Assessment of the Regional Portfolio Model

Prepared for the Northwest Power and Conservation Council

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A. Executive Summary of the RPM Assessment

The Northwest Power and Conservation Council (NWPCC) engaged the Regional Portfolio Model Review Panel (the Panel) to evaluate and assess the Regional Portfolio Model (RPM) as a tool to address regional power supply planning in the Pacific Northwest. The Panel's assessment of RPM was based on a review of written documentation, analysis of select output data, multiple presentations and question and answer sessions with the model author, and discussions with some stakeholders. The Panel followed the request of the NWPCC and focused on four areas:

- RPM Methodology
- Enhancement and Maintenance of RPM
- NWPCC Use of RPM
- Possible Use of RPM by Others

1. **RPM Methodology:** *Review, evaluate, and make recommendations about the conceptual methodology employed by RPM to evaluate resource strategies, with emphasis on how RPM represents decisions about resource commitments that must be made without knowledge of the future.*

The Panel has concluded RPM has the capability, with correct inputs, to adequately address the analytic criteria for regional resource planning. RPM solidly captures the central economic tenants of resource planning under uncertainty, as summarized in Table 1.

Table 1. Core Modeling Components Evaluated for Resource Planning

Core Component	Implications	Mark	Summary Assessment
Resource-selection logic, including conservation and generation.	The logic for resource selection should rationally add the most economic supply and conservation options.	√	Resource selection in the model follows from the fundamental need for generation and conservation, as well as the economic rationale to add resources. It reasonably reflects the relative value, economic merit, and portfolio risk of a broad range of supply and conservation options, but does not address sub-regional needs.
Long-run equilibrium.	Generator earnings on average are not excessive or too paltry; they follow the "Goldilocks" principle.	√	On average, new generating units entering the portfolio realize "normal" returns. RPM's use of economic business cycles, fluctuations in regional reserve margins, and the adherence to long-run equilibrium under uncertainty provides a consistent and realistic economic framework for resource selection.

Implied heat rates (IHR).	IHR is a market measure of heat input to generation produced. Implied heat rate corresponds to power plant efficiency of converting heat to electricity. IHR is expected to be reasonably consistent with the heat rate of a power plant or the ratio of the monthly forecast price of electricity divided by the forecast price of gas. $$IHR = \frac{\frac{\$}{MWH}}{\frac{\$}{MBtu}} = \frac{MBtu}{MWh}$$	√	Monthly and annual on-peak and off-peak IHRs track a reasonable range, consistent with forward-market history and with the annual on-peak heat rates. IHRs range between 6 and 13 MBtu/MWh across the model simulations.
Resource adequacy to meet capacity and energy requirements for the region.	The economic criteria to construct new generation ensure adequate resources are available to meet regional energy requirements even under low hydro conditions.	√	The model incorporates solid economic rationale to ensure resource adequacy is maintained.
Flexibility of generation.	The flexibility of a generator is akin to the maneuverability of an automobile. The generation fleet needs a certain number of highly flexible generators to meet rapidly changing supply conditions.	√	The model captures and values resource flexibility relative to the price of hourly energy. However, the value of generation flexibility region wide requires a more integrated view of hydro, wind, and thermal generation, and consideration of ancillary services.

The Panel has also identified areas that could be improved and limitations with RPM. The most substantial areas for improvement include:

- Communications about the model and its output
- Wind generation
- Generation asset attributes
- Demand reduction under high carbon-price simulations
- Hydro modeling
- Application and use of risk
- Transmission modeling
- Receptivity and openness to broader input from regional participants.

At the writing of this report, Council staff plans to address most of RPM’s identified limitations. The limitations do not seem to give a large bias in favor of one type of resource over another. In addition, the analytic processes do not appear to have limitations that are causing compensatory errors or that require special adjustments to input values to correct for known model biases.

Stakeholders have identified two other RPM limitations: transmission and the inability to assess resource flexibility. The first concern, transmission, is well founded and openly discussed as a known limitation in the Sixth Power Plan. If transmission congestion is not considered, the RPM results may provide inadequate generating capacity for sub-regions of the four Northwest states. Broad regional modeling has the potential for a number of reasons to overlook sub-regional resource requirements.

The NWPCC develops a regional plan, and local needs are left to individual utilities. The Panel finds this approach to be consistent with the NWPCC's mandate under the Northwest Power Act. However, the Panel recommends incorporating large zonal transmission constraints to better address sub-regional requirements.

The second concern, resource flexibility, has been reasonably well addressed in terms of valuation with the price of energy. RPM's limited ability to capture flexibility is primarily a product of the treatment of ancillary service constraints and the simplifying assumptions of hydro generation. In addition, the input assumptions in the Sixth Power Plan may understate the relative value of flexibility by modeling wind generation as uniform and constant and keep all existing generating resources from retiring.

The absence of ancillary service constraints for each operating utility in the region may understate the value of flexibility. Increasing wind generation with limited expansion of hydro could leave the system short of balancing services. Increased wind generation adds a layer of uncertainty that should be treated as a risk variable in RPM, similar to natural gas prices. Hourly wind volatility will add to the value of resources offering flexibility. The simplifying assumptions of hydro generation limit the regional interplay between wind, thermal, and hydro to meet ancillary requirements.

2. **Enhancement and Maintenance of the RPM:** *Review, evaluate, and make recommendations for enhancement, maintenance, and documentation of the RPM to meet the Council's ongoing needs.*

The Panel has a number of observations about the level of effort required to maintain RPM. In addition to suggestions offered in the previous section, we have provided recommendations for enhancing and improving the model.

With regard to maintenance, the Panel believes it is unreasonable to expect one person to handle the amount of work involved in maintaining and supporting RPM. A single Council staff person, Dr. Michael Schilmoeller, currently has full responsibility for RPM, and the Panel recommends an additional staff person be assigned to assist in maintaining the model and analyzing results.

In addition, the Panel recommends formalizing the Council staff's analytical review of RPM results and ensuring a critical examination of them. Analytical support from the staff's subject-matter experts is crucial to applying RPM results to development of the region's power plan. An outside consultant might be engaged to assist with the analysis and play the role of "devil's advocate." This type of critical review would help build Council and stakeholder confidence in the results.

Potential enhancements and specific RPM improvements are summarized in Table 2. These enhancements address limitations the Panel found in the RPM methodology.

Table 2. RPM Potential Enhancements for Future Release

Issue	Impact
Uniform modeling of hourly wind generation.	Wind generation modeling does not currently account for the supply dynamics of wind generation on market prices and the ensuing cycling of regional resources. Linking wind generation to load either through observed statistical relationships or through simulating weather as a fundamental model driver will better reflect the hourly variation of wind generation.
Simplified hydro generation.	BPA's HydSim model, which currently provides hourly hydro generation based on simulated regional flows, may need to be augmented to account for the impact of additional wind generation and provide more detailed dynamic optimization of the regional hydro system.
Ancillary service requirements.	Ancillary service constraints yield more value to flexible generation. The absence of a utility-level ancillary service constraint overlooks recent and critical regional dynamics within wind, thermal, and hydro resource operations.
Elasticity of response to increasing energy prices.	The current modeling structure does not dynamically adjust energy demand under alternative carbon-price scenarios/simulations. Introducing a long-run elasticity of response would recognize the likely loss of demand with high carbon-price scenarios.
Generator characteristics of start-up costs, minimum run-time, and start-up time to reach full load.	More granular descriptions of generator asset characteristics will support a better assessment of the trade-off between alternative supply resources and load control programs.
Transmission constraints.	RPM may overlook the need for capacity and energy in select sub-regions that are transmission constrained.
Risk metric provides one view of risk that does not account for annual variability and views risk from a single distribution rolled up over 20 years.	To better represent risk issues, adopt several risk metrics and develop some weighting mechanism between them, such as annual variability in rates or sensitivity to market conditions versus regulatory conditions. For example, CO_2 prices, which have greater price uncertainty and potential impact on resource selection, should be distinguished from known hydrological or fuel price risks. The latter has a greater degree of certainty in the expected shape of the probability distribution and realized time-series pattern and should receive greater weight in resource selection.
Monetize risk to remove the burden on decision makers to place their own dollar value on risk.	Monetize risk into a single risk-value additive to costs. This modification should eliminate the need to present the risk-return (efficient) frontier and simplify the process of resource selection. There are multiple techniques to monetize risk; this would greatly enhance the presentation and use of RPM results for decision makers.
Risk-return frontier presents too many plans that are very similar	Run RPM on larger increments of risk to produce a handful of plans for presentation to decision makers.

to each other.	

3. **Council Use of RPM:** *Review, evaluate, and make recommendations on how Council staff uses RPM for analyses to support development of the Council's regional power plans.*

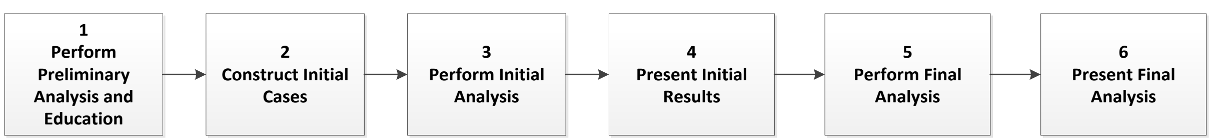
The Panel believes that communications and developing input assumptions are key areas in which the Council staff could improve its use of RPM in the NWPCC's power planning process. With regard to communications, the Panel contemplated how interaction between staff and the Council might be structured to promote understanding of RPM and the most effective exercise of the Council's judgment in guiding the modeling process.

The Panel outlined a suggested approach to using RPM in the NWPCC planning process. There are undoubtedly other approaches that could achieve the same objectives and this one would likely need some changes to address practical issues. It is also important that Council members and the public see the process and policy issues as driving the model, not the model driving the process or policy.

In the Panel's view, training on RPM should be integrated with the power planning process, rather than scheduled as a separate activity. Concepts should be introduced as they become relevant in the process. A synchronized, integrated training approach will make the concepts more concrete, less abstract, and more relevant to the plan. The full training should be updated and repeated with each five-year power planning cycle. More than five years is too long to expect people to retain the kind of thorough understanding of RPM that is needed to contribute to the process, and there will also be turnover among the Council members and stakeholders.

The suggested approach is illustrated in the process flow diagram, Figure 1. This process has three phases of analysis – preliminary, initial, and final – and two phases of interaction with stakeholders – when constructing the initial cases and when presenting the initial results.

Figure 1. Process Flow Diagram



With regard to assumptions, the Panel concluded RPM is a solid and appropriate tool for resource planning. Issues with the model outputs can generally be traced to the inputs. As with any model, inputs drive the results, and the Panel questioned whether the Council and perhaps stakeholders have been adequately engaged in vetting the inputs. A vetting process for key inputs is needed and should include education about RPM, as well as dialogue for generating the inputs and assumptions.

To counter skepticism in the region about RPM, the Panel would advise that more time and education be invested in collaborating on the inputs used in the model. It is important to establish buy-in from all stakeholders in order to earn credibility for the RPM results.

Additionally, the Panel offers the following specific recommendations on inputs for use in the next cycle of developing a regional power plan:

- Enable RPM's capability to retire generating facilities since many of the region's current concerns focus on capacity/reliability needs.
- Consider removing or significantly increasing the limit on hourly prices since capacity to support reliability needs to rely on strong price signals.
- Investigate wind generation risk tied with load and hydro capability.
- Incorporate additional attributes for generating assets, including minimum up and down time, minimum capacity, minimum heat rate, and start cost. Such an addition to the generation dispatch logic can help support an appropriate level of capacity for reliability.
- Incorporate the large known and present transmission issues on a high-level zonal basis to help in identifying potential reliability concerns.
- Allow RPM to produce the renewable resource portfolio (meet Renewable Portfolio Standards) through a mechanism in the model (i.e., negative prices to represent Renewable Energy Credits) rather than forcing renewable generation as an input to the model.

RPM also needs to be validated more transparently to increase the Council and stakeholder confidence in its results. In general, validation means demonstrating that model results match reality. While it is difficult to validate a model like RPM that is focused on the future, it is possible to compare the results with another already well-established model. This type of benchmarking could be accomplished with the following three activities:

- Run a case from RPM through a utility regional planning model. The two models should yield consistent outputs from consistent inputs.

- Apply a commercial utility planning model with risk-based planning capabilities and consistent inputs. The two models should yield relatively consistent output.

- Compare the 5th, mean, and 95th percentiles of price, load, and generation by resource type to check for consistency of results.

4. **Possible Use of RPM by Others:** *Evaluate and make recommendations about potential use of RPM for resource planning at the individual utility level.*

RPM is a very powerful tool for resource planning. The Panel agrees that making it available for use by others is an appropriate long-term objective. However, it would require additional staff resources or a contract with an outside party, or both, to support the model for others' use. Utilities would also have to commit considerable staff time to becoming proficient in using the model. The learning curve for RPM will be at least as high and steep as for the most complex planning model used at any utility in the region. And it could be even more so since RPM has not reached the grade of commercial software. Whether the utilities would be willing to make this commitment is an open question.

A more immediate issue is whether the Council should undertake this activity at this time. The review of Council staff's model-improvement work plan leads the Panel to recommend that the priority at this time should be on further development of the functionality of RPM. Specific development recommendations, generally related to concerns arising from the Sixth Power Plan, are outlined above.

Only after this development work has been completed and confidence in RPM among Council members and stakeholders has been strengthened would the Panel recommend resources be assigned to making RPM available to others.

1. RPM Model Assessment and Method

The Regional Portfolio Model Review Panel (the Panel) was assembled and charged with critically evaluating and assessing the model used by the Northwest Power and Conservation Council (NWPCC and the Council) for regional power supply planning. The assessment of RPM was based on review of written documentation, analysis of select output data, multiple presentations and question and answer sessions with the model author and architect Dr. Michael Schilmoeller, and discussions with some stakeholders. This review is not exhaustive and has been limited by resource constraints. The Panel approached the model assessment with a critical eye to identify limitations, weaknesses, fundamental flaws, biases, inconsistencies, and areas of improvement.

The model assessment focuses on the structure, approach, and capabilities of the underlying analytic algorithms. This assessment is distinct from the evaluation of input assumptions used to run the model and how the Council staff communicates model results.

The Panel concluded that the model has the capability, with the correct inputs, to adequately address the analytic criteria for regional resource planning. RPM solidly captures the central economic tenants of resource planning under uncertainty, as summarized in Table 1.

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The Panel also identified areas that could be improved and limitations of RPM. The most substantial area for improvement is communications about the model and results, a topic addressed in Section 3 of this report. Other areas of improvement relate to the following:

- Modeling wind generation
- Generation asset attributes
- Generation flexibility
- Loss of demand under high carbon-price simulations
- Hydro modeling
- Application and use of risk metrics
- Transmission modeling.

At the writing of this report, Council staff has plans to address most of the identified limitations of RPM. The limitations are not seen as giving a large bias in favor of one type of resource over another. In addition, the analytic processes do not appear to have limitations that are causing compensatory errors or that require special adjustments to input values to correct for known model biases.

Stakeholders have identified two of the limitations of RPM: transmission and the inability to assess resource flexibility. The first concern, transmission, is well founded and openly discussed as a known limitation in the Sixth Power Plan. If transmission congestion is not considered, RPM results may provide inadequate generating capacity for sub-regions of the four Northwest states. Broad regional modeling has the potential for a number of reasons to overlook sub-regional resource requirements.

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The absence of ancillary service constraints for each operating utility in the region may understate the value of flexibility. Increasing wind generation with limited expansion of hydro could leave the system short of balancing services. Increased wind generation adds a layer of uncertainty that should be treated as a risk variable in RPM, the same as natural gas prices. Hourly wind volatility will add to the value of resources offering flexibility. The simplifying assumptions of hydro generation limit the regional interplay between wind, thermal, and hydro to meet ancillary requirements.

1.1 Model Objective

The objectives of the RPM are tied directly to the Northwest Power Act of 1980. Sections 4d and 4e of the Act spell out elements to be included in a 20-year power plan for Washington, Oregon, Idaho, and Montana. According to the Act, the plan should include evaluation of costs, conservation, renewables, and traditional forms of generation. Other parts of the Act have been incorporated into NWPCC activities, including:

- Develop a cost-efficient region-wide energy resource plan.
- Minimize regional ratepayer total cost and risk.
- Make the analysis accessible and transparent to stakeholders.
- Focus on sources of risk that are likely to be of significant size, both in magnitude and duration.
- Evaluate the likelihood of futures by running probability analysis of possible future outcomes for market prices, hydro operations, and regulatory policy.
    - Explore rather than predict – avoid the pitfalls of assuming perfect foresight.
    - Use decision criteria that do not rely on foreknowledge to evaluate capacity expansion decisions.
- Achieve the high computational performance necessary to evaluate a large number of plans over futures that represent combinations of a dozen sources of uncertainty.

These modeling objectives have been the cornerstone for the analytic capability of RPM. The model incorporates uncertainty in a way that sets up the region's energy future as a trade-off between risk and uncertainty. Most utilities in the region have begun systematically to integrate uncertainty into their own resource plans.

The Council staff recognizes the need for additional analysis of resource adequacy beyond the RPM and applies the GENESYS model. GENESYS provides a Loss of Load Probability (LOLP) analysis and in the planning process, effectively evaluates the system reliability of resource plans RPM produces. RPM and GENESYS take a region-wide perspective that may fall short of addressing local needs. Although RPM can capture the general need for flexibility in energy supply through market price signals, it does not explicitly model ancillary services or incorporate detailed hydro generation. Hydro generation has traditionally provided an ample balancing mechanism in the region so an in-depth analysis of resource flexibility was not required. A large increase in the amount of wind generation, however, has shown the limits of hydro to balance the system.

RPM could be improved to address the value of flexibility with enhancements to the commitment logic, more in-depth wind analysis, and more dynamic modeling of the hydro system. It is reasonable to omit ancillary services and dynamically optimized hydro resources to simplify the model and/or acknowledge the difficulty of capturing the necessary attributes of hydro generation across the four states. The Panel does not believe this limitation substantively biases the assessment for the general need and type of resource.

While the analytic objectives of RPM have been largely achieved, communications about the modeling process, assumptions, validation of simulations, and readily interpretable results have fallen short. It is the Panel's belief that improved communications will substantially improve the acceptance and use of the model. Suggestions to ameliorate the communication of results are discussed in Section 3 of this report.

1.1.1. Decision Analysis Framework

The RPM develops a risk-based resource expansion plan for the Pacific Northwest (PNW). The objective function seeks to minimize both the net present value (NPV) of costs and the risk inherent in the plan. By including risk as a planning consideration, the modeler substantially enhances a robust resource selection and addresses the trade-off between cost and risk through probabilistically enveloping a broad set of future scenarios. The model minimizes costs and risks to produce resource plans that systematically add and retire resources based on economic and fundamental needs. By introducing uncertainty into the planning process, the quality of the modeling has been improved over traditional utility planning approaches.

Traditional utility-based resource plans develop deterministic scenarios to minimize the NPV of revenue requirements. Regional planners and utilities have often applied load duration curves to represent the energy requirements for base, intermediate, and peaking resources. Load duration curve models (e.g., Strategist and System Optimizer) do not incorporate the hourly dynamics of load, market prices, wind, and unit commitment (start-up, shut-down, minimum run times), which causes them to be relatively poor planning solutions for addressing the regional dynamics in the PNW. Chronological modeling approaches, which model all 8,760 hours in a non-leap year or a carefully constructed subset of these hours, in chronological order, model the physical operating dynamics of generation explicitly.

Traditional resource planning methodologies have further been limited to deterministic runs and do not include the broader range of future states, as in a simulation framework. RPM's decision analysis framework represents a substantial improvement over traditional planning models by simulating 20 years of physical and market dynamics over 750 futures. However, most NWPCC stakeholders do not understand the analytic precepts of RPM and may discredit the model's results when questionable input assumptions may be the issue.

The analytic construct of RPM and the modeling results could be presented more clearly to the Council and stakeholders. Section 3 outlines various improvements for communications about RPM. These measures address synchronizing the RPM training program with the RPM process and organizing RPM input and output data into tiers.

Risk is summarized by a single value for each plan, called $TailVaR_{90}$, which is presented together with the expected cost for each plan on an X-Y graph. Particular plans are highlighted on this graph as the "efficient frontier." The plans on the efficient frontier are those for which there does not exist another plan with both lower expected cost and lower risk. Thus, each such plan is the one that yields the lowest risk for a given expected cost, and vice versa. All of the other plans on the graph are inferior in that they yield higher cost or higher risk than a plan on the efficient frontier. This shows explicitly the trade-off between cost and risk.

However, the Council and stakeholders are more likely to understand risk values if they were monetized into a dollar value. Absent a monetization of risk, which is the current state of RPM results, decision makers are forced to put their own value on risk without the proper economic context.

The Panel recommends that the use of risk metrics be expanded and translated into a direct monetary value that is added to costs. The current risk metric in RPM assembles 20 years of cost uncertainty into a single number. A risk metric that accounts for annual variability in rates and/or the average annual risk would provide additional insight. It would serve as a solid basis to monetize risk into a dollar value that is added to costs. In the current process, decision makers select from a single risk metric and produce their own internal valuation. It would be more appropriate to apply techniques from actuarial sciences and economics to translate risk into a monetized value. The model results would benefit from the use of an economically robust risk metric.

1.1.2. Resource Selection

RPM does not assume perfect foresight, as do traditional planning tools. RPM results may or may not deliver "expected" returns depending on a variety of events. On average and over time in RPM, new investment generally achieves "normal" returns. In the model, the ebb and flow of business cycles and hydro conditions affect regional energy reserve margins. The difference between a generator's cost of production and the market price of electricity can spread as a result. RPM adds resources to minimize the overall cost of supply through the most economically profitable resources relative to market prices. The addition of capacity or energy becomes a trade-off between the relative economics of each candidate resource. The economic merit of each resource is evaluated relative to simulated market prices. To the extent that market prices in the model reflect regional or sub-regional surpluses or shortages, this methodology will yield results similar to a "build to need" approach.

RPM derives an economic value for each candidate resource based on a plant's physical attributes. For generation assets, RPM performs economic dispatch to hourly market prices for a typical week for each quarter. Generation asset characteristics are distilled to the following core components that reflect the general value of energy and capacity: 1) capacity; 2) full-load heat rate; 3) variable O&M; and 4) CO_2 emissions. The Panel suggests including start-up costs, start-up time to full load, and minimum run time as resource attributes to enhance RPM's ability to address resource flexibility.

For conservation resources, RPM economically selects measures from supply curves on the basis of the market price of electricity. The use of a supply curve for selecting conservation measures will naturally balance conservation levels to their cost-effectiveness. Because RPM derives value exclusively through energy sales, conservation resources with the flexibility to rapidly cycle on and off capture the hourly variability in the simulated market prices. Direct load control programs can shift demand from high price hours to low price hours, but they also have the potential to provide ancillary service benefits not ascribed to these resources in RPM.

Additional value related to ancillary services is not explicitly incorporated in RPM; however, a flexibility penalty to reflect the costs for ancillary services to support wind generation is modeled as $6/MWh to $12/MWh. The exclusion of ancillary services as a system constraint may slightly understate the value of select resources such as duct firing on combined cycles and direct load control programs.

RPM simplifies the assumptions for ancillary services in accordance with the modeling structure of the regional hydro system. It would take more detailed modeling of the region's hydro system to understand the value of ancillary services across the region. The RPM uses a 70-year history of regional hydro flows to represent the seasonal variation. The historical annual hydro flows are drawn and then shaped into monthly hydro generation following BPA's HydSim model. The shape of hourly hydro generation is a function of system sustainable peaking capacity, a reversible supply curve that shifts hydro generation among time periods and market prices.

The correlation of hydro flows to market prices is maintained in RPM by aligning random seasonal on/off-peak price draws with seasonal hydro flows. This approach may be adequate for balancing regional energy supply and demand. However, it would take more detailed modeling of hydro operations to zero-in on issues of system flexibility, potential "dump energy" conditions, and ancillary services.

RPM will identify opportunities to permit and site new resources in order to minimize risk in the market. In some cases, the model may permit and site projects years ahead that are then never constructed. Utility regulators may not allow utilities to recover their investment for permitting and siting resources that are never built. This limit on cost recovery casts doubt on the early permitted and sited projects identified by the model. The Panel recommends that RPM be run with and without the resource optionality mode and that the modelers present the pros and cons of resources for utilities and regulatory bodies.

1.2 Fundamentals

RPM embraces the fundamental tenants of demand and supply. On the surface, the inclusion of fundamentals in RPM is far from obvious. On closer inspection, fundamentals clearly drive new resource additions. The need for new resources (either conservation or generation) is signaled in the model by increased market prices. A feedback loop in RPM between fundamental supply scarcity and market prices is different from traditional planning approaches that set a target reserve margin for new resource additions. The market-based approach in RPM reflects real business cycles, which creates periods where reserve margins (the ratio of available energy to peak load) become relatively tight and periods of excess capacity.

Traditional planning tools can reflect business cycles, but by nature skew results to current conditions. Most fundamental models do not reflect the critical relationship in which market prices follow the cycle of surpluses to scarcity, but RPM does. RPM systematically incorporates the vicissitudes of market dynamics from energy surpluses and shortages, and reflects these conditions in market prices. Fundamentals of fuel costs, hydro conditions, and CO_2 costs serve as determinants to the market price of electricity.

RPM's functional form represents the fundamental drivers of electricity prices. A dynamic feedback loop links the addition of new resources back to market prices, which serves to prevent conditions of extreme scarcity or surplus. The model could be further enhanced if it included changes in the composition of the supply stack.

RPM captures the dynamics of business cycles and their impact on market prices. The model could be further enhanced, extending business cycles to include demand-side logic. The simulation of prices in RPM recognizes the need for a feedback loop that captures the effect of surpluses and shortages on market prices. The same holds true on the consumer side where there is a demand response to prices.

Energy prices directly impact economic activity, i.e., disposable income is reduced to pay the higher prices. An integral part of load forecasting is the interplay between economics and load. The key variable that directly connects load to economics is the price of power. If the model were to incorporate an elasticity of response, the demand would adjust for conditions like high carbon prices; gas-price shock events that last less than a couple of years can probably be ignored by the model. The Panel recommends applying a long-run elasticity of response for electricity demand.

A central tenant of market modeling is that no opportunity to earn an abnormal return through construction or forestall losses through retirement of uncompetitive generation will exist for extended periods of time. A model demonstrates this precept if new resources earn "normal" returns on average over time. More explicitly, a new combined cycle (CC) or combustion turbine (CT) would earn on average over a decade or more, its levelized capital cost.

RPM embraces the long-run equilibrium logic explained above with the application of real business cycles. Periods of market opportunity for greater earnings (larger spark spreads) are generally followed by periods of limited earnings (relatively narrow spark spreads). RPM satisfies long-run equilibrium conditions over a broad range of simulations and input conditions, which gives the Panel substantial comfort that the model produces sensible results.

The range and impact of resource adequacy are second only to long-run equilibrium as the most critical criterion to assess overall model performance. Because the PNW is fuel constrained (hydro) but not short of physical generating capacity, the NWPCC evaluates resource requirements in terms of "sustained peaking capability." RPM produces a consistently reasonable resource level to provide adequate energy to meet the region's need under low hydro conditions.

RPM functions to connect regional energy reserves to market prices. This connection captures a critical driver of electricity prices and the opportunity for generators to earn scarcity rents when energy supply conditions are tight. As a direct result of satisfying long-run equilibrium conditions, RPM adheres to the cause and effect relationship between gas and electric prices. In RPM, there is a structural relationship between the effects of gas prices on electric prices, which provides far more consistent results than models that use correlations between forward market prices. The impact of regional energy reserves on market prices is verified through examination of market-implied heat rates.

The market-implied heat rate represents the relative earning potential of a new CC or CT. As the name connotes, an implied heat rate is the calculated apparent heat rate to convert natural gas to electricity in the market at a particular time. Implied heat rates are the ratio of the monthly price of electricity divided by the monthly price of natural gas. RPM produces average market-implied heat rates that range from approximately 4 to 12 MBtu/MWh, which is generally consistent with the observed market values.

1.3 Uncertainty

Many resource planning models aim to introduce uncertainty into the decision analysis. The challenge remains to introduce meaningful uncertainty. For it to be meaningful, a model should apply a random element to the principal risk drivers in resource planning. The application of stochastic disturbances (random events) should represent a realistic set of potential outcomes. In other words, the simulated values need to preserve critical structural relationships among the following: 1) implied heat rates; 2) the impact of load on market prices; and 3) the impact of reserve margins on implied heat rates.

The RPM distinguishes itself from other software solutions by integrating meaningful uncertainty into the decision making process. The model applies a two-stage process to introduce uncertainty in the following way.

RPM disaggregates the simulation problem into a quarterly time-step of macro conditions and then an hourly component. The model parallels market dynamics by simulating prices on a quarterly contract basis followed by realized daily/hourly spot prices. The resulting time-series price paths are consistent with the generally observed pattern of forward prices over time.

The Council staff should more closely benchmark the model results for consistency with the historical record. The observed pattern of prices produced by RPM, however, reasonably reflects the observed market patterns. The model adequately follows the peaks and captures the movement of prices from disequilibrium events (high and low) back to the mean level price within one to two years.

On an annual basis, the Sixth Power Plan has clean implied heat rates, consistent with observed market values over the last decade. As mentioned above, implied heat rates are the ratio of the monthly price of power divided by the monthly price of gas. The market implied heat rates reflect market expectations of the efficiency of the marginal generating unit to convert fuel to electricity. Extracting the impact of CO_2 allowances (i.e., 117 lbs CO_2/MWh), RPM realized a value of 7 MBtu/MWh, with a 5^{th} and 95^{th} percentile of 3.8 MBtu/MWh and 11.5 MBtu/MWh, respectively. The minimum and maximum implied heat rates from the Sixth Power Plan are 1 and 60 MBtu/MWh out of 15,000 observations. These outlier heat rates are relatively infrequent, however, and are closely followed by events that produce a value closer to 7 for the next period. The overall range of implied heat rates remains relatively consistent with market observations but a more complete validation analysis and presentation of results is recommended and discussed in Section 3.

The RPM simulates seasonal prices, hydro conditions, and load. The model develops hourly loads and prices for electricity and gas following a time-series stochastic process. The process creates an hourly profile with uncertainty. The model correlates the random components between load, power, and gas at approximately 95 percent. The hourly correlations of the random component provide additional variability beyond simply applying a fixed profile. The Panel inspected a limited set of hourly results and found the RPM approach replicates the observed time-series pattern of prices. A more complete validation analysis for hourly results would be to perform a back-cast to historic values, as discussed in Section 3.

Hourly simulations for wind and perhaps load and prices could be enhanced through introducing weather as a causal variable. RPM simulates wind with a uniform profile and a 33 percent capacity factor. Wind generation should be simulated to capture the observed diurnal cycle and seasonal variation similar to what is done for the GENESYS model.

The Panel suggests using the time series of wind generation from multiple locations to develop an aggregate composition consistent with the observed time-series pattern and relationship to load. Under a more advanced modeling approach, wind could be derived through simulation of weather across multiple stations in the four-state region. The weather simulation could also be used to better align hourly load with wind generation and market prices.

The way in which the RPM integrates quarterly to hourly values represents a logical progression. The progression moves from prior-to-delivery uncertainty of forward market prices and regional hydro forecasts to actual during-delivery uncertainty. The use of 750 simulations for each quarter over 20 years provides a broad range of outcomes. RPM could reflect seasonal variation in load, hydro, and market prices more closely by applying a monthly model instead of a quarterly model. Maintaining the same computational demand, RPM may more closely capture seasonality with 250 monthly simulations instead of 750 quarterly simulations.

1.4 Limitations Suggestions

In the preceding sections, the Panel has been supportive of the general approach and direction of the RPM. The Panel has also recommended areas for improvement, which would be advances in the modeling capabilities. In some cases, the Panel believes inclusion of the suggested capability will yield more consistent planning results. The suggested limitations and improvements are summarized in Table 2.

Table 2. RPM Potential Enhancements for Future Release

Issue	Impact
Uniform modeling of hourly wind generation.	Wind generation modeling does not currently account for the supply dynamics of wind generation on market prices and the ensuing cycling of regional resources. Linking wind generation to load either through observed statistical relationships or through simulating weather as a fundamental model driver will better reflect the hourly variation of wind generation.
Simplified hydro generation.	BPA's HydSim model, which currently provides hourly hydro generation based on simulated regional flows, may need to be augmented to account for the impact of additional wind generation and provide more detailed dynamic optimization of the regional hydro system.
Ancillary service requirements.	Ancillary service constraints yield more value to flexible generation. The absence of a utility-level ancillary service constraint overlooks recent and critical regional dynamics of wind, thermal, and hydro resource operations.
Elasticity of response to increasing energy prices.	The current modeling structure does not dynamically adjust energy demand under alternative carbon-price scenarios/simulations. Introducing a long-run elasticity of response would recognize the likely loss of demand with high carbon-price scenarios.
Generator characteristics of start-up costs, minimum run-time, and start-up time to reach full load.	More granular modeling of the physical attributes of generator asset characteristics will support a better assessment of the trade-off between alternative supply resources and load control programs.
Transmission constraints.	RPM may overlook the need for capacity and energy in select sub-regions that are transmission constrained.
Risk metric provides one view of risk that does not account for annual variability and views risk from a single distribution rolled up over 20 years.	To better represent risk issues, adopt several risk metrics and develop some weighting mechanism between them, such as annual variability in rates or sensitivity to market conditions versus regulatory conditions. For example, CO_2 prices, which have greater price uncertainty and potential impact on resource selection, should be distinguished from known hydrological or fuel price risks. The latter has a greater degree of certainty in the expected shape of the probability distribution and realized time-series pattern and should receive greater weight in resource selection.
Monetize risk to remove the burden on decision makers to place their own dollar value on	Monetize risk into a single risk-value additive to costs. This modification should eliminate the need to present the risk-return (efficient) frontier and simplify the process of resource selection.

risk.	There are multiple techniques to monetize risk; this would greatly enhance the presentation and use of RPM results for decision makers.
Risk-return frontier presents too many plans that are very similar to each other.	Run RPM on larger increments of risk to produce a handful of plans for presentation to decision makers.

2. Application and Assumptions of RPM

After reviewing the application of RPM and the assumptions used in the modeling, the Panel reached the following general conclusions:

- Prices in the model are appropriately reflecting the changes in key variables (i.e., natural gas price, hydro generation, CO_2 price, reserve margin).
- RPM is appropriate for educational and discrete traditional resource planning.
- Inputs drive the model, and certain issues with the model outputs can generally be traced to the inputs instead of the model itself.

Additionally, the Panel offers the following recommendations for using RPM in the future:

- A vetting process for key inputs is needed and should encompass education about RPM as well as dialogue for generating inputs.
- For the Seventh Power Plan, RPM's capability to retire facilities should be turned on since many of the region's current concerns focus on capacity/reliability needs.
- Consideration should be given to removing or significantly increasing the limitation of hourly prices since capacity to support reliability needs to rely on strong price signals.
- An investigation of wind generation risk tied with load and hydro capability needs to be undertaken for the Seventh Power Plan.
- Generation dispatch logic can assist in supporting an appropriate level of capacity for reliability. The attributes that need to be added to accomplish this include the following: minimum up and down time, minimum capacity, minimum heat rate, and start cost.
- Known and present transmission issues should be incorporated on a high-level zonal basis to help in identifying potential reliability concerns.
- Renewable generation in the Sixth Power Plan was forced by an input to RPM, not solved through the modeling. We recommend allowing the model to produce the renewable resource portfolio (meet Resource Portfolio Standards) through a mechanism such as negative prices to represent Renewable Energy Credits (RECs).

As mentioned in the previous section of this report, the RPM methodology produces reasonable outcomes given the model inputs. As with all models, the inputs drive the result.

We understand there is some skepticism in the region about the model results. The Panel advises that more time and education are needed to design the inputs used to drive the model. It is important to establish buy-in from all stakeholders on the inputs. A discussion on various input impacts would assist in helping stakeholders understand RPM and the relationship of the inputs to the results. The model could in fact facilitate this discussion as certain inputs can be processed ahead of time. More discussion of these ideas will be presented in Section 3 of this report.

In the Sixth Power Plan, certain deficiencies and anomalies that may have been attributed to RPM could have been prevented through more thorough communication about the modeling inputs. The deficiencies include the relationship of CO_2 impacts to results and reliability concerns. All of those deficiencies can be attributed in some form to communication, or lack thereof, about the model and the inputs.

The Panel found a troubling issue in the CO_2 relationship with load. This is not necessarily a model problem, but highlights an important part of the process for vetting RPM inputs. CO_2 price scenarios and the corresponding load growth in the Sixth Power Plan simulations do not follow appropriate price response logic. The highest load in all the cases is presented with the highest CO_2 case. While there is some rational logic to developing such a case, the corollary is also as possible, that a high CO_2 case corresponds to the lowest load case.

The logic used to support producing a high load with high CO_2 prices follows from the Northwest as the lowest CO_2 emitting region in the country. But those scenarios also assume a national carbon policy. The high load, high CO_2 price scenarios also assume businesses in the rest of the country would transfer their operations to the Northwest versus going elsewhere or leaving the country altogether. It is possible to conceive of a solely regional CO_2 market, which could result in an economic destruction scenario. Again, this is an input issue, not a model issue.

The level of CO_2 pricing is also a subject open to much discussion. In many cases, CO_2 was priced in RPM at $100/ton by the end of the study. Once again, this is a matter of getting buy-in among all the stakeholders. It could be justified to have so many cases this high if the idea is to use CO_2 as a proxy for other environmental concerns. Education and an open dialogue with stakeholders are needed for treating variables such as CO_2.

With regard to capacity/reliability concerns related to the Sixth Power Plan, three areas of input require examination: plant closure, issues related to wind, and transmission. The plant closure concern can be traced to input. Modelers responded to a policy request and removed RPM's ability to retire facilities. A better approach to such a request would have been to conduct an impact study of removing that capability and the effect it would have on various resource plans. Failure to incorporate possible retirements may produce a plan that has significant reliability concerns. Over time, certain units need to be replaced if they are no longer cost-effective. The reliability issue will likely become more pronounced as more wind generation enters the system. There is a potential in the model to use low capacity factor units as balancing resources when in reality, these units would have been retired.

In the Sixth Power Plan, capacity/reliability concerns are a legitimate area to examine, particularly when we look at scenarios that build more wind to meet RPS. Three interrelated areas of input that influence the outcome in these scenarios are: hourly power price limits, wind generation variability risk, and commitment logic. Hourly power price limits are not a modeling issue, but a function of input.

The Council decided to place a cap on hourly prices in the Sixth Power Plan. In the absence of a capacity market and a low limit on hourly prices ($600/MWh), a potential is created for long-term reliability assets not to appear on the system. Most of the value of flexible units is driven by the capability of the unit to turn on in distress times. High power prices are needed at these times to make up for the fixed cost of these units. Typically these units do not generate enough energy revenue to cover fixed costs over the year with low prices capped.

The other issue involves an item we understand will be addressed in the Seventh Power Plan. For the Sixth Power Plan, the hourly wind risk as it relates to load and hydro availability was not investigated. Over the past few years, the region has seen high hydro, low loads, and high wind generation. These conditions have caused issues, not from a reliability standpoint but from an economic one. Is it possible that with greater wind generation in the future, a situation arises with low hydro, high loads, and low wind generation? The Panel believes this question needs to be investigated.

In the Sixth Power Plan, the model had no commitment logic implemented. In RPM simulations, generating units had the ability to turn on and off in each hour. Many generation technologies, including combined cycle combustion turbines, do not offer this level of flexibility. Given the potential for more futures to see significant wind resources and decreasing capability of hydro to balance those resources, commitment logic becomes a greater issue.

The Seventh Power Plan is expected to incorporate commitment logic. The generation attributes related to commitment logic need to be vetted for both existing and new generation.

Some of the concerns with regard to reliability in the Sixth Power Plan may stem from the lack of proper incorporation of start-up cost. For the Seventh Power Plan, attributes for the commitment logic should be start-up cost, minimum up time, minimum down time, minimum capacity, and minimum load heat rate. The Panel would stress the importance of working with utilities and power producers to review the inputs to produce better results for the Council and its stakeholders.

The role of transmission is another concern with regard to capacity/reliability. We understand there are transmission constraints in southern Idaho because the system there is summer peaking. While RPM is not a transmission model, incorporation of high-level zonal transmission constraints, may help identify potential regional requirements for capacity. The Panel agrees the modeling for the Seventh Power Plan would be improved with this addition.

We understand that in the Sixth Power Plan, the Council chose to restrict the model from solving for an optimal path for RPS. The Panel recommends allowing the model to produce the RPS portfolio through a pricing mechanism, such as negative pricing to represent RECs. In so doing, the model would incorporate some of the latest issues introduced by wind generation, including negative power pricing.

Another overlooked area of inputs that can significantly alter results is financial inputs related to cost of capital and discounting. A discount rate for the Northwest should take into account a weighted average cost of capital for all regional players. Projects and programs requiring non-utility investments should also incorporate an appropriate cost of capital. The Panel advises the Council to be diligent in choosing appropriate financial inputs.

The Council staff should subject the choices for new generation and its attributes to greater review and vetting. Given concerns about flexibility, RPM's commitment logic should support new generation offering the needed attributes, such as reciprocating gas engines. The Panel identified concerns in its review of some of the new generation unit attributes, including Variable Operations and Maintenance Cost (VOM), Heat Rate (HR), and Fixed Operating Costs (FOM). The input process for the RPM should incorporate developing a list of new generation resources and their respective attributes from the Integrated Resource Plans (IRPs) prepared by various utilities.

The Panel took an extensive look at the path of the impacts of variables (natural gas price, hydro generation, CO_2 price, reserve margin) on wholesale power price. Price is changing as expected from the model methodology established. Long-term impacts of CO_2 price produce market-expected heat rates for various facilities. Gas price changes are behaving as expected in terms of power price impacts. In addition, the model changes wholesale power prices when excessive and deficit capacity scenarios arise. Any power price abnormality is likely a function of inputs versus the model's functionality.

The inputs are critical in understanding the outputs. A case in point was the $50/MWh cost-effectiveness premium for conservation in the Sixth Power Plan. This premium was a result of RPM inputs, i.e., extreme carbon-price scenarios and constraints placed on the model. Removing most of the constraints brought the premium to a more reasonable level of $15/MWh. Spending more time on the inputs will reduce contentious results such as this.

3. Communications

The Panel found that RPM is a very sophisticated and useful approach for electric resource planning under uncertainty, as presented in the preceding sections of this report. We have also made several suggestions for various enhancements (none of them major) to the methodology that will allow RPM to address more directly the concerns raised by various Council members and other stakeholders. These suggestions are presented throughout this report.

But the value of the methodology, however powerful, is limited to the extent to which it is not well understood by the Council members and the public. This section discusses and provides recommendations for communication of the RPM methodology, assumptions, and results. It further addresses the involvement of Council members in specifying assumptions, scenarios, and plans to be analyzed with RPM, with the objective of increasing the interactivity between the Council and the RPM process. This topic overlaps some points made elsewhere in this report.

A small handful of key stakeholder representatives came individually to the NWPCC office on days when the Panel was meeting with Council staff and expressed their perspectives on RPM. One stakeholder, Dick Adams of PNUCC, stated the following concerns (paraphrased). This section discusses educational and procedural ways to address these and related concerns.

- RPM is a black box. The form of the answers from RPM does not necessarily help the Council decide what to do. People are not even sure what problem RPM is trying to solve.
- Council members need clarity on what the model is saying.
- Policy makers don't know how to make the trade-off between cost and risk from RPM results. There needs to be a robust discussion on the metric of risk.
- People don't understand the option concept as used in RPM. Further, optioning seems to be less applicable now with short lead-time resources than it might have been 20 years ago.
- The Council doesn't want to be at the mercy of the analysis or models. They need to understand the implications of the analysis using these complex tools.
- The plans run in RPM should be characterized by philosophies and policies. This is key to understanding the RPM.
- Utility executives need to understand the rationale for all aspects of the view of the future portrayed in the Council's regional plan, including forecasts of need and the amounts and costs of new supply.
- The build-new-generation logic seems more like an independent power producer view (build to make a profit) than a utility view (build to meet need).

The comment that RPM is a "black box" is true to a large extent. But that doesn't mean it can't be used. Some people consider a GPS a black box. They don't know how it works inside, but they use it because they have confidence in it derived from their experience, observing predictable relationships between inputs and outputs. RPM also exhibits predictable relationships between inputs and outputs. Some of the activities outlined in this section provide opportunities for Council members and stakeholders to observe the relationships between inputs and outputs and make their own judgments about RPM's predictability. We expect that this involvement will build confidence in the approach.

3.1 Transparency

There are various ways the Council staff can increase Council members' and stakeholders' understanding of RPM. These are discussed below under the headings of Concepts and Methodology.

3.1.1. Concepts

RPM is based on the principles and techniques of traditional generation planning, as they have evolved up to the 1980s, and is best understood in reference to these principles and techniques. These factors include:

- <u>Engineering economics, particularly, net present value analysis</u>. Alternatives are defined and analyzed in a way that facilitates consideration of the differences and similarities of resource options or plans, accounting for the time value of money.
- <u>Merit order dispatch / supply stacks</u>. Blocks of generating capacity are dispatched to meet demand in order of increasing incremental cost, subject to consideration of transmission and other operating constraints. Graphical representations can show the electricity supply and demand balance of RPM.

- Production (or dispatch) simulation. Computer simulation estimates the dispatch of a fleet of generating units given a set of inputs, including unit capacities, heat rates, and availability statistics; fuel prices; and hourly loads.
- Hydro modeling. This modeling incorporates the unique nature and constraints of hydropower resources, including energy limitations and cascading.
- Reliability analysis. Reliability analysis in the Northwest has traditionally focused on energy availability because of the dominance of hydro. (Elsewhere, the focus is on capacity availability. Now that the aggregate capacity of other types of generation is eclipsing hydro in the Northwest, concern is shifting toward capacity availability, as discussed above.)
- Adverse conditions modeling. Reliability requires that demand be met even when many things are going wrong. Under dry hydro conditions, the availability of hydro energy is sharply reduced. Hence, critical year hydro conditions underlie reliability analysis in the Northwest.

RPM builds on traditional generation planning by incorporating additional concepts whose development started in the late 1970s, accelerated in the 1980s, and went into suspension in the mid-1990s as focus shifted from planning to deregulation and competition. Interest in these concepts has been renewed in recent years as utilities and regulators are recognizing that there is still a need for planning. These newer concepts include:

- **Optimization.** Although the notion of optimization has always been implicit in creating a generation plan, there was little need of formal optimization techniques when the resource options consisted only of hydro, fossil, and nuclear units, and there were few constraints that weren't solved by building transmission reinforcement. But as the set of resource options has expanded to include renewable resources (and demand-side resources) with much different characteristics from traditional resources, environmental constraints have multiplied and transmission constraints have become persistent. Formal methods for optimization have become more important and much effort has gone into their development.
- **Uncertainty analysis.** In the post-war boom times, demand growth was forecast by laying a ruler on semi-log graph paper, and plants were built as fast as materials and equipment could be delivered, or so the legend goes. But the 1970s introduced uncertainty in fuel prices, and the 1980s brought uncertainty in demand growth, construction lead times, alternative resource development, and regulatory action. Utilities were suddenly confronted with the need to develop resource *strategies* to address these uncertainties, rather than resource *plans*. New analytical tools were developed, but were limited by the computational power available at the time.
- **Demand-side resources.** Actions by legislatures and regulators at both the federal and state levels to promote conservation and load-management resources as a way to reduce the need for new generating resources led to the need to evaluate demand-side as well as supply-side resources on a comparable basis. Integrated resource planning became the dominant paradigm, until it and all planning were swept away by industry restructuring and competition.

RPM has succeeded in integrating these newer concepts with the traditional approaches in a practical and effective way. It truly represents a significant advance in the state of the art.

Given this heritage, the RPM methodology should be presented in terms of these principles, techniques, and concepts.

3.1.2. Methodology

The Panel identified several specific concerns with the communication of the RPM methodology. These are elements that, although sound, as discussed in Section 1, are difficult to explain and, if misunderstood, can be stumbling blocks for acceptance of the methodology. Council staff already senses the need for careful exposition of these elements. We list some of the key issues below, in Table 3. We expect that stakeholders' comprehension of RPM would be enhanced by additional effort in explaining these topics.

Table 3. Methodological Elements that Are Challenging to Explain

Methodological Elements Requiring Further Examination
Market vs. Region: A boundary on the analysis needs to be drawn somewhere. Is the model optimizing for the region or for a broader market?
Open system model: A key principle is that RPM is an open-system model, in which the electricity price is decoupled and other outcomes are not forced to be completely consistent.
Decoupling by Price: The mathematical formulation gives the appearance of power going to the market, which is disconcerting to some. RPM seems to be using independent power producer (IPP) logic to solve a utility problem.
Accounting for IPP Capacity: What is the appropriate accounting for IPPs that are not committed to regional loads?
Strategic risk mitigation. The methodology by which RPM seeks plans that reduce strategic risk for the region need to be better understood.
Optimizer: The optimizer's role may be unclear.
Optioning: Optioning is hard to understand.
Game changers: A short history of game changers to justify considering cases outside of the mainstream could be added.
User control: How does the user have control over the results?

3.2 Validation

RPM needs to be validated to increase public confidence in it. In general, validation means demonstrating that model results match reality. However, this is difficult for a model focused on the future. It is theoretically possible for a model to be run for a historical period, with historical data as the inputs, and the outputs compared with other historical data. This process is sometimes called back-casting. However, constructing the historical data set can be very tedious, and conceptual problems arise when the input data could be considered the results of random processes.

A more common validation approach is to compare the results of one model with another already well-established model. This approach is called benchmarking, although the term can also be used for back-casting. We recommend two benchmarking activities:

- Run a case from RPM, defined as a particular plan mated to a particular scenario, through Aurora. The two models should yield consistent outputs from consistent inputs.
- Compare the hourly hydro profile between RPM and the utilities' analyses. These profiles should match in some key ways.

Some benchmarking has been done already. The Panel recommends this be repeated from time to time as RPM enhancements are implemented and assumptions move into untested ranges, and the results shared with stakeholders.

We also recommend other ongoing informal validation activities such as the following:

- Present the results from a small number of wide-ranging assumptions to stakeholders to demonstrate the extent to which the results correspond to intuition. Intuition need not be the final arbiter, as intuition can also benefit from calibration against model results.
- Apply specific reality checks to model results, including at least the following:
    - Long-term equilibrium. The model should not keep adding generating capacity if plants are consistently losing money. Similarly, there should not be persistently abnormal high returns on capacity.
    - Implied heat rates. An implied heat rate is obtained by taking a wholesale power price (\$/MWh) and dividing it by a natural gas price (\$/MBtu). The result (MBtu/MWh) should not be consistently higher than the most inefficient gas units in the region, unless oil-fired capacity is on the margin or the market price reflects an adder such as a carbon fee, or be consistently lower than the most efficient gas units, unless coal or other low-cost units are on the margin.

3.3 Reaching Out

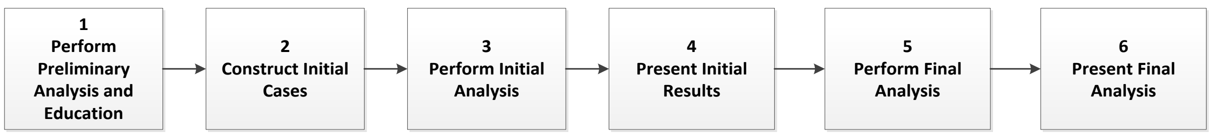
The Panel considered how interaction between Council staff and the Council might be structured to realize both the highest level of understanding of RPM among Council members and the most effective exercise of the Council's judgment in guiding the RPM process. We outline a suggested approach to using RPM in the NWPCC planning process in this subsection. There are undoubtedly other approaches that could achieve the same objectives. Even if our suggested approach were followed, it is likely that some changes would be needed to address practical issues.

The Panel also recommends that training on RPM be synchronized, even integrated, with this process, rather than scheduled as a separate activity. Specifically, we mean that concepts be introduced only just as they become relevant in the process, rather than scheduling RPM training in blocks detached from, or only loosely coupled to, the process. A synchronized, integrated training approach will make the concepts more concrete, less abstract, and more relevant to the planning process. The full training should be updated and repeated with each five-year cycle, as five years is too long to expect people to retain the kind of thorough understanding of RPM needed to contribute to the process, and there will unavoidably be turnover among the Council members and stakeholders.

It is also important that Council members and the public see the process and policy issues as driving the model, not the model driving the process or policy.

The suggested process is illustrated in the process flow diagram, Figure 1**Error! Reference source not found.**. This process has three phases of analysis – preliminary, initial, and final – and two phases of interaction with stakeholders – when constructing the initial cases and when presenting the initial results.

Figure 1. Process Flow Diagram



Phase 1. Perform Preliminary Analysis and Education. This phase starts internally with a set of deterministic RPM runs constructed with two purposes in mind:

1. To exhibit the behavior of the model through sensitivity cases, delta analysis, and the like, illustrating how input data drive results and the inner workings of RPM.
2. To set the stage for eliciting stakeholder input on assumptions to use and cases to run in RPM, through cases that demonstrate to stakeholders the meaning of key variables when processed through RPM.

Both purposes serve the overarching purpose of this phase, which is education of Council members and stakeholders. This phase concludes with training, including a presentation of the results of the analysis in which the key model behaviors and meanings are highlighted and explained.

Phase 2. Construct Initial Cases. This phase begins immediately following the presentation at the end of Phase 1, in the same meeting or set of meetings. Council staff asks stakeholders what concerns they see in the future markets and what outcomes they are interested in. Staff solicits assumptions from which to build input scenarios to incorporate the information provided by stakeholders. Subsequently, staff publishes those input scenarios and validates them with stakeholders.

Although it is important to reflect mainstream thinking in the assumptions, it is still necessary to incorporate scenarios that are outside the mainstream because current fundamentals and politics will not last forever. These scenarios need to be constructed carefully. There are certain well-known perception biases, discussed in the decision analysis literature, such as availability and anchoring, that can cause a set of scenarios to be too wide, too narrow, or skewed inappropriately in one direction or another. Staff or a facilitator should employ a structured process when soliciting input from stakeholders in order to avoid these biases.

In addition, staff requests stakeholders to provide whatever analytical support they can with regard to major inputs, attributes, financial inputs, load forecasts, etc., and validates those inputs with both stakeholders and analytical support.

Staff further seeks input regarding plans and strategies to run with an eye toward illuminating key philosophical and policy issues. The objective is to allow Council members to play a key role in constructing a small set of plans to use as starting points for the analysis. These plans should include different identifiable, near-term actions, such as starting pre-construction work on particular generating options or committing to additional blocks of efficiency. Then RPM results will have a more direct connection to decisions.

Phase 3. Perform Initial Analysis. Council staff runs the model first with deterministic scenarios, then incorporates risk features. Staff identifies risk and key differences between the plans or strategies. Staff performs a careful review of the results internally, and either fixes problems or finds valid reasons to answer any potential objections.

Phase 4. Present Initial Results. Staff publishes validated scenarios and results for review by stakeholders. The report includes a presentation of the risk perspective and discussion of the implications of the analysis for key policy decisions. Staff solicits feedback from stakeholders – in writing, at a public forum, or both – and responds to various concerns.

The results should include some sensitivity analysis showing the influence of the input distributions on the key policy decisions. It is at this stage, and probably not before, that staff can effectively solicit input on probabilistic assumptions from stakeholders.

Phase 5. Perform Final Analysis. Staff revises the assumptions and analysis on the basis of the feedback obtained in Phase 4 and conducts a final set of RPM runs. Staff may interact with particular stakeholders or Council members on revision of specific cases, as needed.

Step 6. Present Final Analysis. Staff prepares a final report on the analysis for potential incorporation in a power plan report.

These steps could occur in different venues. Some of them could occur in Council meetings. Others, such as sessions soliciting inputs or feedback, could occur in a more distributed fashion, in meetings with small numbers of utility personnel or other stakeholders.

3.3.1 Results

The RPM decision analysis framework would benefit the Council and broader audiences by presenting the results tiered into multiple levels. The first level would provide the “actionable intelligence” for decision makers, and the remaining levels would provide the “situational awareness” data, from critical inputs and validation reports to hourly simulation values. The multiple layers of background data for situational awareness address input data, assumptions, validation reports, and more granular modeling results. The application of a pyramid approach for the RPM will make suggested resource plan solutions and input assumptions more readily understood.

The Council staff could make the decision analysis framework more transparent by modifying the way the risk constraint is used in creating plans and the presentation of results. For example, the efficient frontier is confusing and contains a density of information too detailed to be considered “actionable intelligence.” If the modelers solved the objective function over more widely spaced values of the risk constraint, or starting with a small number of carefully constructed plans, it would reduce the number of plans for the Council to consider from hundreds to a handful. The smaller number of resulting plans could then be more readily compared against each other, yielding greater insight without any substantial loss of resolution.

Further, the Council and stakeholders would be more likely to understand risk values if they were monetized into a dollar value, as discussed in section 1.1.1.

There are presently several tools available for presentation of RPM results. These include:

- Spinner Graph. This tool enables a user to review key results for a particular plan from each of the 750 futures conveniently and in graphical form. This tool requires the user to think through the dynamics of each case and understand results that might at first glance appear counter-intuitive.
- RPM Data Extraction Utility. This tool enables a user to extract various kinds of results for further analysis in a spreadsheet.
- Snapshot Utility. This tool enables a user to capture specific futures for detailed analysis.

The Panel believes that the increased understanding of RPM obtained through the six-step process outlined above will better equip stakeholders to obtain additional understanding of the results through the use of these tools.

Other specific suggestions we have are:

- Present the differences in results between two plans for a small number of scenarios. The directions of the differences should correspond to intuition or be explainable by considering the dynamics of the scenarios.
- The efficient frontier, which has been used in the past to explain RPM results, is a convenient way to look at a large spectrum of scenarios and plans all at once. It is particularly useful for looking at the results of sensitivity analysis. However, the efficient frontier should be viewed as an advanced topic, more useful for analysts than policy makers.
- Staff should continue looking for new graphs and tables that communicate key insights.

4. RPM Support and Maintenance

After reviewing the support and maintenance protocol for RPM, the Panel reached the following general conclusions:

- The RPM architecture is based on MS Excel, which allows the model to be transparent and readily accessible to a large pool of talent to draw from for support and maintenance.

- Support and maintenance of the model will require additional staffing beyond Dr. Michael Schilmoeller.
- Analytical review is currently dependent on the Council's Power Division staff.
- Several work items have been identified and should be carried out to improve RPM.

4.1 Enhancements

Additionally, the Panel offers the following recommendations for supporting and maintaining RPM in the future:

- Increase staffing by at least one person to provide an understudy for Dr. Schilmoeller.
- Provide support for critical assessment of the results from RPM. Potentially hire an outside consultant to play devil's advocate as Council staff interprets the results.
- Focus the RPM work plan to address concerns identified from the Sixth Power Plan before proceeding with work items that increase the potential for outside users.

The basic RPM architecture is driven by Microsoft Excel, which means the Council staff can easily incorporate new components into the model. In addition, Microsoft Excel should lend itself to recruiting a larger pool of users since many modelers are fluent in MS Excel.

The Panel notes that the OptTek solver add-in for Crystal Ball is no longer directly supported and available. However, we understand the NWPCC is in direct discussion with OptTek to license its solver. Because the RPM does not currently require Crystal Ball to produce the Monte Carlo simulations, applying the OptTek solver independent of Crystal Ball may be advantageous.

4.2 Resource Staffing

RPM is currently supported and operated by Dr. Schilmoeller. Although much of the development work on the model has been done over the past few years, continued enhancements and updates will need to occur. The Panel advises against having only one person support and operate the model. Our experience suggests in the long-run, it is not reasonable to expect one person to handle the amount of work involved. Based on information about what happened during the development of the Sixth Power Plan, Dr. Schilmoeller spent seven days a week, including evenings, from December 2008 to August 2009, running the model and reviewing the output with only two weekend breaks. This is unsustainable and not productive for either Dr. Schilmoeller or the Council.

In addition to operating the model, analytical support is a crucial part of establishing the credibility of the model output. Currently, there is a lengthy internal analytical review of output by the Council's Power Division staff. This review process needs to be formalized and the environment needs to support a critical examination of the results. It is very important for members of the staff to take a devil's-advocate position with regard to results coming from RPM. That may be easier said than done given the working relationships among the staff and the potential for common beliefs and points of view on results.

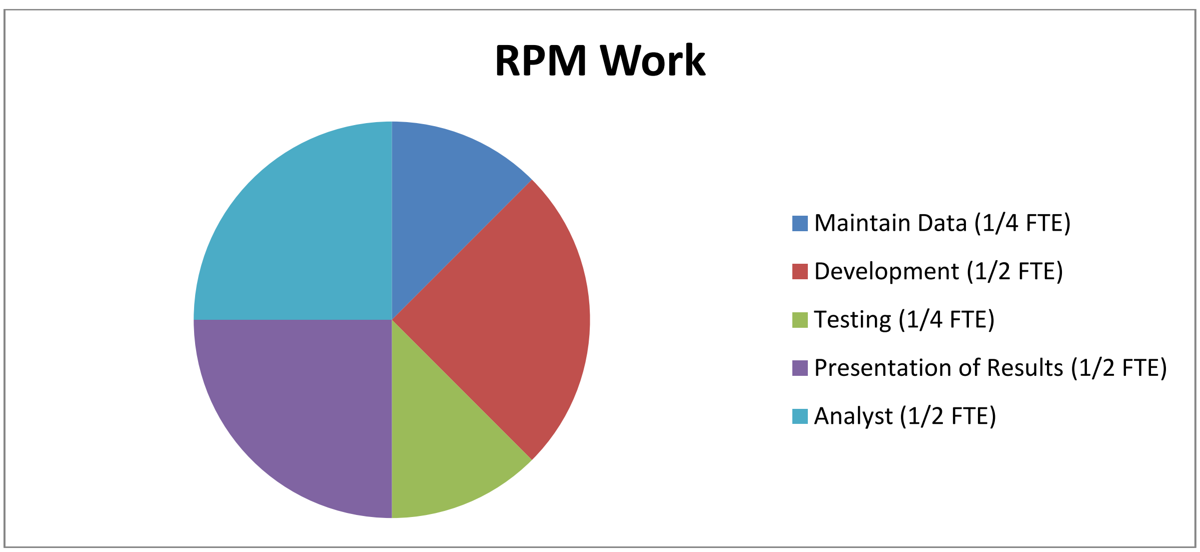
The Council staff also has a process for external analytical review by various advisory committees. It has been noted that the harshest critics of RPM, however, are still those outside this review process. It may be advisable to hire a consultant to strengthen the process. The Council staff would not need to resolve all of the issues identified by the consultant, but establishing coherent responses to them in a timely fashion would further validate and lend credibility to RPM and the analytical process. In addition, it is important to communicate to those who have issues with the model that their concerns are being heard and will be addressed.

Since analytical support can come from the Council staff, the larger issue for staffing is model development. As noted above, the architecture is built in MS Excel, which allows someone fluent in that program to assist in development. Incorporating stakeholders concerns with each pass through the model runs and the stages of developing a power plan will build confidence in RPM and the process.

The Panel recommends at the very least one additional person be added to understudy Dr. Schilmoeller. This person should have an active role in all parts of the modeling. This would free Dr. Schilmoeller's time and allow his expertise to be used in key areas that improve the model and build greater stakeholder support.

The Panel understands the NWPCC Power Division is currently recruiting a system analyst, who would ultimately undertake an active involvement in RPM work, including vetting inputs, interpreting and presenting results, and providing decision support for the Council members, as well as outreach to the Council's stakeholders. The Panel views this as a positive development both in terms of assisting Dr. Schilmoeller and in engaging Council members with the model and its results.

In terms of RPM work, the Panel believes the effort can be broken out to the tasks below:



*Based on two FTE and the assumption that Council staff with multiple areas of expertise will participate in reviewing the model output.

Our recommendation for staffing is based on the modelers receiving analytical support from the staff's subject-matter experts during the review. The Panel is concerned with the prospect of Council staff retirements and departures in the near future, which may cause a drop in the availability of analytical support. Given that the potential for staff not to be fully critical of the model results and the potential loss of staff resources, an additional energy subject-matter expert may be needed. An additional person could be an outside consultant brought in to review and play the devil's advocate role before model results are released for public viewing. As noted above, being prepared ahead of time to respond quickly and coherently to critics will enhance support for RPM and the modeling process.

4.3 Projected Work Items

The Panel has examined Dr. Schilmoeller's work plan for RPM, and there are many items. Several of them address making RPM more accessible for outside users, and the tasks range from providing further documentation to replacing third-party software. While these are good long-term goals, the focus at this point needs to be on development. Concerns that arose with the Sixth Power Plan need to be addressed soonest, particularly the reliability issues. The recommendations in the RPM Application and Assumptions section need to be developed and given priority. If progress is demonstrated in addressing the stakeholder concerns, it will boost confidence and support for RPM.

Once staffing is increased and personnel brought on-board, a review of the work items and priorities can take place. In the long-term, documentation and replacing the third-party software will become important to accommodating more users outside the Council. Until the Council staff builds confidence in RPM for the Council and the current stakeholders, there is no point in targeting the larger objective of supporting more users.

4.4 Documentation

The documentation for the model is quite overwhelming as seen in the Fifth Power Plan, and it forms a critical part of the presentation and communication of results. Dr. Schilmoeller has done an extensive job of documenting the model in its most technical form; however, the technical form is most useful for those interested in RPM's details and inner workings versus the results. Documentation is important for reproducibility and for Dr. Schilmoeller himself to recall the inner workings. This process needs to continue and as such, we noted time for it in the above RPM work breakout. Simple documentation to communicate the model's concepts and mechanisms needs to be improved. Much of this can come from the work outlined in the communication efforts above.

5. RPM Distribution and Use

As noted above, RPM is a very powerful methodology. The Panel was asked to consider the possible use of RPM by others, particularly by individual utilities for resource planning. We agree it could be very useful to utilities in the Northwest and making it available for use by others is an appropriate long-term objective. The Council staff has intended to make available utility-specific versions, but has not done so because of staff constraints.

It would require additional staff resources or a contract with an outside party, or both, to support RPM for others' use. It would entail the following additional activities:

- Enhancements to the user interface and reliability to make it easier to use by others.
- Distribution of RPM and Olivia upgrades.
- Creation of user documentation.
- User training.
- Technical support.

It would also require the commitment of considerable utility staff time to become proficient in using the model. RPM will have a learning curve at least as high and steep as the most complex planning model in use at any of the utilities in the region, and even more so since RPM has not reached the grade of commercial software. Whether the utilities would be willing to make this commitment is an open question.

A more immediate issue is whether the Council should undertake this activity at this time. The review of Council staff's model improvement work plan in Section 4 recommends that staff's priority at this time should be on further development of the functionality of RPM. Specific development recommendations, generally related to concerns arising from the Sixth Power Plan, are outlined above.

Only after this development work has been completed and confidence in RPM among Council members and stakeholders has been strengthened, should resources be assigned to distribution and use of RPM by others.

Appendix : List of References Provided

1. Dr. Schilmoeller's note to the Panel 8/29/2012

I would recommend reading the Power Plan material in the following order (all links will initiate document downloading):

Fifth Plan, Ch 6, Risk Assessment & Management
Fifth Plan, Ch 7, Portfolio Analysis & Recommended Plan
Fifth Plan, Appn L, Description of the Portfolio Model
Fifth Plan, Appn P, Treatment of Uncertainty and Risk

While the Council members who participated in the Fifth Plan understood the RPM model and relied on its results, the Sixth Plan Council members elected to adopt a more general resource plan. The RPM model results were de-emphasized in the Sixth Plan, although staff continued to use the RPM to evaluate various issues. Consequently, the discussion of the RPM is relegated to Sixth Plan, Appendix J, Regional Portfolio Model. That appendix has a technical description of the enhancements made to the model for the Sixth Plan. It also has the only results that explicitly reference any particular RPM model study and resource strategy per se. In contrast, the most explicit language about the resource plan in the Sixth Power Plan appears in the first ten pages of Sixth Plan, Chapter 10, Resource Strategy.

The presentations and notes for the SAAC meetings are also available from the Council's website. The notes from the September 2011 SAAC meeting, a list of SAAC achievements, membership list, the agenda for next SAAC meeting, and so forth are also available upon request.

Finally various versions of the model itself are available for download. The Fifth Plan Appendix L references a then-current version of the RPM model to provide the reader a row-by-row walkthrough of the logic and algorithms. (Links are also provided in the Appendix.) By the time the Fifth Plan Appendix P was completed, a newer version was available for illustrating the formulas and calculations. In 2011, we also conducted a workshop that permitted participants to install the model on their own machine, and the executable for installation is here. The 2011 workshop used the same version of the model that produced the final set of Sixth Power Plan recommendations.

2. Dr. Schilmoeller's Powerpoint presentations on the model

120904 RPM Review 00 - Overview 01.pptx
120904 RPM Review 01 - Model Objectives 01.pptx
120904 RPM Review 02 - RPM Introduction 01.pptx
120904 RPM Review 03 - RPM Methods 00.pptx
120904 RPM Review 04 - Platform 00.pptx
120904 RPM Review 05 - Using RPM Results 01.pptx
120919 RPM Review 05 - Using RPM Results 01 120918.pptx
120919 RPM Review 06 - Developing Futures 00.pptx

120919 CO2 costs for Michael.pptx ← I believe we avoided getting into this presentation
120919 Council Treatment of Environmental Costs.pptx ← I believe we avoided getting into this presentation

3. PSE IRP Powerpoint slides

2013 IRP Advisory Group Meeting, *September 6, 2012* (2013 IRP IRPAG Slides-Final.pptx)

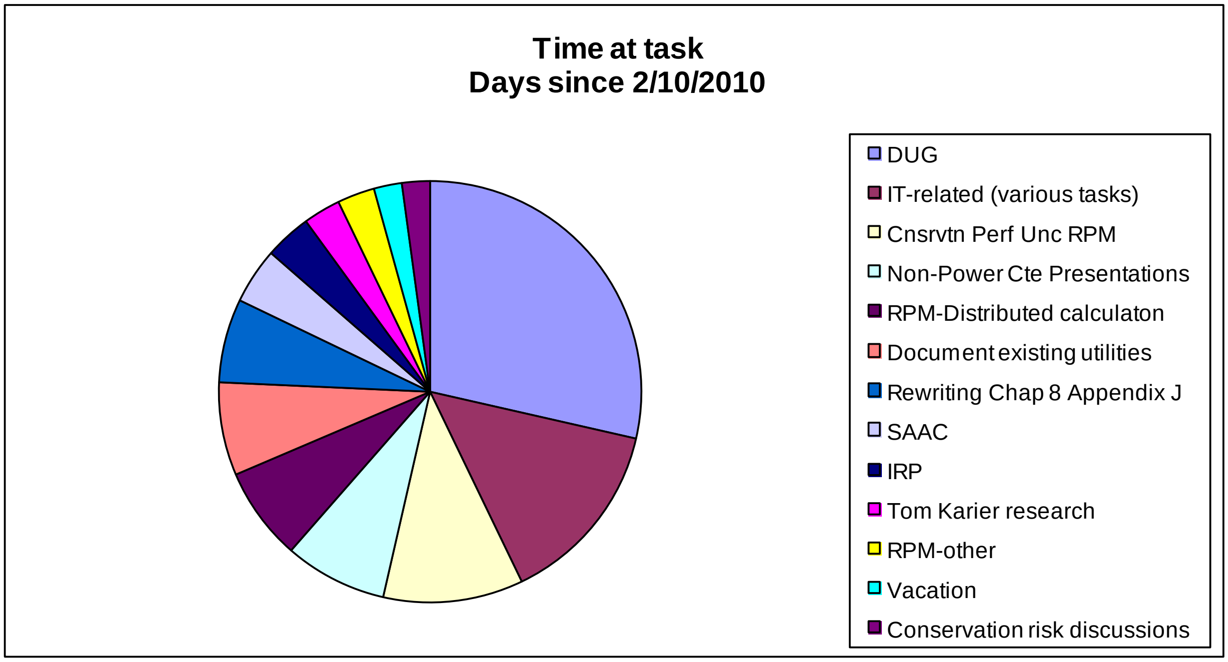
This contains, among many other things, an illustration of current PSE IRP assumptions and EPA for CO2 penalties.

4. Dr. Schilmoeller's status reports

Status_080201.doc – personal time log Friday, February 01, 2008 to Thursday, May 29, 2008
Status_080530.doc - personal time log Friday, May 30, 2008 to Tuesday, June 17, 2008
Status_080617.doc - personal time log Tuesday, June 17, 2008 to Monday, September 22, 2008

By October, my work and activities had become apparent to the Division Director, because of their nature. Much of my time was spent making presentations, reviewing input assumptions with staff, and preparing data. Studies and data development for the Sixth Power Plan persisted from October 2008 until adoption in February 2010. Clean-up and documentation lasted another six months. Consequence, logs are missing until October 29, 2010.

The purpose of providing these logs is to give the panel an idea of work required for various activities related to the RPM. Unfortunately, for that purpose, an important window is missing. I will look elsewhere for a means to reconstruct some of the information we need. I have found a few summaries that will be useful, such as the following, which bridges February 2010 to September 2010:



5. Documents about the future work for the RPM/OLIVIA

Work plan for the RPM model and Olivia_120920_104116.pdf ← a description of the outstanding work to be done on the RPM and Olivia, including strategy and rationale for sequencing and priority

Copy of Gantt_111019_Schilmoeller 04_120920_104116.xlsm← an estimate of time requirements for the work to be done on the RPM and Olivia, as well as various staff studies seen as requisite to the Seventh Power Plan.

6. New Resource Assumptions

Note to David Bellman, Thu 9/20/2012 11:25 AM

You wanted some information about the resources in the RPM. Here are a few references.

1. Start with the Sixth Power Plan
   http://www.nwcouncil.org/energy/powerplan/6/final/SixthPowerPlan_Appendix_I.pdf

2. For new resources, I will use various sources. For conventional supply side resources, the attached workbook will be the form that Jeff King typically passes what I will use.

3. To develop the input for the attached workbook and data for Aurora, Jeff uses another model, MicroFin. A current copy of this model is on our website and I am attaching a version more contemporaneous with the Sixth Plan data development process.

Attached:

PRM New Resource Assumptions 040309_120921_112735.xls ← specific resource assumptions prepared by Jeff King for implementation in the Sixth Power Plan final resource strategy

MicroFin 14.2.4 020409_120921_112736.xls ← Workbook model that Jeff King used to prepare the preceding summary input data.

7. Assumptions for Existing and Planned Units

http://www.nwcouncil.org/energy/powersupply/projects/Projects.xlsm ← Council's workbook database of existing and proposed power plants in and adjoining the PNW

8. Assumptions regarding VOM for new gas-fired power plants

DOE/NETL-2007/1281, ***Volume 1: Bituminous Coal and Natural Gas to Electricity, Final Report*** (Original Issue Date, May 2007; Revision 1, August 2007)

9. Model Objectives

From: Schilmoeller, Michael [mailto:mschilmoeller@nwcouncil.org]
Sent: Thursday, September 20, 2012 3:14 PM
To: Gary W. Dorris
Cc: Doug Logan (douglas.logan@wallawalla.edu); David K. Bellman (dkb@allenergyconsulting.com); Corum, Ken; Black, Charlie
Subject: RE: Model Objectives

10. An Overview of the Council's Power Planning Methods

http://www.nwcouncil.org/library/report.asp?d=48

This describes how various data sources and models come together to guide staff resource strategy (plan) recommendations.

c:\users\cblack\documents\regional portfolio model review december 2012.docx (Charlie Black)