] By 1981, the demand that was forecast had failed to materialize and the collapse known as "Whoops" soon followed.

By 1984, six large nuclear plants had been cancelled and two placed indefinitely in mothballs. These eight plants represented 10,000 Megawatts (MW) of capacity and a total regional bill amounting to over $7 billion.[12] The WPPSS crisis induced a rate shock that increased wholesale electricity prices over 400% between 1979 and 1983 and spurred a regional recession. [13]

In 1981, the Northwest Power Planning Council was created and charged with developing an energy plan for the region that accorded top priority to cost-effective conservation. The central to the residential sector conservation plan is the Model Conservation Standards (MCS), a regional building code for electrically heated homes. The Council also designed a regional weatherization program for existing electrically heated residences, which, along with the MCS is designed to cut heating energy by up to 60%.[14]

III. VIRTUAL SPACE HEATING LOAD

The virtual space heating load (VHL) is the upper-limit amount of electricity that a Northwest energy planner can expect electrically heated homes in the region to consume. A virtual heat load calculation assumes that all consumers keep their thermostat at the regional average set point 24 hours a day and use no secondary fuels.[15] But, the VHL is determined more by the efficiency of the building, than by the lifestyle of the occupants. In essence, the virtual load of a building is the engineering calculation of electric heating use. Engineering models allow us to remove wood heating and other lifestyle modifications or curtailments and simply simulate building shell loss under conditions of maximum plausible interior temperatures.

This approach is similar to the common utility practice that one author has called "critical economy" planning.[16] Critical economy assumptions call for high and sustained annual growth rates in the economy, which translate into high growth trends in the number of electricity end-users, insuring that demand forecasts err on the high side.

To calculate the 1985 average virtual heat load, we began with the Council's 1983 Plan calculation of 1980 average regional space heating use in existing buildings of 15,600 kWh/yr.[17] This number is an engineering estimate based on regional average construction characteristics from the 1980 Pacific Northwest Residential Survey (PNWRES) and National Weather Service data. Estimates of post-retrofit use--11,100 kWh/yr--were calculated from this number, assuming savings of 4,500 kWh/yr per retrofit.[18] We then had calculations run using the Council's engineering model on the heatloss of an average building built to "current practice"[19] in each zone and obtained a regionally-weighted average of 10,028 kWh/yr. These use assumptions were then used as input in a simple exponential decay model which, using implicit new housing construction and retrofit rates between 1980 and 1985, calculated a 1985 regional average virtual heat load for single family electrically heated homes of 13,974 kwh/yr.[20] Since the virtual load depends upon a building's average efficiency, virtual load in future years is influenced greatly by whether the MCS and Council weatherization programs are implemented.

IV. UNCERTAINTY IN THE RESIDENTIAL SECTOR

The massive uncertainty in individual residence space heating consumption outlined above is due primarily to lifestyle changes and curtailment rather than improvements in the building stock. However, the magnitude of Northwest consumer response to the rate-shock of the early 1980's--wood burning, room closures and thermostat set-backs--is only now being understood. Data deficiencies account for much of the uncertainty surrounding actual space heat use in the Northwest. However, analysis of the Hood River Conservation Project, which currently represents one of the only two comprehensive in situ measurement programs in the Northwest, is beginning to yield results, and will provide a better picture of energy use in homes weatherized to the Council's specifications. The other program, Bonneville's End-Use Load and Conservation Assesment Program (ELCAP) will provide additional measured data on heat use in existing homes.

We compare past estimates of 1985 electric space heating use with current estimates to get the full range of possible values. We use the 1980 PNUCC estimate of 13,860 kWh/yr for existing 1980 buildings and 10,500 kWh/yr for new electrically heated buildings (11,720 kwh/yr minus an arbitrary 10% price-induced demand reduction) to arrive at a 13,384 kWh/yr estimate of average 1985 space heating use.[21] The other earlier forecast we use is the 1981 BPA analysis of the 1980 PNUCC model which predicted a 1985 average use of 11,814 kWh/yr.[22] We compare these estimates with the current BPA (1985) forecast estimates and the analysis done by PNGC, which show average space heat use of regional stock to be 10,900 kWh/yr and 6,228 kWh/yr, respectively.[23]

If the 1985 number of existing electrically heated single family dwellings is 1,180,000,[24] then the predicted 1985 space heating load under PNUCC use estimates is 1,802 aMW. Using BPA '81 estimates, the regional load is 1,591 aMW and the 1985 BPA and PNGC estimates produce loads of 1,468 and 839 aMW, respectively. Comparing the 1980 PNUCC and 1981 BPA estimates, the regional uncertainty is 211 aMW; comparing the 1985 BPA and PNGC estimates, the uncertainty grows almost three-fold to 629 aMW. The 1980 high estimate (PNUCC) compared with the 1985 low estimate (PNGC), produces an uncertainty of 936 aMW, which exceeds the reliable output of a 1,250 MW nuclear power plant. Using the virtual load number of 13,974 calculated above, the regional load is 1,882 aMW. When compared with the low estimate the total range of uncertainty becomes 1,043 aMW.

V. PLANNING IMPLICATIONS

The problem facing Northwest energy planners today is that they have plausible values for average regional stock space heating use ranging from 13,974 kWh/year to 6,228 kWh/year (see Table I). Another way to state the range of average space heating consumption for existing homes is 10,000 kWh/year ± 3,800 kWh. Thus, the range of plausible Northwest space heat use assumptions for existing stock creates an uncertainty of 7,600 kWh (over 75%). Uncertainty of this magnitude, which is compounded tremendously by regional growth uncertainties, is clearly unacceptable from a planning perspective.

Most analyses break energy savings into two categories; permanent, or those that are a result of physical improvements to the building stock and temporary, or savings that are a result of behavior modification and could be reversed at any time.[25] And from a planning perspective, the distinction between the two types are very important. One scenario that should alarm planners is a consumption "take-back" scenario in which consumers, after a period of static or declining real energy prices, begin to revert back to old consumption habits. This could lead to rapidly rising demand and could conceivably give rise to over-planning and over-building.

Interesting parallels can be drawn with the rise in gasoline consumption in recent years. Gasoline prices declined almost 30% in real terms 1981 and 1985.[26] Analyses by DOE and the CEC have found that since 1983, after a four year decline between 1978 and 1982, gross sales of gasoline have risen almost 10% since 1983.[27] Similarly, per capita sales of gasoline have risen over 2% since 1983.[28] In California, the number of discretionary trips has increased by about 14% and total mileage driven has risen by over 15%.[29] These increases are out-stripping vehicle registrations.[30] DOE also projects that the growth rate of gasoline consumption in 1986 will be nearly double that of 1983 (2.6% vs. 1.4%).[31]

VI. USING MCS AND COUNCIL WEATHERIZATION PROGRAMS TO REDUCE UNCERTAINTY

The MCS and the weatherization program effectively limit the amount of space heating energy buildings can physically consume under reasonable living conditions. These buildings have a much smaller range of possible heat use values than is currently the case. In fact, the range of uncertainty (7,600 kWh/yr) shown above is greater than the annual use of buildings constructed under either program. It is presently unknown what the range of uncertainty is with MCS and weatherized homes, but results from the Hood River project and ELCAP are expected to clarify this question.

Since a smaller range of space heat use is being extrapolated to the regional level, the "jaws" of uncertainty will necessarily be narrower, especially under high growth scenarios.

A. Methodology

The total future uncertainty facing energy planners is the the difference between the amount of energy used in a high regional growth/high space heat use scenario and a low growth/ low space heat scenario over a planning period. In our analysis, we use a ten year time frame over which to analyze the uncertainty reducing process. The ten years represents the lead time to license and construct a medium-sized (500 MW) coal plant.

We developed a set of high- and low-growth scenarios (subsequently referred to as "No-MCS" scenarios) to portray the possible range of demand uncertainty without the MCS and a weatherization program realizing savings equivalent to BPA's Residential Weatherization Program (RWP).[32] We compared these "jaws" of uncertainty with those resulting from scenarios in which the MCS and the Council's weatherization program are adopted (subsequently referred to as "MCS scenarios"). In both the MCS and No-MCS cases, we used the new construction and retrofit rates implicit in the NPPC forecast in the 1986 Northwest Conservation and Electric Power Plan for the high and low growth cases.[33] The common and individual case assumptions are listed below in Table II.

Table II. Assumptions for high and low growth cases for "MCS" and "No-MCS" scenarios

Common Assumptions: High case

1. Initial electrically heated homes = 1.302 million
2. Average annual rate of new construction = 4.6%
3. Average annual rate of retrofitting = 4.7%
4. New homes constructed = 542.4 thousand
5. Total homes retrofit = 463.9 thousand
6. Average life of buildings = 100 years

Common Assumptions: Low case

1. Initial electrically heated homes = 1.302 million
2. Average annual rate of new construction = 1.45%
3. Average annual rate of retrofitting = 1.3%
4. New homes constructed = 121.9 thousand
5. Total homes retrofit = 153.6 thousand
6. Average life of buildings = 150 years
7. Virtual load of existing buildings = 6,228 kWh/yr

Scenario Assumptions: MCS

1. Virtual load of existing buildings (high case only) = 11,860 kWh/yr
2. Annual space heat use: MCS house = 5,332 kWh/yr
3. Annual space heat use: Current practice house = 10,028 kWh/yr
4. Council retrofit space heat use = 6,077 kWh/yr
5. Non-Council retrofit space heat use (high case only) = 7,360 kWh/yr
6. MCS and Council retrofit penetration = 85%; rest = No-MCS scenario heat use assumptions

(cont.)

Table II. (cont.)

Scenario Assumptions: No-MCS

1. Virtual load of existing buildings (high case only) = 12,787 kWh/yr
2. Annual space heat use: Current practice house = 10,028 kWh/yr
3. Retrofit space heat use (high case) = 8,287 kWh/yr
4. Retrofit space heat use (low case) = 6,077 kWh/yr

B. Scenarios[34]

For both the MCS and No-MCS cases we ran the high growth forecast using virtual space heating assumptions and compared it with the low growth/low space heat use scenario to get the full range of potential load attributable space heating in the Northwest. As shown in Figure 1 below, the range of uncertainty is enormous in the No-MCS case and is significantly reduced in the MCS case.

We set up the MCS and No-MCS cases in three steps. First, we calculated the average virtual load for houses existing in 1985 as described above. Second, using a model similar to the one described in the Virtual Load section, we calculated the average virtual load for existing houses in the first year of full MCS implementation, or 1990 in real-time, for the MCS case and the No-MCS case.[35] This gives us three starting points: one for each high case and one for the two low cases. Each high case has a different starting point because the virtual load for existing buildings in 1990 is different, due to the ramped MCS implementation. We started the two low cases from the same point because we had no way of modelling the lifestyle changes that lead to the original estimate and could not extrapolate from the 1985 estimate. Thus, our assumption is that the low boundary for average stock space heat use remains static between 1985 and 1990.

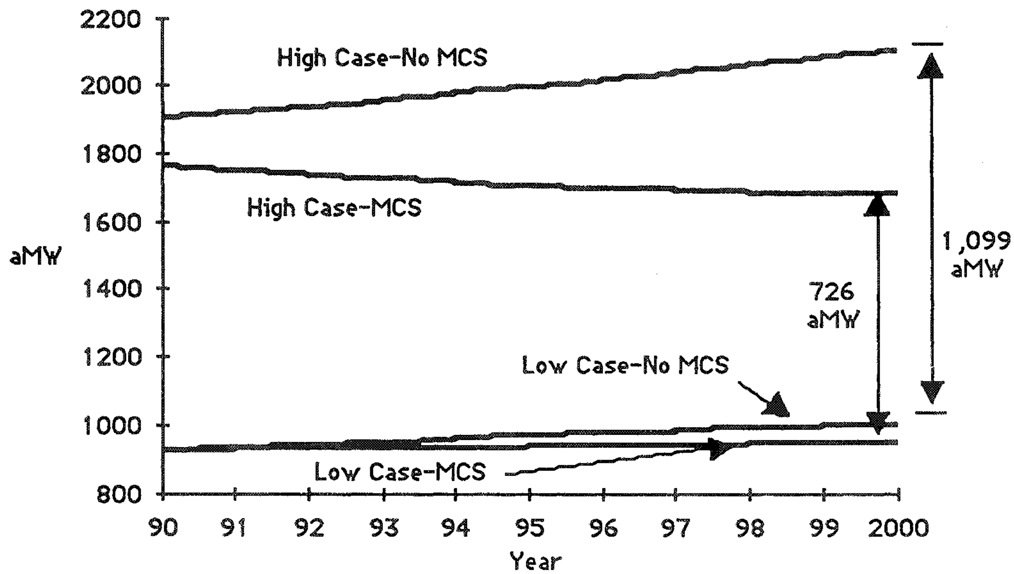

Figure 1. Comparison of MCS and No-MCS scenarios under high- and low-growth cases.

VII. ECONOMIC VALUE OF REDUCED UNCERTAINTY

We define the regional economic value of reduced uncertainty as the cost of the generation capacity that would have to be optioned, then built, in order to meet the additional load.[36] As can be seen from Figure 1, MCS adoption can reduce uncertainty in Northwest space heating loads by approximately 375 aMW.

The actual cost of generation capacity can be described over a range of values. A "worst-case" scenario would be one in which coal-fired capacity were built, then not needed. This hypothetical situation could arise if consumer take-backs lead to high-growth planning responses and the Council's "options" process does not work due to inherent institutional barriers. The entire capital expenditure is then assigned to the region as a "cost". If this cost were foregone due to decreased uncertainty, then the reduction could be said to have the value of the avoided cost.

For the purpose of demonstrating the methodology for including the value of uncertainty reduction in a cost-effectiveness calculation, we use 375 aMW of uncertainty avoided as calculated above. The amount of gross capacity that would have to be installed to meet this additional demand is approximately 485 MW.[37]

The capacity addition is represented by a generic 500 MW coal-fired power station as described in Appendix 6C in Volume II of the 1986 Council Plan.[38] This plant would provide up to 385 MW of available capacity. The total construction cost is $886.3 million in January 1985 dollars. As described in the "worst-case" scenario above, this entire cost is "credited" to the approximately 925,000 MCS and weatherized homes that could be constructed or retrofitted under a high growth/MCS-adopted scenario.[39] The upper value of reduced uncertainty is $958 per house.[40]

VIII. RE-CALCULATING THE COST-EFFECTIVENESS OF THE MCS AND WEATHERIZATION PROGRAM

In the Pacific Northwest, "regionally cost-effective" measures save energy at a cost per kWh below the cost per kWh to build coal-fired generating capacity that produces the equivalent amount of energy. The cost-effective limit for the Model Conservation Standards was calculated to be 40-45 mills or 4 to 4.5 cents per kilowatt hour: the cost of building a new coal-fired generating station.[41] The total capital cost for conservation measures under 45 mills/kWh (levelized) is $3,332, and we re-calculate the cost-effectiveness from this figure.[42]

There are two possible methods for applying the value of reduced uncertainty to the calculation. One way is to apply the value of uncertainty reduction to the MCS package's total cost, thereby reducing the net expenditure. This method acts like a "discount" on the cost of the conservation measures. If the original capital cost of measures is $3,332 (levelized cost 45 mills), then applying the $958 to the capital cost reduces the regional outlay to $2,374, or between 30 and 35 mills/kWh levelized cost. The result is to "purchase" 45 mills' worth of conservation for between 30 and 35 mills/kWh.

Alternatively, the uncertainty-reduction value could be applied as a "credit" to purchasing additional conservation measures. By crediting the $958 to the existing package, measures with a total marginal cost of $4,290 could be bought for a net regional cost of $3,332. This method would enable the region to take advantage of packages costing between 50 and 55 mills/kWh. for a net regional cost of only 45 mills/kWh. Since more conservation is being purchased for the same price, it is interesting to note that this latter method further narrows the "jaws" of uncertainty in the scenarios where the MCS is adopted. This increases the amount of uncertainty reduced by the code, which would further extend the cost-effective range.

The results are similar for the weatherization program. The total marginal regionally-weighted cost of the Council's conservation package is $2,660.[43] Applying the $958 as a "discount", the same measures could be purchased for a net regional cost of only $1,702, or between 15 and 20 mills/kWh, levelized. If the $958 were applied as a "credit", a conservation package with a total marginal cost of $3,618 (over 80 mills/kWh, levelized) could be purchased at a net regional cost of $2,660 or 40 mills/kWh.

IX. CONCLUSION

Implementation of the Model Conservation Standards and regional weatherization program could lead to a significant--375 aMW--reduction of space heating load uncertainty over a five- or ten-year planning horizon. This uncertainty reducing property has an economic value of $958 per MCS and weatherized house, which can be applied to cost effectiveness calculations. This lowers the net regional cost of MCS homes to between 30 and 35 mills/kWh or raises the cost-effective ceiling to between 50 and 55 mills/kWh; the net regional cost of weatherized houses is reduced to between 15 and 20 mills or the cost-effective ceiling is raised to over 80 mills.

FOOTNOTES

1. This is apparent from the current surplus as well as the trend in forecasts to assume lower space heating values as shown in Table I. See also: Northwest Power Planning Council: Northwest Conservation and Electric Power Plan, (Subsequently referred to as 1986 Plan.) Vol. II, 1986, Chapter 5.

2. 1986 Plan, note 1 above, p. 5-23.

3. Bonneville Power Administration: Technical Documentation: Forecasts of Electricity Consumption in the Pacific Northwest. 1985, pp. 105-116, calculated from forecast figures; 1984, pp. 143-144; 1983, pp. 128-129; 1982, pp. A-76-77 (Subsequently referred to as BPA 1985/4/3/2); Bonneville Power Administration: Technical Review of the Pacific Northwest Utilities Conference Committee Econometric Model, 1981, Table 14, p. 40 (Subsequently referred to as BPA 1981); Northwest Conservation Act Coalition: Model Electric Power and Conservation Plan for the Pacific Northwest. Appendix 9, p. 17. (Subsequently referred to as Model Plan); Northwest Power Planning Council: Northwest Conservation and Electric Power Plan. Vol. II, 1983, Table K-9, p. K-7; 1986, Table 3-5, p. 3-15. (Subsequently referred to as 1983/6 Plan); Pacific Northwest Utilities Conference Committee: Econometric Model. Electricity Sales Forecast Technical Appendix for the West Group Area, 1980, Table 3-3, p. 45; 1979, Table VI-1, p. 70; 1978, Table VII-1-a, p. 103 (Subsequently referred to as PNUCC 1978/9/80); Usibelli, A, et. al.: A Residential Conservation Data Base for the Pacific Northwest. Lawrence Berkeley Laboratory, 1983, p. I-21 (Subsequently referred to as LBL 1983).

4. Sher, Phill: "Draft Discussion Paper, Analysis of Space Heat Estimates Based on PNGC Survey." Written comments submitted before the Northwest Power Planning Council October 21, 1985.

5. For a general discussion of the significant uncertainty-reduction value of conservation see: Cavanagh, Ralph, "Least Cost Planning Imperatives for Electrical Utilities and Their Regulators," 10 Harvard Environmental Law Review 299, 316-17, (1986)

6. See: Sher, note 4 above.

7. Table I shows the predicted 1985 values for several forecasts. None of these forecasts has space heating consumption below 11,000 kWh/yr. The Bonneville forecasts include heavy weatherization; e.g. 1982 forecast shows approximately 213,000 homes weatherized with an average savings of 4933 kWh/yr/household. See BPA 1982, note 3 above, p. A-58.

8. Id., note 6 above.

9. The 13,500 kWh/yr figure is rounded from and average of the BPA, PNUCC and 1983 Council estimates listed in Table I.

10. Cavanagh, R. C.; Electrical Energy Futures, 14 Environmental Law 133, 145-75, (1983)

11. Id. at 136-37.

12. Id. at 149.

13. Id. at 150.

14. See 1983 Plan, Vol. II Appendicies J & K and: 1986 Plan, Vol. II pp. 5-4-10, note 3 above.

15. This is an approach similar to the Council's when using the engineering model to determine the base energy use.

16. See Cavanagh, note 10 above, at 152-53.

17. 1983 Plan, note 3 above, Vol. II, Table K-9, p. K-7.

18. See, for example: Hirst, Eric and Keating, Kenneth: "Dynamic Effects of Utility Energy Conservation Programs: A Residential Retrofit Program Example", Oak Ridge National Laboratory & Bonneville Power Administration, 1985. The 4,500 kWh/yr figure cited is the average

savings per household, prior to consumer take-backs.

19. The Council's engineering model was run using the author's building shell heat-loss inputs for an "average" house built to "current practice" in the three climate zones (UA 487 in Zone 1, UA 467 in Zone 2, and UA 396 in Zone 3). These results do not represent the Council's opinion. We used an average house floor area of 1344 square feet, which is slightly below the regionally-weighted average of 1355 square feet. This downward adjustment has the effect of reducing the virtual load of the average building and is thus a conservatism. See: 1986 Plan, note 3 above, Vol. II, pp. 5-15-17.

20. Documentation of this model is in the Appendix, which is available from the author upon request.

21. We used a simple exponential decay model using the implicit growth rates in the PNUCC model. Documentation of this model is in the Appendix, which is available from the author upon request.

22. BPA 1981, note 3 above, Table 14, p. 40.

23. See: note 4 above; BPA 1985, note 3 above, pp. 105-116 calculations were done from the forecasting model output which appears on these pages.

24. This number was calculated from BPA 1986, note 3 above, forecast estimates of the total number of 1985 households (pp. 105-116) and the electric space heating saturation assumptions in the 1986 Plan, note 3 above, Vol. II, Table 3-5, p. 3-7.

25. See: Hirst and Keating, note 18 above. This is an example of consumer take-back after weatherization has ocurred. We are not aware of any analyses which measure actual space heating take-backs ocurring during a time of flat or declining real electricity prices. See the discussion in the text on the potential parallel with gasoline consumption.

26. Energy Information Administration, Annual Energy Review, 1985, Table 64, p. 139. DOE/EIA-0384(85) Government Printing Office, May, 1986.

27. Energy Information Administration, "Motor Gasoline Trends," Petroleum Supply Monthly, February, 1985, pp. vx-xx. DOE/EIA-0109(85-02) Government Printing Office, April, 1985; California Energy Commission, "Energy Watch," pp. 1-2, March, 1986.

28. Ibid. CEC Energy Watch, note 27 above; Department of Transportation, Annual Highway Statistics, 1978-1984, Table: "Annual Vehicle Miles Travelled and Related Data." Government Printing Office.

29. Id. CEC Energy Watch, note 27 above.

30. Id.

31. Energy Information Administration, "Short-Term Energy Outlook: Quarterly Projections" p. 14, April 1986, DOE/EIA-0202(86/2Q).

32. 4,500 kWh/yr as reported in Hirst and Keating, note 18 above.

33. Derivation of these rates are in the Appendix, which is available from the author upon request.

34. Documentation of these scenarios are in the Appendix, which is available from the author upon request.

35. Both the MCS and weatherization program assume full adoption January 1986 were phased as following (1986 Plan, see note 3 above, Vol. II, p. 5-27): 35% of total new construction in 1986, 45% in 1987, 60% in 1988, 75% in 1989 and 85%, or full penetration, in 1990. Houses not built to MCS standards were assumed to be built to "current practice" and homes not weatherized to Council specifications were assumed to realize savings of 4,500, see note 18 above. Further details of these calculations are in the Appendix.

36. To some extent, one could consider the collapse of the Hydro-Thermal Program as a real-life example of the true cost of uncertainty and the economic value of its reduction. The inferred uncertainty in this case is

the difference in the forecast load that the five plants were supposed to meet and the load that actually materialized. The upper range of the "cost" (value) of this uncertainty equals the total expenditures for the six cancelled nuclear plants, (Skagit/Hanford 1 & 2, Pebble Springs 1 & 2, WPPSS 4 & 5) plus total expenditures on the mothballed WPPSS 1 & 3 (including preservation costs) if the remaining two plants are terminated. This figure could greatly exceed the over 7 billion dollars already invested (see Cavanaugh, note 10 above, at 147-49). The lower range would be the above total cost, including the cost of whichever --or both-- of the mothballed units is not completed. The above is this type of situation that the Council's Options process seeks to prevent. However, it is not clear that the significant institutional barriers which remain can be resolved so that the process can work as envisioned.

37. Calculation: 500 MW coal plant with an equivalent availability of 77% = 485 MW. See 1986 Plan, note 3 above, Vol. II, Appendix 6-C.

38. This generating option was chosen because it best fit the additional "load" placed on the system by the uncertainty. We also assumed that base-load rather than peaking or firming plants would be preferable to the region.

39. This number was generated by our model. See the Appendix for details.

40. Calculation: $\$886.3 \times 10^6$ capital costs (January 1985$) ÷ 925,000 MCS (542,400*.85) and weatherized (463,900) homes ≈ $958/house. See the Appendix for details.

41. 1986 Plan, note 3 above, Vol. II, pp. 4-14-5

42. Id. Table 5-23, p. 5-22.

43. Id. Table 5-11, p. 5-10.