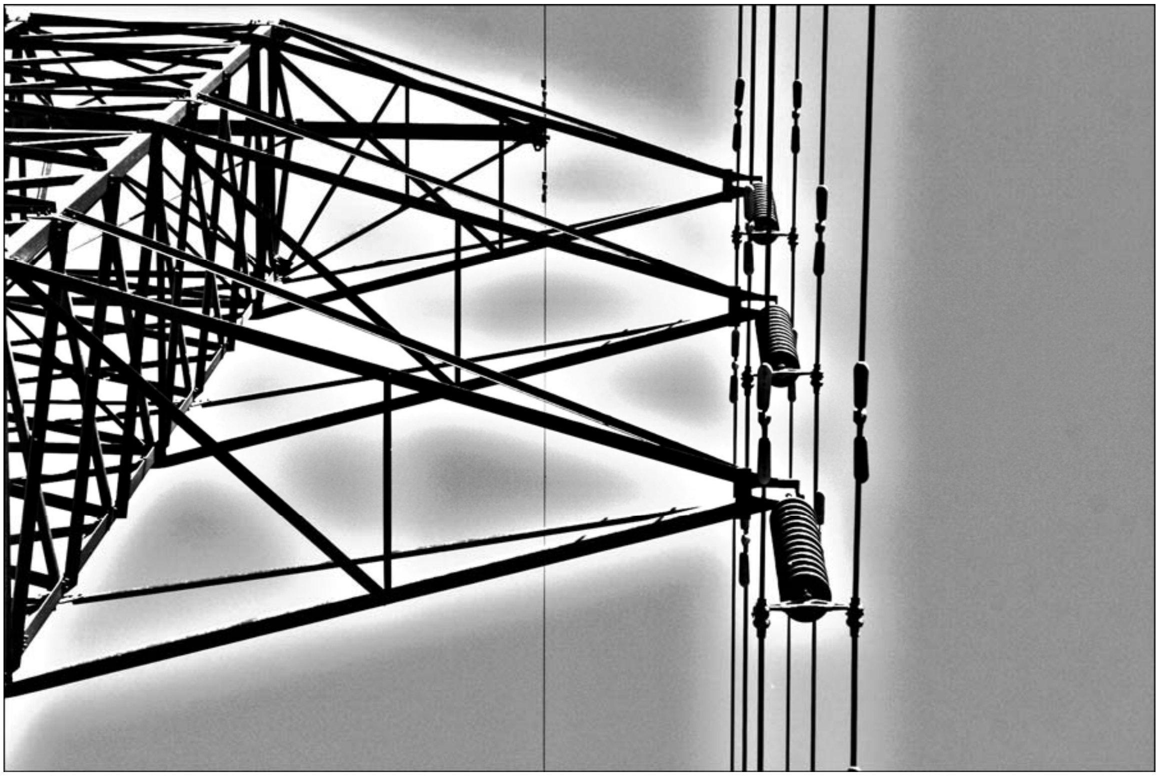
An Overview of the Council's Power Planning Methods



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It has been 30 years since the Northwest Power and Conservation Act was passed and the Pacific Northwest Power and Conservation Council was created. One of the primary requirements of the Act is for the Council to develop a least-cost plan for meeting the region's future electricity needs. The essential characteristics of the Council's power planning methods were established in the Act and implemented in the first power plan, which was adopted in 1983. The Council established the basic principles and methods for integrated resource planning in that first power plan. Since then, the methods and tools have been refined with each plan. The Council adopted its Sixth Power Plan in March 2010.

The purpose of this paper is to document the Council's electricity planning methods. There is currently no single readily-accessible description that provides an overview of the entire process. There are detailed descriptions in plan appendices, various papers, and presentations of parts of the planning process, but there is no summary of the entire process in significant detail or how the methods have evolved. This paper is intended to fill that void. It is the Council's hope that this document will prove useful to utilities and others involved in electricity planning.

This paper describes the Council's planning methods in an intermediate level of detail. Each chapter will start with a short summary of the approach, followed by more detail on the tools and strategies. The rationale for the methods used will also be described. References are provided to more detailed descriptions of methods and models.

BACKGROUND

The Northwest Power Act prescribed the basic scope and stance of the Council's planning. [1] The power plan is required to be a long-term, 20-year strategy for meeting the region's electricity needs. Its objective is to describe a resource strategy that ensures an "adequate, efficient, economical and reliable power supply" at the lowest cost. The Act refers specifically to the Bonneville Administrator's obligations as the object of the Council's power plan. The Act provided Bonneville the tools to acquire resources to meet the entire region's electricity needs, but in reality, resource acquisition has been more diverse. Nevertheless, the Council still plans

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[1] 16 United States Code Chapter 12H (1994 & Supp. I 1995). Act of Dec. 5, 1980, 94 Stat. 2697. Public Law No. 96-501, S. 885.

from a regional perspective to guide Bonneville, and the plan has a long-term focus to minimize the cost of the entire regional power system.

The Act also includes directives about resources that should be considered in the Council's planning. Resources included in the plan are to be cost-effective. That is, they should result in a resource strategy "to meet or reduce the electric power demand … of the consumers of the customers at an estimated incremental system cost no greater than that of the least-cost similarly reliable and available alternative measure or resource." System cost is defined to include all costs of a resource over its useful life, including quantifiable environmental costs.

A great innovation of the Act was to include conservation as a resource. Conservation is specified as the first priority resource, and it is given a 10 percent cost advantage for planning purposes. The Act is clear that conservation is the more efficient use of electricity, not conservation in the sense of going without the services electricity helps provide. In the remainder of this paper the term improved efficiency is used to refer to the conservation described in the Act. The definition of efficiency as a resource has wide-spread implications for the Council's planning methods.

The Act specifies additional resource priorities after efficiency. Second priority is generation from renewable resources, followed by high-efficiency generation such as combined heat and power applications, and finally other generating resources. However, these additional priorities serve only as tie breakers when costs are equal.

Defining improved efficiency of use as a resource implies that the Council's least-cost objective is not the cost of electricity itself, but rather, the cost of the services that electricity provides to consumers. These services, such as heated space or cooled beer, are provided by electricity combined with various types of equipment and buildings. It is quite a different proposition to minimize the cost of electricity services than to minimize the cost of electricity itself. It puts the focus on consumers' electricity bills, rather than electricity prices, or the cost of the electricity itself.

The Act's focus on electricity services also creates an important tension between the Council's planning and the typical focus of individual utilities on electricity as a commodity and the prices they charge for electricity. The Act requires a societal focus as opposed to a utility business focus. Although the Act itself does not impose requirements on individual utility planning to have a societal perspective, many state laws have done so. Most states have imposed integrated resource planning requirements for investor-owned utilities that generally mirror the requirements of the Northwest Power Act. In addition, Washington has imposed requirements on investor-owned and consumer-owned utilities of a certain size to use the Council's planning methodology to develop their own resource plans.

The other important guidance in the Act regarding resources to consider in planning relates to technology. The Act defines a cost-effective resource to be “reliable and available within the time that it is needed” and lower cost than “the least cost similarly reliable and available…resource.” This has been interpreted by the Council to mean that Council plans should not be overly speculative about future technology development and costs in either efficiency or generating technologies.

The Act also takes into account “other criteria which may be set forth in the plan.” The most important of these, which constituted an innovation by the Council in electric power planning, was systematic accounting for uncertainty and risk. The Council’s power plans have always focused on uncertainty about the future and how to plan in the face of that uncertainty. In the history of the regional power system, we have experienced the twin dangers of future uncertainty: overbuilding and underbuilding. In the time leading up to the Act and the formation of the Council, the region planned its power system without recognizing uncertainty. This resulted in a huge overinvestment in new generation plants that turned out to be unneeded and increased electricity costs by several hundred percent. A different effect of uncertainty was demonstrated in 2000-2001. In this case, uncertainty about the extent and nature of power industry restructuring led to inaction by utilities that resulted in a shortage of resources to serve load and another large increase in power costs. Recognizing the cost of these events led to improved techniques for planning under uncertain futures in the Council’s most recent power plans. The purpose of the Council’s analysis of uncertainty is to understand future risks and recommend actions that meet electricity needs reliably while avoiding those two major risks.

Finally, the power plan must also incorporate the Council’s fish and wildlife program. This means that the plan must accommodate the requirements of the fish and wildlife program and ensure that the power system can provide for them. Specifically, the estimate of the hydro resource in the forecast of available generating resources has to take into account how the operations for fish and wildlife will affect generation. Further, the resource plan for the next 20 years has to not only address the potential growth in energy demand but also accommodate the effects of the fish and wildlife program in a way that will allow the administrator to meet his or her obligations under that program, too.

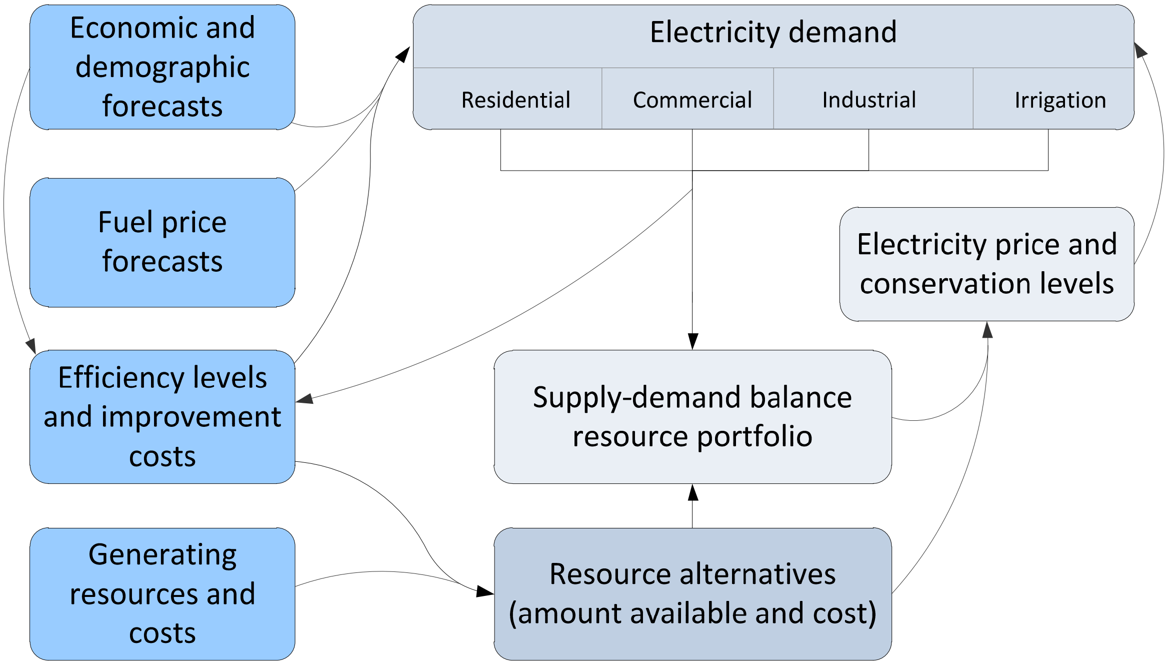
All these requirements have guided the development of the Council’s planning methods from the first power plan to today. They have a profound effect on the individual components of a power plan, and on how they are combined to develop a plan. The Council has typically considered the following major components of planning: a 20-year demand forecast, generating resource alternatives, potential efficiency improvements, and a resource plan to meet demand.

OVERVIEW OF PLANNING PROCESS

Prior to the Northwest Power Act, the typical planning process was a fairly straightforward process: forecast the demand for electricity and then stack up a set of resources to meet that demand. Treating efficiency improvement as a resource changes the process significantly, illuminating the dynamic interactions among efficiency, demand, and resource choice and composition.

All these considerations create the need for a feedback loop in planning. An initial demand forecast is made based on a preliminary forecast of electricity price. An assessment of a least-cost resource strategy is developed to meet the demand. The resource strategy, which includes efficiency improvements, changes electricity prices because both the cost of generating resources and also amount of electricity sales through which the costs are recovered change. To the extent that electricity prices are different from the preliminary assumption, demand changes and the process starts again. This is an iterative process that continues until the beginning and ending prices are close enough to make little difference. Figure 1 provides an overview of the Council's planning process.

Figure 1: Overview of Planning Process



The Council uses several models in its planning process. The Demand Analysis System is used to assess electricity demand and the potential number of applications for efficiency measures. A fuel price forecasting model is used to develop estimates of wholesale and retail fuel prices based on assumptions about energy commodity prices. The commodities considered include natural gas, oil, and coal. There are two models that provide detailed financial calculations for generating and efficiency resource costs. Microfin is used to calculate the levelized cost of generating resources and ProCost is used to calculate the levelized costs of efficiency resources and build efficiency supply curves. Three other models are used for resource planning. The AURORA^{xmpTM} Electric Market Model[2] of Western electricity markets is used to forecast electricity market prices at different points in the Western Electricity Coordinating Council area. The Genesys model provides a detailed assessment of the Pacific Northwest electricity system, with particular focus on the capabilities of the hydroelectric system. It is also used to evaluate the adequacy of the Northwest power system. The Resource Portfolio Model is used to develop the Council's power plan resource strategy. The role of these models is discussed further in the following sections and a summary table is appended to the paper.

GETTING STARTED

IDENTIFYING KEY ISSUES

Even before the Council begins collecting forecasts and data, it proposes and solicits comments on the key issues that a power plan should address. For example, for the Sixth Power Plan important issues included uncertain climate legislation, improving the ability to evaluate seasonal and peak electricity requirements, and enhancing flexibility to integrate variable output resources, such as wind, into the regional power system. Key issues can help shape the organization and focus of the power plan and dictate certain types of analysis. The key issues have been different for each of the Council's power plans.

CURRENT SYSTEM AND FORECASTING ASSUMPTIONS

Developing a power plan begins with collecting information on the existing power system, assumptions about future conditions, and setting important parameters for planning. These, and a set of planning models, form the basis of the analytical work for a power plan. A good representation of the existing regional power system is an important first step for the plan. The Council maintains data on existing generating resources, energy prices, past efficiency improvements, existing codes and standards, and demand for, and uses of, electricity.

The major assumptions going into the plan include economic growth forecasts, fuel price forecasts, costs and availability of efficiency and generation resource alternatives, and financial parameters such as interest rates and discount rates. These assumptions and forecasts drive the various planning models used by the Council. An important part of the assumptions and forecasts about future conditions is recognizing uncertainty and determining a range of

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[2] The AURORA^{xmpTM} Electric Market Model, available from EPIS, Inc (www.epis.com).

reasonable futures to consider. Public input and the advice of various advisory committees are important to developing these assumptions.

The starting assumptions about fuel and electricity prices are focused on basic commodity prices. For natural gas it is the average U.S. wellhead price; for oil it is the world oil price; for coal it is the minemouth price of Powder River Basin coal; and for electricity it is the wholesale market price (typically at the Mid-Columbia trading hub).

Consumers' demand for these energy sources and the costs of fuels for power generation are based on retail prices or wholesale delivered prices. These forecasts are based on historical relationships to commodity prices, adjusted for expected changes likely to affect the relationships. For example, oil price assumptions will affect coal transportation costs, and new natural gas pipeline development can affect the relationship of natural gas prices at different locations.

WHOLESALE MARKET ELECTRICITY PRICES

The wholesale market price of electricity is both an important input to the planning process and a result of the planning. These prices are determined in a Western interconnected power grid, and the influences on the prices extend well beyond the Pacific Northwest. At the same time, there are variations in these prices at different locations within the system.

Wholesale electricity prices are important for power planning. These prices, as they vary over time, are the key determinants of how cost-effective particular generating or efficiency resources are. In planning, and in electricity markets, the value of a particular power plant is determined by its costs relative to the market price of electricity. Similarly, the value of improved efficiency is to a significant extent determined by its relationship to market electricity prices.

The Council uses a model of the Western power market called AURORA^{xmpTM} to forecast wholesale power prices. The AURORA^{xmpTM} model is developed and marketed by EPIS, Inc. The Council runs a version of the model that takes the Council's data on existing power plants, fuel prices, and growth in electricity demand and produces forecasts of hourly wholesale electricity prices. The AURORA^{xmpTM} model forecasts used by the Council are point forecasts assuming expected conditions. Uncertainty in these forecasts is examined by scenarios relating to the ranges of demand, fuel price, and carbon policies. Additional variation and volatility are added when the wholesale prices are provided to the Resource Portfolio Model.

When a resource strategy is developed, the types of new resources for the region typically change from what was initially assumed in the AURORA^{xmpTM} model. In addition, the level of efficiency included can change the demand for electricity in the region. Both can affect the forecast of electricity prices, although in practice, unless the price of natural gas or the assumed average cost of carbon emissions change, the changes in market electricity prices caused by demand or efficiency changes tend to be small.

DEMAND FORECASTING

SUMMARY

Treating efficiency as a planning resource has important implications for the approach to forecasting electricity demand, as well as for the interactions between the demand forecast and the resource plan. To properly include efficiency into resource planning, the demand forecast must be based on a model of electricity end-uses and an inventory of the number, and technical efficiency, of the equipment and buildings used to convert electricity into energy services. Only then can efficiency improvements and generating resources be truly integrated in planning.

The major alternative to end-use structural demand models is an econometric approach. This approach is based on historical trends in electricity use, and economic and other measures likely to have affected those trends. Problems with this approach for electricity planning include: an inability to determine to what extent the demand forecast might already reflect assumed continuation of past efficiency gains; and an inability to estimate the effects of future efficiency actions or codes and standards on demand. For these reasons, the Council does not use an econometric approach to demand forecasting.

Regardless of the effort put into modeling and forecasting, however, many uncertainties remain about future electricity demand. Forecasts of demand are driven largely by assumptions about economic growth, energy prices, future technologies, and other factors that cannot be predicted with a significant degree of certainty. Limits to the available data and the necessary simplifications in any model add doubt, too. Therefore, the Council focuses on a wide range of potential future demand scenarios and includes potential cycles in demand growth.

END-USE FORECASTING OF DEMAND

The Council's forecasts of demand are built from estimates of electricity use for a large number of specific end-uses in several building types. For any specific end-use, such as residential space heat for example, total electricity use is built from a relatively simple relationship: space heating electric use equals the number of electric space heaters times the electricity use per space heater. The electricity use per space heater includes two concepts, the technical efficiency of the space heat appliance and building shell, and the demand for the energy services it provides. The latter will depend on weather, home size, occupant behavior, and the cost of heating, among other factors. A well constructed end-use model can estimate the effects of an efficiency measure through its effect on technical efficiency, the resulting reduction in the cost of heating, and any change in consumer usage as a result of lower heating costs (so-called take-back effect).

Not all energy services are provided by electricity. Therefore, most end-use models will include other fuels for selected end-uses. Space and water heating, cooking, and clothes-drying, for example, may use alternative fuels. By modeling these, along with electricity, the forecast can capture changing fuel shares over time.

The number of end-uses that are modeled varies by sector. In the current version of the Council's demand forecasting system there are three types of residences (single-family, multifamily, and manufactured homes) with 12 end-uses for each. Residential demand growth is driven primarily by growth in population and households, but it is also affected by the prices of electricity and alternative fuels, and efficiency improvements found to be cost-effective in the resource strategy.

The commercial sector models 17 different building types and 7 different end-uses. The commercial demand forecast is driven by square footage for each specific building type, which in turn is driven by employment in associated non-manufacturing sectors related to specific building types. This detailed approach helps capture the effects of the changing structure of the economy over time. Different building types can have significantly different end-uses and levels of electricity use. As the population ages, for example, the need for retirement facilities and health care is likely to increase as the growth in educational facilities decreases. These trends can affect not only electricity demand, but also will change the efficiency improvement opportunities over time.

Industrial electricity use is forecast separately for 20 different manufacturing sectors and four end-uses. It is driven primarily by forecasts of output for these sectors. Electricity use varies, often dramatically, among different manufacturing sectors. One key factor in the slowing growth of demand in the region has been a shift away from electricity-intensive industries such as aluminum, pulp and paper, and lumber.

The Council's end-use model also forecasts demand in the agricultural and transportation sectors. This enables the Council to forecast demand for electricity and fuel across all sectors of the economy. In order to model all of the demand sector forecasts, detailed assumptions are required about the possible range and composition of economic activity in the future.

Building a forecast of electricity demand from specific end-uses of electricity is critical to reliably integrating resource planning. Without it, accurately tracking efficiency and its effects on demand and, in particular, other generating resource needs, is difficult. At the same time, end-use structural models require a great deal of detailed data about the stock of buildings and energy-using equipment in the region. Much of the data the Council has relied on is becoming dated because the region has not maintained the investments in data collection needed to support up-to-date end-use planning. Recent efforts by the Northwest Energy Efficiency Alliance have helped to update information, and further data collection efforts are being discussed.

DEMAND FORECASTS FOR INTEGRATED PLANNING

THREE KINDS OF DEMAND FORECAST

The Council's demand forecasts interact with other planning steps in complicated ways. The Council typically produces a forecast of demand reflecting expected economic growth and energy prices. This forecast also includes the effects of existing energy codes and appliance standards on future electricity demand. This is referred to as a "price effects" forecast and is typically what the Council includes in its plan as the required 20-year forecast of electricity sales. The demand forecast is for electricity use as measured at consumers' facilities. For resource planning it is converted to a "load forecast" by adding estimated transmission and distribution losses. In addition to average annual electricity use, planning now requires estimates of peak loads, seasonal demand patterns, and hourly load profiles for specific end-uses. These end-use patterns are important for assessing the effect of efficiency changes on peak loads and seasonal energy demand.

However, another adjustment is needed before the demand forecast can be used in resource planning models. The "price effects" forecast reflects some reduction in demand due to consumer response to changing energy prices. These are the result of changes in the efficiency of equipment and buildings, changing usage patterns, and also changes in fuel choice for some end-uses. These efficiency changes could potentially duplicate part of the efficiency potential estimated in the resource assessment. If these efficiency improvements were left out of the demand forecast (thus reducing demand) and also counted in the potential efficiency resource supply curve, it would be double counting. This was a major concern as the Council developed its first power plan. The solution is to add the technical efficiency changes due to price effects before the demand forecast is used for resource planning. This adjusted (higher) demand forecast is termed a "frozen efficiency" forecast.

There is one additional version of the demand forecast. This involves reducing the demand forecast for the efficiency resource chosen in the resource strategy. Removing future efficiency improvements included in the resource strategy from the demand forecast gives a lower forecast of actual electricity "sales." This forecast, usually referred to as the "sales forecast" is more appropriate for transmission and distribution system planning for example, or for sizing the need for new generating resources, because it represents the expected consumption of electricity after achieving the efficiency improvements recommended in the resource strategy.

HELPING SIZE EFFICIENCY POTENTIAL

The demand forecast also provides direct input to the estimate of efficiency potential. The end-use forecasts are built from the number of new and existing buildings and equipment. The potential savings from, for example, a more efficient heat pump will depend on how many new homes might install heat pump systems and how many existing heating systems might be converted to new heat pump systems. This information is provided from the demand forecasting system to the efficiency resource estimation.

The demand forecast helps determine the availability of lost-opportunity efficiency improvements over time. Those are efficiencies only available and cost-effective in new buildings and equipment when they are constructed or purchased. One way to achieve these savings is through codes and standards. The effect of an appliance efficiency standard, for example, will depend on the number of new appliances expected to be bought during the planning period. In addition, by putting cost-effective efficiency levels into the demand model, any significant take-back effects that might reduce the expected net savings from an efficiency measure can be estimated.

An important part of the planning process is making sure the end-use categories and starting efficiency levels in the demand model are consistent with the assumptions in the efficiency resource evaluation. Significant inconsistencies between the demand model representation and assumptions used in the efficiency resource calculations would lead to planning errors.[3]

POTENTIAL RESOURCES AND COSTS

Potential resources include choices about new generating capability as well as cost-effective improvements in efficiency. The Act requires comparable treatment of these two types of resources in the Council's power plan. The treatment of generating resources and efficiency is described in the following sections. A more complete description of what is required to treat efficiency comparably to generation is provided in a staff paper.[4]

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[3] Schilmoeller, Michael. *Utility Conservation Targets and Load Forecasting*. Northwest Power and Conservation Council. November 2010.

[4] Eckman, Tom. *Some Thoughts on Treating Energy Efficiency as a Resource.* Northwest Power and Conservation Council. November 2010.

RESOURCE COSTS

The Act provides guidance on how the Council calculates resource costs. It specifies that the costs of a conservation or generating resource are to include an estimate of “all direct costs” over the effective life of the resource, including “quantifiable environmental costs and benefits ... directly attributable” to the resource. More precisely, Section 3(4)(B) provides:

> “For purposes of this paragraph, the term ’system cost’ means an estimate of all direct costs of a measure or resource over its effective life, including, if applicable, the cost of distribution and transmission to the consumer and, among other factors, waste disposal costs, end-of-cycle costs, and fuel costs (including projected increases), and such quantifiable environmental costs and benefits as the Administrator determines, on the basis of a methodology developed by the Council as part of the plan, or in the absence of the plan by the Administrator, are directly attributable to such measure or resource.”

For purposes of minimizing the cost of the resource plan, the Council takes the perspective of the region’s consumers. This perspective is sometimes called “total resource” or “societal” cost. All quantifiable regional costs of a resource are included regardless of who pays the costs.

Direct generating resource costs, when owned by or contracted to utilities, typically fall directly on the utility’s customers. However, most generating plants also have indirect costs associated with environmental effects. These costs may be external in some cases, so that the costs do not fall directly on the utility or its customers through electricity bills. In other cases, the utility has taken required mitigation actions whose costs are included in its customers’ bills. The Council’s general policy is to use required mitigation costs to reflect quantifiable environmental cost. This may be the cost of pollution-control equipment that is recovered through electricity bills, or it might be the cost of emissions permits for SO_2. In the Sixth Power Plan, carbon emissions were treated as a risk with a range of possible costs. In general, the Council has not attempted to place values on damages from emissions. The decision about the desirable level of emissions mitigation is assumed to be determined in a different policy arena, and the Council includes the cost of the mitigation actions.

In the case of efficiency resources, the costs are less frequently borne entirely by utility ratepayers. Typically, a utility efficiency program will include incentive payments that do show up in consumers’ electricity bills, but the consumers’ contributions do not. When efficiency is achieved through codes and standards or market transformation activities, most of the cost falls directly on consumers. The Council uses the total resource cost for efficiency regardless of who pays the cost.[5] For efficiency resources, the Council includes quantifiable direct costs of measures and programs. This includes equipment, labor, maintenance, periodic replacement, quantifiable non-energy costs or benefits such as water savings, program administrative, and evaluation costs.

The planning measure of total power system cost for the regional power system is only the “forward-looking” costs. Those are costs that can be affected by future assumptions and resource choices. They include the variable operating costs of existing resources, and the capital and operating cost of future resources, including the cost of efficiency improvements. The “sunk” capital costs of existing resources are irrelevant to the development of the power plan because they are not changed by any of the future assumptions or resource choices in the plan.

The cost of alternative resources and the cost of the regional power system as a whole are typically expressed in constant dollars, that is, in dollars valued at a particular point in time with the effects of general inflation on prices and costs omitted. Further, costs are generally summarized as present values or levelized costs. These measures are necessary in order to compare the cost of resource alternatives that have different time patterns of costs.[6] Figure 2 shows a supply curve of generating and efficiency resources, including cost-uncertainty ranges. It is an illustration of how resources alternatives are developed for the plan.

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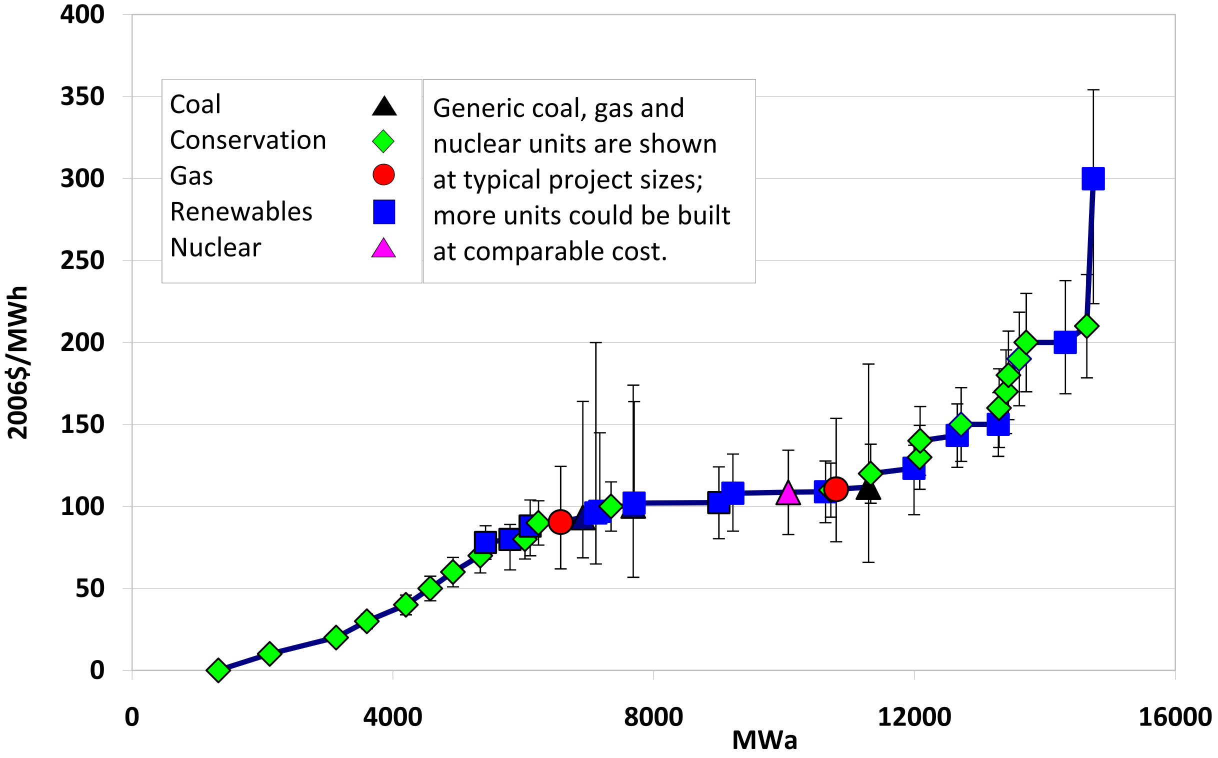
[5] Note that the Council’s approach is consistent with the test referred to as societal in the “California Standard Practice Manual for Economic Analysis of Demand-Side Programs and Projects.” That manual includes a test called the total resource cost test, which is not the same of the Council’s use of the term.

[6] Additional information on discounting and levelization is provided in Chapter 13 of the 1991 Power Plan, and Appendix N of the Sixth Power Plan.

Figure 2: Example of a Total Resource Supply Curve



GENERATING RESOURCES

SUMMARY

In order to find the best resources for the regional power system in the future, the Council evaluates a wide-range of possible generating resources. Each resource is considered in terms of its costs and other important characteristics. Costs include a resource's capital and fixed operating cost and fuel and other variable operating costs. Varying cost patterns over a resource's life-time are converted to present values or levelized costs to compare resources with different time patterns of cost. Important resource characteristics, in addition to cost, include: the time required to put a resource into service (lead-time); the size of a typical generating unit; generating efficiency; emissions; expected technology trends; contributions to capacity, energy, and flexibility; access to transmission; and uncertainty levels of cost and technology. The term flexibility refers to the degree to which a resource can be shaped to help meet loads on an hourly basis and its suitability to provide within-hour reserves.

EXISTING GENERATING RESOURCE DATA BASE

It is important for planning and modeling purposes to understand the existing generating resources available to the region. The Council maintains a detailed data base on all generating resources in the region, committed to the region, or located within the region in the case of independent generation facilities. This data base is located on the Council's website and is a popular source of information for many people in the region. It is also an important input to the Council's three resource-planning models, the AURORA^{xmpTM} Electric Market Model, the Genesys model, and the Resource Portfolio Model (RPM).

The existing resource database is clearly a critical component for planning new resources, and for understanding how alternative new resources, whether efficiency or generation fit into the regional power system. It is particularly critical to have a good understanding of how the hydroelectric system is used and the kinds of energy, capacity, and flexibility it can provide. The Council uses the Genesys model to quantify the capabilities of the hydroelectric system and how it interacts with other generating resources in the region.

POTENTIAL NEW GENERATING RESOURCES

Analyzing potential new generating resources falls conceptually into three categories: significant and currently available technologies that are most likely to be able to play an important role in the power system in the near term; available generating technologies that may play a role but have issues such as high cost or limited availability; and finally, generating technologies that are presently immature but hold some promise for the long term.

SIGNIFICANT CURRENTLY AVAILABLE GENERATING TECHNOLOGIES

Significant generating technologies that are currently available for development are given the most detailed attention in the Council's planning. For the Sixth Power Plan, these included natural gas-fired and high efficiency coal-fired generation, wind power, and conventional nuclear energy. For these technologies, the costs and resource characteristics are developed in significant detail. Particular attention is paid to the time required for the design and construction phases of the plants, their typical size, emissions, and transmission requirements. Such characteristics are important risk considerations. The costs for these resources are developed within the Microfin model which compiles and finances all of the capital costs and combines them with operating costs to calculate a preliminary levelized, or annualized, cost of the generation technologies.

These resources are typically modeled directly in the RPM to compete with other generating and efficiency alternatives unless they are precluded by policy or uncompetitive costs and risk. For example, in the Sixth Power Plan, it was assumed that no new coal would be built in the region because of current policies and perceived risk. Conventional nuclear energy was tested within the RPM but found to be uncompetitive and therefore was removed from the model to save time and space in the model.

CURRENTLY AVAILABLE RESOURCES WITH ISSUES

Some generating resources are relatively mature but have problems that make assessing their potential more difficult. These problems may include currently high costs, limited availability, technological or economic barriers to significant development, or simply insufficient information about their resource potential and characteristics. In the Sixth Power Plan, these resources included technologies like coal gasification with carbon sequestration, advanced nuclear designs, geothermal, new small hydro, woody residue biomass, certain types of solar energy, and methane from animal wastes. The Council estimates the cost of these resources from the best available information, but it is not feasible or practical to analyze them in as much detail as the first category.

Some of these resources were modeled with enhanced uncertainty about their availability and costs to reflect their greater uncertainty. Others were not specifically modeled as part of the resource plan, but are discussed as potential resources where they are available and cost-effective, which may depend on specific local conditions. The plan may include actions to better understand their costs and potential. The plan may also identify barriers to developing these resources and suggest actions to overcome them.

DISTANT FUTURE GENERATION POSSIBILITIES

The final group of generating technologies includes those in the very early stages of investigation. These are technologies that are unproven, but have the potential to become important resources as technology improves and costs decline. In the Sixth Power Plan such resources included wave, ocean thermal, and tidal energy.

The power plan limits its treatment of these resources to a discussion of the technology and current activity exploring their feasibility. Actions are typically limited to supporting further research or demonstration projects and tracking the developing technology.

The Council devotes significant effort to maintaining data on existing and planned generating resources, collecting technical and cost information on potential new generation technologies, and tracking the development of innovative technologies that could hold potential for the future. The Council works closely with Northwest utilities, the Bonneville Power Administration, and the Pacific Northwest Utility Conference Committee, to review and verify this database.

TRANSMISSION COSTS AND CAPABILITY

Transmission costs for generating resources are included in the analysis in one of two ways, depending on the location of the resource. Since the Resource Portfolio Model has limited spatial representation, the transmission costs for generating resources are included as adders to the cost of the resources themselves, rather than separately calculated.

In the case of resources located within the region and close to current transmission lines, where those lines can be assumed to be upgradeable, if necessary, without significantly changing the current transmission rate, that rate is used as the cost adder. For generating resources at remote locations that would require significant and costly new transmission construction, the fully allocated cost of the new construction is used as the cost adder.

The Council does not do transmission planning, other than in the very limited sense described above. It does, however, review utility transmission planning efforts in a number of other forums and takes account of the constraint information and remedies developed there.

EFFICIENCY OPPORTUNITIES

SUMMARY

Potential for improved efficiency in the regional power system is built from technical assessments of hundreds of individual efficiency improvements in many electricity uses and sectors. The approach recognizes that many efficiency improvements are only cost-effective when a new building is constructed or new equipment purchased. Such efficiency improvements are categorized as “lost-opportunity” investments. Their timing is linked to economic growth and building and equipment replacement cycles. Other efficiency improvements are cost-effective as retrofits to existing buildings and equipment and can be developed at any time. These are often referred to as “discretionary” efficiency investments.

The Council’s planning for efficiency improvements starts with assessing individual actions that could be taken to improve the technical efficiency of electricity use. The costs and temporal savings patterns of these technologies over seasons and times of the day are estimated. Before efficiency gains can be added to the plan, however, these technologies are screened for cost-effectiveness, limits to the share of the cost-effective potential that can be acquired, and constraints on the rate of development over time. For resource planning, the detailed technology assessments are aggregated into supply curves, one for discretionary efficiency and a set for lost-opportunity efficiency because its supply varies over time. Supply curves summarize the amounts of efficiency available at various costs and at various times in the future.

The final amount of efficiency in a power plan integrates information from the demand forecast and the assessment of resource alternatives and their risks. Integrating future electricity resources and demand is discussed further in the section on building a resource plan.

ESTIMATING ACHIEVABLE TECHNICAL POTENTIAL

The Council analyzes hundreds of potential efficiency improvements in specific applications in the residential, commercial, industrial, and irrigation sectors. The analysis also includes improved efficiency in utility distribution systems. For the Sixth Power Plan, 1,400 different efficiency measures were evaluated. The generic steps involved in estimating the technical efficiency potential for a specific measure include determining a baseline efficiency level, the efficiency level attainable with better technology, the number of applications that the measure could be applied to, estimating the limits to how much of the potential can actually be achieved, and assessing the limits on the timing of achievement.

Some examples may help illustrate these steps. Consider a more efficient electric resistance water heater than one built to current minimum federal efficiency standards. This water heater may save 140 kilowatt-hours per year over the baseline federal standard. The total technical potential will depend on how many water heaters are likely to be bought or replaced over the planning period. The information on the number of possible applications comes from the end-use demand forecast as discussed earlier. More efficient water heaters fall into the category of lost-opportunity resources, because the savings are cost-effective only when new water heaters are purchased.

The last step in determining achievable potential efficiency savings is to apply some limits on how many applications of the improved efficiency many be feasible over time. The Council understands that there are limits to the amount of technical potential that can be feasibly achieved. The assumptions vary for different types of efficiencies and technologies. For a mature technology, the Council typically assumes that no more than 85 percent of the technical potential can be achieved. For newer technologies, the penetration rates are assumed to develop over time and are likely not to exceed 65 percent of the technical potential during the planning period. For lost-opportunity efficiency, the amount and rate of development is determined by assumptions about economic growth, which vary depending on how the future unfolds.

THE SHAPE OF ELECTRICITY SAVINGS

The Resource Portfolio Model (RPM) is where the actual amount of cost-effective efficiency is determined. The role of the RPM is discussed in the next section. For now, it is important to note that the cost-effectiveness of efficiency is determined in the context of alternative resource choices and their cost and economic risk in the face of uncertain future conditions.

One of the important considerations in determining the value of efficiency improvements is their pattern over time. This includes how the potential develops over future years, the seasonal and hourly shape of the savings, and the amount of reduction expected to peak demand. This information is developed as part of the efficiency assessment and used in the RPM.

EFFICIENCY COST

The Council determines the total resource cost of energy savings from all measures that are technically feasible. This process compares all the costs of a measure with all of its benefits, regardless of who pays those costs or who receives the benefits. An example is the case of efficient clothes washers, where the cost includes the difference (if any) in retail price between the more efficient Energy Star model and a standard efficiency model, plus any utility program administrative and marketing costs. On the other side of the equation, benefits include the energy (kilowatt-hour) and capacity (kilowatt) savings, water and wastewater treatment savings, savings on detergent costs, and reduced transmission and distribution costs.[7] While not all of these costs and benefits are paid by, or accrue to, the region's power system, they are included in the evaluation because ultimately, it is the region's consumers who pay the costs and receive the benefits.

The cost to install and operate a measure, as well as its program administrative costs, is estimated over the entire planning period. In cases where a measure's life is less than the planning period, its replacement cost is also included.

To the extent that an efficiency measure is expected to change other costs, and these changes can be estimated, they are accounted for in the calculations. For example, improved lighting in a commercial building may result in increased heating and reduced cooling costs due to less waste heat from the lighting. On the other hand, a more efficient clothes washer will reduce water heating costs and water use.

The Act gives efficiency an advantage equal to 10 percent of the avoided generating resource cost. The cost of alternative generating resources is increased to reflect this advantage. Additional benefits considered in the total resource cost approach include effects on transmission and distribution systems. Electricity that is not consumed does not have to be delivered to the customer and therefore does not increase transmission and distribution losses.

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[7] Energy-efficient clothes washers use less water and require less detergent.

Efficiency is also given a benefit to reflect the fact that improved efficiency reduces the need to expand the distribution system for growing electricity use.

COMPARING THE BENEFITS AND COST OF EFFICIENCY MEASURES

Efficiency benefits are based on the value of energy savings. The value of savings is based partially on an estimate of market prices for power at different times of the year and day. An initial estimate of market prices is developed using the AURORA$^{\text{xmpTM}}$ Electricity Market Model of the Western United States, the Western Electricity Coordinating Council area. The difference between efficiency costs, adjusted for the 10 percent cost advantage in the Act, and market prices depends on the day of the week, time of day, and season as market prices vary. Therefore, the shape of efficiency savings is an important part of the analysis. Measures that save energy during peak demand hours, such as space heating, will have more value to the power system than a measure that saves energy during off-peak hours, such as street lights.

The cost-effectiveness of an efficiency measure depends on the comparative benefits, or savings, to its net cost. Each measure, which in some cases can be a bundle of specific related technologies, is evaluated for its benefits and costs using a model called ProCost. ProCost does the financial calculations of the time pattern of savings and costs and translates them into present values. In a simple analysis, measures whose benefits are less than their costs would not be considered cost-effective. However, the Council's planning methodology is not a simple analysis.

The cost-effective level of efficiency depends on how efficiency compares with other resources in terms of not just cost, but also how it contributes to or mitigates economic risk. Those calculations are done in the Regional Portfolio Model (RPM).

The primary purpose of ProCost is not to determine cost-effectiveness, but the savings and costs of the efficiency measures considered. This information allows the Council to build efficiency supply curves for further analysis in the RPM.

DEVELOPING SUPPLY CURVES

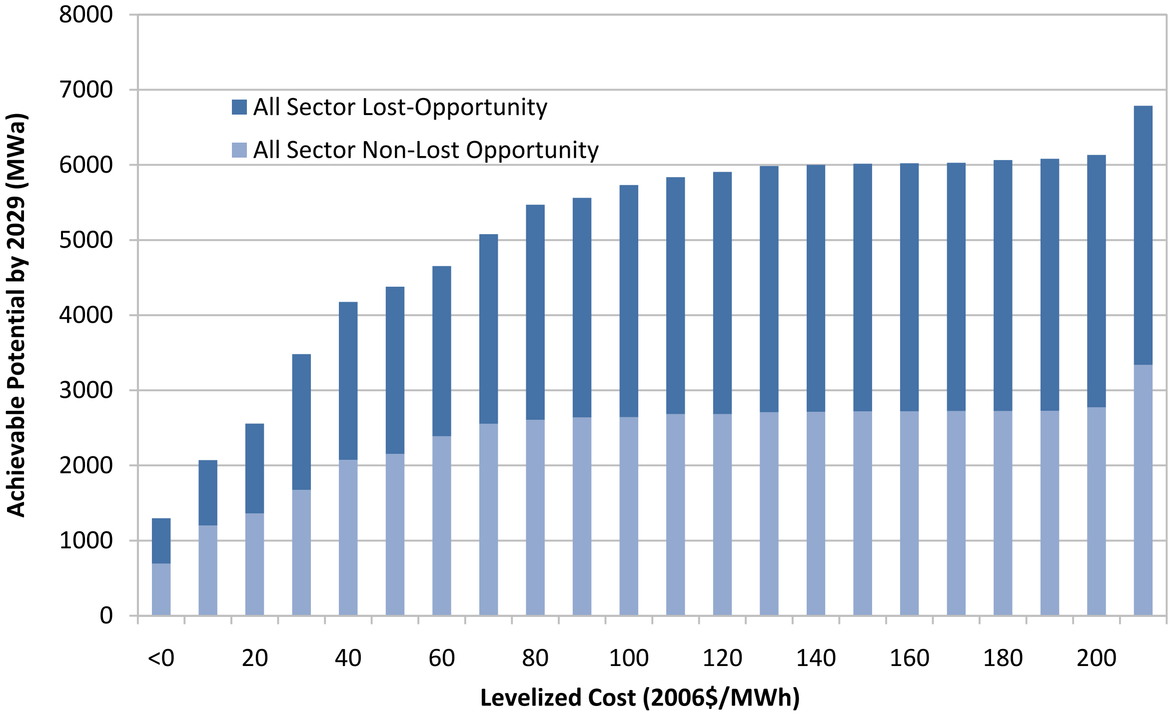
An efficiency supply curve shows how much efficiency saving is available at different cost levels. A supply curve is based on an aggregation of the savings and levelized costs of individual measures. As costs are increased, more measures become available. Typically, the Council has not put much effort into identifying measures that cost over $100 per megawatt-hour. As a result, the supply curve does not increase greatly as costs increase above that level.

The efficiency supply curves are developed in two categories. One is for lost-opportunity efficiency. Its availability over time is determined by economic activity and appliance replacement patterns constrained by limits on availability, allowed development rates, and maximum penetration rate assumptions. Because of variations in economic growth, there is a separate lost-opportunity supply curve for each year of the analysis.

The second efficiency supply curve is for an aggregation of measures that can be implemented at any time. These are often called discretionary or non-lost-opportunity efficiency. Although they can be acquired at any time, their annual implementation rate is severely constrained to reflect the feasible scale of efficiency programs.

These aggregate efficiency supply curves are inputs to the resource portfolio analysis described in the next section. An example of conservation supply curves is shown in Figure 3.

Figure 3: Aggregate Efficiency Supply Curves Illustrated



BUILDING A RESOURCE STRATEGY

SUMMARY

From its beginnings, the Council has recognized that the future is unpredictable. History is filled with failed forecasts and the consequences of decisions based on those forecasts. The Council's approach to building a resource strategy incorporates the inherent uncertainty of the future.

The objective of the Council's resource strategy is to avoid exposing the region to the risks of very high-cost futures, while seeking an adequate, reliable, and low-cost power system.

All of the Council's power plans have focused on uncertainty and its implications for resource decisions. Achieving this objective requires a non-traditional approach to planning; one that focuses not just on the cost of the power system under specific scenarios, but one that also identifies major risks to the power system and develops strategies to quantify and mitigate those risks.

With its Fifth Power Plan, the Council significantly advanced its ability to evaluate the effects of uncertainty and risk in its planning by developing a new planning tool, the Resource Portfolio Model (RPM). In addition to uncertainty of long-term trends in electricity demand, fuel prices, and variable hydroelectric conditions, the RPM recognizes and evaluates the implications of variability in future conditions caused by climate policy, business cycles, natural gas and electricity market price volatility, variations in temperature, and other departures from long-term equilibrium conditions. It recognizes that economic growth and electricity demand may not develop as steady, predictable trends over time. Given particular resource choices for the electricity system, such factors can cause significant variations in future costs.

So the Council's approach to building a resource strategy is focused on finding a minimum-cost and minimum-risk resource mix. It may be obvious, however, that minimizing cost and minimizing risk are two different objectives, and that reducing risk typically will cost something. The Council's planning process identifies the cost of reducing risk levels. The increased cost necessary to reduce risk levels can be thought of as an insurance premium. Generally, the Council has decided that power system adequacy and reliability require a relatively low-risk resource strategy, and the plan's resource strategy finds the lowest cost approach to that lower risk future.

THE RESOURCE PORTFOLIO MODEL

Unlike most electricity planning models, the RPM is not an equilibrium model; it does not evaluate resource strategies with foreknowledge of future conditions. This is important because different strategies can be tested as alternative futures unfold and the resource choices made result in differing costs to the power system. The model considers a wider range of futures than might be typical of scenario analysis because history has demonstrated that we are not very good at predicting the future, or even the level of uncertainty about the future.

The RPM searches through thousands of potential resource strategies or plans. A candidate plan, or resource strategy, consists of optioning dates for various generating resources. An option date is defined as the earliest date when the region could begin construction of a resource. For example, a strategy might include completion of the siting, licensing, and design of a gas-fired combined-cycle turbine by 2016. A typical resource strategy would include a number of different kinds of generating resources with varying option dates. For efficiency resources, the strategy is defined by how much the region should be willing to pay for efficiency improvements relative to the market price of power; typically a premium over the market price of electricity.

Each candidate plan that the model considers is subjected to 750 future conditions to determine how costs vary under alternative future conditions. Analysis with the RPM has been referred to as "scenario analysis on steroids." From the 750 futures, two key measures are extracted. One is the average net present value of power system costs across all 750 futures. The second is an economic risk measure that consists of the average cost of the highest 10 percent of the net present value cost results across the 750 futures.

The 750 futures consist of random draws of uncertain future conditions over a 20-year time span that includes: electricity demand growth, natural gas prices, wholesale electricity prices, hydro conditions, resource costs and outages, carbon pricing levels, and renewable energy incentives. Some of the uncertain variables are correlated to each other. For example, high natural gas prices tend to result in higher electricity prices. Poor water conditions tend to cause higher electricity prices. Inadequate electricity resources are likely to lead to an increased incidence of high electricity price events.

The variation in these uncertain conditions is not limited to different long-term trends. There are also cycles lasting several years and volatility on a shorter-term basis. Capturing such variations, given a set of resource decisions, is important because some resources are greatly affected by these changes, while others are more resilient. This structure allows the Council to evaluate the role of different resource characteristics in creating or reducing risk.

The key to assessing risk is a model structure that makes resource decisions without assuming knowledge of future conditions. As each of the 750 futures unfolds, decisions are made about moving ahead with construction on optioned plants and acquiring efficiency. In any given future, an optioned power plant might start construction at its option date or not, depending on conditions in the most recent few years preceding the decision. Once construction has started it can be delayed, cancelled or completed. Each of the alternatives has associated costs. For example, if a plant is not built, the system incurs only the cost of siting, licensing, and design. If a plant is completed, but turns out not to be needed in most of the following years it will generate little value to offset its costs. It would also be possible to build a simple-cycle turbine and then experience unexpectedly rapid load growth that causes the turbine to be run at a relatively high capacity factor and incur high operating costs.

As different futures unfold, resource strategies tested in the RPM turn out to be good or bad. By searching through thousands of possible resource strategies, or plans, and documenting how each one performs in terms of its costs under hundreds of future scenarios, the Council can identify an optimal strategy that achieves the desired level of risk protection at the lowest possible cost for the regional power system.

The approach used in the RPM leads to a better understanding of the risks facing the power system and how alternative resources can help mitigate those risks. In some cases, resource characteristics that tend to mitigate risk are intuitive but cannot be quantified by traditional analysis. Resources likely to be favored by the RPM include low-cost resources that are resilient to fuel price volatility, carbon policy, and demand forecast errors. In addition, resources that have short lead times or can be developed in small increments have less capital risk in case of unexpected changes in supply and demand.

While the cost of resources is very important in developing a resource strategy, risk plays an important role as well. Efficiency improvement scores well on both counts. It is low cost, uses no fuel, emits no carbon, and can defer or eliminate transmission expansion. Because of its low cost and risk relative to other resources, the chosen resource portfolios typically put a premium on efficiency over market price. Efficiency turns out to be a low-cost insurance policy against high market prices, rapid unexpected growth, as well as high fuel and carbon prices.

Wind, although not low cost, is attractive, to a degree, because of its lack of fuel and carbon pricing risk, small scale, and short lead time. However, the role of wind and other renewables tends to be driven by renewable portfolio standards in three of the four Northwest states rather than by their economic characteristics.

Natural gas-fired generation fares well in the RPM analysis compared to other generating alternatives in spite of its fuel price risk because it is less capital intensive and smaller-scale. However, coal-fired and nuclear generation do not compete well due to their large unit size and long lead time, in spite of coal’s relatively low and stable fuel cost and nuclear generation’s lack of carbon emissions.

IMPLEMENTATION PLAN

The Council’s power plan includes an action plan, or implementation plan, to identify specific things that need to be accomplished to make the plan a reality. These action plans have typically been for the next five years. The action plan is broken down into various areas such as efficiency, generating resources, emerging technologies, and Bonneville. The categories vary in each plan, but the intent is to identify actions that should be taken by various organizations, including the Council, in order to measure the region’s progress in implementing the Council’s plan.

A biennial assessment checks on this progress and the development of economic growth, fuel and electricity prices, and other basic assumptions in the plan, and the Council decides whether the plan is on track or if a plan revision is necessary.

Assessing progress on achieving efficiency gains is particularly important. This is necessary because it is more difficult to measure efficiency changes and their effects than it is to identify specific development of generating resources. At the same time, to treat efficiency as a resource requires a significant effort to measure and verify efficiency changes. The region has made great progress in this area through the work of the Regional Technical Forum and contributions by Bonneville and the region’s utilities.

Council Planning Models

AURORA^{xmpTM} Electricity Market Model	Proprietary model from EPIS, Inc. Used to forecast wholesale electricity market prices at various pricing point in the western U.S. (WECC area)
Genesys	Used to simulate the PNW power system with a focus on hydroelectric system capability and how it works with other generating resources. It is used in the Council's assessment of power system adequacy.
Resource Portfolio Model	Used to choose low-cost and low-risk resource strategies given uncertain future conditions and policies. It determines cost-effectiveness of alternative generating and efficiency resources.
Demand Analysis System	Used to forecast the demand for electricity, potential applications for efficiency resources, ensure consistency between the demand forecasts and efficiency assessment.
Fuel Price Forecasting Model	Used to convert assumptions about fuel commodity prices to regional wholesale prices at various locations, and to convert to estimate retail fuel prices for input to demand forecasts and resource costs estimates
ProCost	Used to calculate levelized costs of efficiency changes and develop aggregate supply curves
MicroFin	Used to calculate the levelized cost of generating resources depending on cost structure and who is building and financing the construction.