THE EVOLVING ROLE OF END USE FORECASTING MODELS: THE CASE OF THE PACIFIC NORTHWEST POWER PLANNING COUNCIL

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ABSTRACT

The Pacific Northwest Power Planning Council has made extensive use of end use models to forecast demand for electricity and to analyze impacts of conservation programs. As the planning process has developed, it has stimulated refinements in the models and data. The paper describes several of these refinements. In some cases we have been able to address these new issues reasonably well (e.g. effects on space heating fuel choice of fuel-specific building efficiency standards). In other cases we have been less successful (e.g. projecting weatherization in response to fuel prices, or projecting changes in wood heat use).

While we expected that the models would be a valuable means of forecasting and analyzing conservation questions, we did not foresee how useful they would be for achieving consistency among the components of the Council's integrated planning system. The paper describes a number of ways in which the models have made this achievement possible. The detailed inputs and outputs of the models provide a natural means of checking conservation analysis for consistency with projected demands. In addition, we developed an artificial concept called a "frozen efficiency" forecast, which is useful in the system-wide simulation of conservation, thermal generation resources and our region's large hydroelectric system.

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INTRODUCTION

The Northwest Power Planning Council uses end use models of energy demand for both the residential and commercial sectors. Both models are descendants of models originally developed at Oak Ridge National Laboratory. This paper describes refinements made at the Council over the last few years. A distinction is drawn between changes made to improve forecasting accuracy and those made to enhance analytical consistency.

Forecasting Accuracy

All users of such models are concerned with their forecasting accuracy. Model improvements designed to improve accuracy usually involve the development of improved logic or data; such work is ongoing in a number of places, including the Council. The most significant developments of this type at the Council are in improved data, in improved fuel choice simulation and in the interaction between appliance use and space conditioning requirements.

If the models were used only to forecast energy demand or to estimate the effects of specified policies, in isolation from other analysis, their forecasting accuracy would be the Council's only concern. However, the Council uses the models for an important additional purpose.

Analytical Consistency

The Council's planning process requires consistency among its analytical components. For reasons which will be detailed later, this consistency is particularly important in the Pacific Northwest (PNW), but it should be a significant concern in any of the growing number of integrated resource planning efforts around North America.[1]

In order to ensure maximum consistency in its planning process, the Council has developed new features for its end use forecasting models. These features are not intended to improve forecasting accuracy. Rather, they put the demand forecast in terms which are more easily compared with the conservation analysis and generating system analysis components of the

Council's planning process. These features can be classified as more detailed output, representation of conservation programs, and the ability to make a "frozen efficiency" forecast.

The next two sections of this paper will elaborate on the council's model development efforts in more detail. A description of the developments directed at improving forecasting accuracy is followed by a section on the developments designed to help achieve analytical consistency.

FORECASTING ACCURACY

Residential Model

The residential model adopted in 1982 by the Council was the then-current version of the model originally developed at Oak Ridge National Laboratory by Eric Hirst, with significant refinements added later by Dennis O'Neal and Dan Hamblin, among others.[2] Due to the press of the Council's early schedule, much of the original development of the model's region-specific base year inputs was done by Charles River Associates (CRA) under contract.[3]

Fuel Choice and Thermal Integrity. An issue which arose early was the effect of minimum thermal integrity standards on heating fuel choice. The fuel choice simulation of the then-current version of the ORNL model reflected reduced operating costs of houses with improved thermal integrity. It did not reflect the increased costs of construction of such homes. Ignoring construction costs affected simulated fuel choice very little when the same thermal integrity standards applied to all houses. However, when standards were applied to electrically-heated houses alone, ignoring construction costs biased the fuel choice simulation significantly. The analysis of standards that are unique to electrically-heated houses was important to the Council, so the model was modified to include increased construction costs (expressed as mortgage payments) associated with improved thermal integrity.

This modification changed the model's projections very little when thermal integrity codes were absent, or when they were the same levels for all houses. However, the assumption of codes which are more stringent for electrically-heated houses than for other houses now reduces the projected market share of electric space heating. For example, simulating the imposition of the Council's Model Conservation Standards (MCS)[4] as codes which affect only electrically-heated houses reduces the number of such houses built by about 15%.

This change also made it possible to simulate the effects of compensating builders or homeowners for the increased construction cost of thermally-efficient houses. This has developed into a policy question of some significance in the Pacific Northwest; debate has grown regarding the proper distribution of the costs of achieving efficiency improvements. The Council modeled incentive payments for improved thermal integrity by reducing the construction costs of the improvements as they appeared in the fuel choice module. In one analysis, the model was used to project the effect of payments of $1200, together with a thermal integrity code at the level of the MCS. The resulting projected market shares for electric space heating in new houses were approximately the same as the shares projected in a base case without incentive payments or MCS. Incentive payments of more than $1200 resulted in higher projected electric space heating market shares. For example, incentive payments of $2000 resulted in about 8% more electrically heated new houses than the base case.

While the Council's simulation of the effects of such incentive payments on space heating market shares is a reasonable one, it can't be viewed as a definitive prediction. The version of the ORNL model used by the Bonneville Power Administration (BPA), using equivalent assumptions, is generally more responsive to fuel-specific codes and to incentive payments. It's fair to say that the simulation of the effects of incentive payments is not based on experience with such payments, but extrapolation of the effects of equipment and fuel costs on market shares. This being so, the results of the model's simulations in this area are reasonable, but are not as reliable as results in other areas.

Appliance Efficiency/Space Conditioning Interaction. A significant enhancement of the residential model, reported at the 1984 ACEEE Summer Study in Santa Cruz, was the linking of appliance efficiencies to space conditioning requirements.[5] Appliances used in the conditioned space of a house give off "waste" heat. Because of this, appliance use in the air conditioning season increases air conditioning requirements, while appliance use in the heating season decreases space heating requirements. If appliances become more (or less) efficient over time, the amount of "waste" heat given off decreases (or increases) and space conditioning requirements change accordingly.

The Council's model was modified to account for this interaction; the effect on overall projected demand was modest. When the new model was used to estimate the energy savings from programs to improve efficiency, however, the results were significantly different than those from the unmodified model. Using climate data from the Pacific Northwest, the estimated net savings of an appliance efficiency standard decreased under the new model, while estimated savings of thermal integrity improvements increased.

These results are sensitive to climate, and the climate of the Pacific Northwest is somewhat unusual. Most of the population of the region lives in areas that have a long, mild heating season and virtually no air conditioning season. Estimates for other climates could be quite different.

For example, in a climate with a long air conditioning season, reductions in energy use by appliances would be accompanied by significant reductions in energy use for air conditioning. A short heating season would mean that reductions in energy use by appliances would impose relatively small increases in heating requirements. In such climates, the net effect of appliance efficiency standards could be an overall decline in space conditioning requirements.

New end-use metered data which is being collected, mainly in BPA's End-Use Load and Conservation Assessment Program (ELCAP) should improve our understanding of the interactions between specific appliances' energy use and space conditioning requirements. For example, some evidence suggests that refrigerators use more energy per day in the summer than in the winter. If this is confirmed by the new data, then efficiency improvements in refrigerators are more useful than our model currently represents them. With the appropriate data, it would be fairly easy to reflect the individual interaction of each appliance type with space conditioning requirements.

Wood Heat. Two problems make the treatment of wood as a space heating fuel more difficult than other fuels. First, sales data for electricity, natural gas and heating oil are reasonably good, and are reliable measures of the use of these fuels. In contrast, sales data for wood are scanty and (since much wood is not purchased, but is gathered by users themselves) are poor indicators of total wood use. Second, wood is usually used in some combination with another heating fuel; either wood is used to supplement another fuel, or wood is the primary heating fuel with another fuel filling the need when stoking the wood stove is inconvenient or impossible.

Given the poor quality of the data, the model does not attempt to simulate the choice of wood as a space heating fuel; rather, it uses judgmentally imposed market shares for new homes primarily heated by wood. These market shares are based on region-wide survey data. The data showed a general tendency for homes using wood as their primary space heating fuel to use electricity as their backup space heating fuel. The model was modified to reflect this electricity use for "backup" heating by increasing electricity use in the "other" end use category in wood-heated homes. Projected electricity use due to this modification varies from run to run, but usually runs about 5% of total projected use of electricity.

Remaining Problems--Weatherization. The Council's residential model does not currently simulate price-induced weatherization. This deficiency will bias the model's projected electricity demand upward, in the absence of a utility program to stimulate weatherization. In addition, using the model to estimate savings due to weatherization programs will tend to overestimate program effects by neglecting price-induced thermal integrity improvements. However, the net effect of these two errors should leave system requirements for generation and conservation (net of residential weatherization) unchanged.

Efforts have been made by the Council and others to devise a workable method to model price-induced weatherization. These efforts have not yet been productive; the problem is a difficult one. A good model of weatherization decisions might simulate the timing of the weatherization, as well as the choice of thermal integrity level. Data which would support such an effort have not been available. The problem remains an important topic for future work.

Remaining Problems--Wood Heat. As discussed earlier, the modeling of wood as a space heating fuel is made particularly difficult by lack of data on amounts of wood used by homeowners, and by the variety of ways in which people combine wood with other fuels to heat their homes. Gaining a better understanding of wood use for heating is important for a number of reasons. First and most obviously, like other fuels wood competes with electricity as a heating fuel. Second, since houses with wood heating equipment nearly always have other heating equipment as well, these houses can switch from using one heating fuel to another almost instantly; this exposure to rapid changes in demand is a problem utility planners must take seriously. Third, a more subtle problem is the confusing effect of uncertain amounts of wood heat on the understanding of space heating requirements; even a small amount of unrecognized wood use can significantly distort cost-effectiveness calculations for thermal integrity improvements.

Commercial Model

The commercial sector demand model used by the Council since 1982 is a descendant of the model originally developed at Oak Ridge National Laboratory by Jerry Jackson.[6] This model shares most of its structure with commercial sector end use models used by the Electric Power Research Institute (EPRI)and BPA. The model was adapted for use in the PNW by Jerry Jackson on contract to the Council.[7]

Base Year Data. In 1985, a review of the model and its base year data, directed at improving forecasting accuracy of the commercial model, was carried out by Jerry Jackson as contractor for the Council. The first stage of this work was an evaluation and adoption of new base year data on floorspace and energy use, data developed for BPA by Synergic Resources Corporation (SRC). The overall effect of these changes was a modest (around 5%) increase in projected energy use at the end of the 20-year forecast.

Fuel Choice. The model's projections of space heating fuel choice were then examined. The data available from utilities indicated that electric space heating was chosen for a larger share of new buildings than the model projected. To address this problem, Jackson used historic fuel prices to simulate fuel choice in new buildings from 1973 to 1979. He adjusted the parameters of the fuel choice module until market shares in new buildings in 1979 matched the data. The resulting performance of the model is in line with recently-observed fuel choices, both in the PNW and other regions of the U.S. Fuel choice remains an area of interest for future development of the model, however.

Forecast vs. Actual Sales. A second concern surfaced when the revised commercial model's projections were compared to sales data through 1984.

The model's projections were lower than sales, by around 15%. A well-documented surplus of commercial floorspace, which has persisted through the early 80's, appeared to be partially responsible for this underforecast.

The commercial model does not project a surplus of floorspace in the early 1980's; it projects sufficient floorspace growth to house projected employment in commercial activities. This algorithm is quite reasonable for the long-term relationship between floorspace and employment, but neglects factors which influence construction decisions in the short term, such as tax law changes. As a result, while the floorspace projected by the commercial model may be accurate in the long term, it may lag behind actual construction for some years in the short term.

This seems to have been the case for the early 1980's in the PNW. The major metropolitan areas of the region, Seattle and Portland, had vacancy rates of nearly 20% in office buildings. Further, interviews with building managers revealed that partially occupied buildings use energy out of proportion with their occupancy rate. In these conditions, the model, even with accurate employment figures, would simulate too little floorspace and too little energy use.

To test whether these conditions were sufficient to account for the errors in projected energy use for the early 1980's, the employment inputs to the model were adjusted to bring more floorspace into the stock during that time. The adjusted floorspace projections were consistent with an assumed vacancy rate 13% higher than normal for three building types, and assumed that vacant floorspace consumed 70% as much energy as occupied floorspace in the same buildings. After 1985 floorspace was assumed to move toward its long-term trend, usually reaching normal vacancy rates by 1990. This process resulted in electricity use projections which were significantly closer to actual sales in the early 1980's. The model continued to underforecast, but by 5-6% instead of the 15% cited earlier.

Based on the results of this test, the assumption of a temporary surplus of floorspace was included in the Council's formal forecasts. The remaining discrepancies between projections and sales data are modest, but are consistent with other data which suggest a growth trend in "miscellaneous" use of electricity in the commercial sector. Commercial building data from ELCAP, mentioned earlier, may help to understand new patterns of use that may be developing.

ANALYTICAL CONSISTENCY

The Council's fundamental objective is to minimize the cost of meeting future demand for electricity services in our region. Estimating that cost is more complicated than simply choosing future resources which can provide a given amount of electricity most cheaply, when standing alone. Instead, planners must estimate the extra cost of new resources as they interact with the entire electrical system, including the hydroelectric resources already in place.

The Hydroelectric System

The hydro system, as it has been developed and used in the PNW, has several qualities which are different from most utility systems. First, the energy capability of the hydro system varies substantially from year to year. Because of varying precipitation, the energy generated by the hydro system can be 25 to 30% more or less than average.

Second, the energy capability of the hydro system also varies from season to season. Each new resource has its own seasonal pattern of energy production. The value of electricity provided by each resource will depend on its match with the seasonal pattern of demand and the seasonal pattern of production by the rest of the generating system.

Third, peak generating capacity is adequate and likely to remain so for some time. The Council's main planning concern is to provide adequate energy, rather than peak capacity.

Fourth, system planning has been based historically on the system's capability to generate electricity in low water years. Since most years will experience more precipitation than historic lows, a significant amount of "non-firm" electricity can be expected. There are over 3,000 average megawatts of non-firm electricity at historical average water flows. This non-firm electricity has variable costs which are close to zero.

Evaluation of alternative resource strategies must take these features of the hydro system into account. The primary tool for evaluation has been a sophisticated simulation model of the operation of the power system, the System Analysis Model (SAM). This model uses a random sample of historical water flows, forecasts of electricity demand, and specified new resources to meet increased demand. New resources are simulated operating when they are needed, or shut down when cheaper (e.g. non-firm) electricity is available. The costs of system operation are simulated over a number of water conditions to generate an expected cost of system operation.

SAM has demonstrated that some kinds of resources interact much differently with our generating system than with a mostly-thermal system. For example, nuclear generating plants, with their very low variable operating costs, are usually operated whenever they are available in a mostly-thermal system. In the PNW, however, they may be shut down when non-firm hydroelectricity is available, since it is even cheaper than nuclear plants' variable operating costs. At the other end of the resource spectrum, combustion turbines, with high variable operating costs, have been reserved for peaking operation in most thermal systems. In the PNW they might reasonably be used as baseload resources in some circumstances. They could be built as insurance against an energy shortage in a low-water year, with the expectation that they would not be used at all in most years, but used around the clock when low water flows do occur.

Interdependence of Analytical Components

The Council's planning process uses three analytical components:

1. load forecasts, which project potential demand,
2. conservation evaluation, which estimates the size and cost of conservation resources, and
3. generating system analysis, which calculates the cost of meeting projected demands with various combinations of generating resources and conservation.

To illustrate the potential problems of inconsistency between these components, consider a conservation resource which is a program to improve thermal integrities of new homes heated by electricity. The conservation evaluation of this resource depends on the number of new homes that will be affected and the degree of improvement in efficiency obtainable by the program. The number of new homes used in sizing the conservation resource should be based on the number included in the load forecast. Likewise, the efficiency improvement obtainable by the program should be linked to the efficiency levels projected in the load forecast. Thus, conservation evaluation depends on the load forecast.

But dependence also runs in other directions. Depending on the form of the conservation program, it may affect the share of new homes which are heated by electricity. Thus, not only does conservation evaluation depend on the load forecast, but vice versa. Similarly, the load forecast will depend on the construction schedule for new resources (resulting from generating system analysis), and the generating system analysis depends fundamentally on forecasted demand and estimated conservation resources.

Ignoring these interactions risks significant distortion of planning decisions. As much as possible, we developed model structure and analytical procedures to reflect interactions and check consistency between components. Achieving complete consistency among all the components of the system is probably impossible; maintaining acceptable consistency requires constant effort.

Consistent Technology. One means of improving consistency was the translation of new information on conservation technology, developed in conservation assessment, into terms usable in the demand models ("technology curves"). The new information was particularly important in updating the thermal integrity technology curves of the residential model, but was also useful for water heating, refrigerators, and freezers.

Independent Assessment of Conservation. The demand models were used as a means of estimating the effects of conservation programs, separate from the primary assessment process. The comparison of estimates made by two independent processes often led to improvement in one or both of the processes. The demand models were the only practical way to take some factors, such as the interaction of efficiency with utilization and fuel choice, into account.

Expanded Output. To make it easier to assure consistency, output of the forecasting models was expanded to provide information in easily usable form for use in other analysis. For example, output included projected efficiencies of new refrigerators in kwh per year, and numbers of new electrically-heated houses constructed, for each year in the forecast. In the case of generating system analysis, the transfer of this supplementary output was automated.

Frozen Efficiency Forecast. Even with expanded output from the forecast models, the Council confronted a further problem of consistency throughout its planning system. This problem was made more acute by the qualities of the PNW hydro system outlined earlier. To describe the problem:

One of the Council's primary tasks was to evaluate conservation as a potential resource, on an equal basis with generating resources. The most natural way of doing this was to treat conservation as a generating resource in SAM, so conservation's interactions with the hydro system would be taken into account. At this point the Council confronted a problem of consistency between the size of conservation resources and the forecast demand for electricity.

The amount of conservation available is essentially the product of cost-effective energy savings per unit and the number of units. For example, assume that the average household's use of electricity for water heating is currently 5,000 kwh per year, that a more efficient water heater can reduce reduce this use cost-effectively to 4,000 kwh per year, and that the number of homes available for this efficiency improvement is 4 million. We can estimate the conservation available from more efficient water heaters by (5,000 - 4,000) X 4,000,000 = 4 billion kwh per year.

Given such an estimate, we can represent a program to improve the efficiency of water heaters as a generating resource which produces 4 billion kwh per year in SAM. But if SAM simulates the use of this resource to help meet a conventional demand forecast, it can introduce a bias due to "double counting" efficiency improvements. Under many planning assumptions conventional demand forecasts project price-induced improvements in efficiencies, such that projected average use is less than current use. For our example, the conventional forecast might project improvements in efficiency in water heating by the end of the planning period which reduce average use by 5%, to 4,750 kwh per year. This would mean that the conservation resource available to meet the conventional demand forecast is only (4,750 - 4,000) X 4,000,000 = 3 billion kwh per year, instead of the 4 billion kwh estimated above.

Thus to compare conservation resource estimates based on current efficiencies to demand forecasts which embody projected efficiencies is inconsistent. Resource plans based on such comparisons will tend to depend too much on conservation resources, and will tend to underestimate the quantity of non-conservation resources which will be required.

There are two solutions to this problem: 1) For every (conventional) forecast, estimate the projected price-induced efficiency improvement, and reduce the size of the conservation resource represented in SAM accordingly. Since the amount of price-induced efficiency improvement will change with every change in projected electricity prices, the size of the conservation resource in SAM will be adjusted for virtually every analysis. 2) For purposes of SAM analysis, make an artificial demand forecast which projects demand for electricity in the absence of efficiency changes which are part of the conservation programs under consideration. It should be emphasized that this artificial forecast should not exclude all response to electricity price changes; it should exclude only those actions which are included in the prospective conservation programs.[8]

The first approach would have required time-consuming recalculation of conservation resources with virtually every variation in assumptions. This appeared to be unnecessary, given the relative simplicity of the second approach, once the required modifications were made to the models. In brief, the models set aside the price-induced efficiency levels of a specified year X, for end uses which are the subjects of proposed conservation programs. These efficiency levels are used in projecting electricity use in each post-X year. The model's simulation of the other components of price response, fuel choice and utilization adjustments, is unchanged. The result is a forecast which is different from a conventional ("price-induced") forecast, by the amount of price-induced efficiency change included in the conventional forecast. This forecast, while artificial, is appropriate for use in SAM in combination with conservation represented as a generating resource.

This forecast is called a "frozen efficiency" forecast. When electricity prices are projected to increase, the frozen efficiency forecast is higher than a conventional, price-induced forecast. In the Council's 1986 plan, the frozen efficiency forecasts of residential and commercial demand were higher than the price-induced forecasts by amounts which ranged from 0.5% for the low growth scenario, to 6.8% for the high growth scenario.

CONCLUSIONS

The end use electricity demand models used by the Council have been used in several roles: They make up part of the forecasting system, they are used to estimate impacts of policy decisions, and they are used to improve consistency between the forecast and other components of the planning process. The Council's recognition of the fundamental uncertainty of demand forecasts has led to an emphasis on flexible planning. In these circumstances, the non-forecasting roles of the demand models have become increasingly important, and the end use models are well-suited to fill these roles. While the Pacific Northwest is unusual in some respects, the use of end-use demand models in similar roles in integrated resource planning should be valuable for other regions as well.

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1./For an illustration of consistency problems which can arise in such planning efforts, see Bruce Tonn, Ed Holub and Michael Hilliard, "The Bonneville Power Administration Conservation/Load/Resource Modeling Process: Review, Assessment, and Suggestions for Improvement", ORNL/CON-190, Oak Ridge National Laboratory, Oak Ridge TN January, 1986.

2./See Eric Hirst and Janet Carney, *The ORNL Engineering-Economic Model of Residential Energy Use*, Oak Ridge National Laboratory ORNL/CON-24, Oak Ridge TN, July 1978 and Dennis O'Neal and Teresa Vineyard, "The Oak Ridge National Laboratory's Residential Energy Use Model: Version 7.1" in *Proceedings: End-Use Models and Conservation Analysis*, Electric Power Research Institute EA-2509 Project 1050, Palo Alto CA July 1982.

3./See Charles River Associates, Incorporated, *Final Report, Volume 1: Model Documentation* Northwest Power Planning Council, Portland OR November 1982, *Final Report, Volume 2: Data and Program Documentation* Northwest Power Planning Council, Portland OR, April 1983. CRA also constructed a model to project electricity prices, and programmed links which allowed all the sectoral demand models to run as a single forecasting system.

4./The MCS are standards which reduce electric space heating requirements by about 70% compared to the region's 1979 stock of residences, or about 45% compared to 1986 levels of building codes in the region.

5./ See Kenton Corum, "Interaction of Appliance Efficiency and Space Conditioning Loads: Application to Residential Energy Demand Projections", Vol. E, Proceedings of the ACEEE 1984 Summer Study on Energy Efficiency in Buildings, American Council for an Energy Efficient Economy, Washington D.C., August 1984.

6./Jerry Jackson, Steve Cohn, Jane Cope, Willam S. Johnson, *The Commercial Demand for Energy: A Disaggregated Approach*, Oak Ridge National Laboratory ORNL/CON-15, Oak Ridge TN, April 1978.

7./Jerry Jackson and Associates, *Development and Application of the NPPC Commercial Energy Demand Model*, Northwest Power Planning Council, Portland OR, November 1982.

8./It's worth noting that both of these approaches depend on the ability to isolate efficiency improvement from other components of price response. The end use models used at the Council have this ability. They simulate price response as a combination of utilization changes, fuel choice changes, and efficiency changes.