Northwest **Power** and
Conservation Council

August 22, 2014

MEMORANDUM

TO: Council Members

FROM: Tom Eckman and Ben Kujala

SUBJECT: RPM Redevelopment Functional Approach Document

As described in our monthly updates to the Power Committee, redevelopment of the Regional Portfolio Model project has been moving along at a rapid pace over the last few months. Council staff and the Navigant consulting team have worked closely to keep the project on track and on the timeline agreed to under the contract.

Work has continued on various fronts, including data input validation and methodology definition and discussion.

A major item called for in the first phase of the project was for the Council and Navigant to agree on a functional approach document that will guide Navigant in redeveloping the model. It also outlines what pieces of the methodology will be available for testing and use in each of the three phases of project delivery.

We have attached the document to this memo to for Council Member review. No action is required on the part of the Council on this document, but do let us know if you have any questions or would like additional information about any section.

The approach document was written by Navigant, and went through an extensive review and comment process with Council staff. Comments and edits were also provided by the Council's two primary project contractors, Doug Logan and Michael

Schilmoeller. Attached is a memo from Dr. Logan summarizing his view of the finalized approach document.

In September or October staff intends to hold a meeting of the System Analysis Advisory Committee along with other stakeholders to present the document and help keep the public informed on the progress of the project. The document will also be posted publicly on the Council's website.

In the future, Navigant and Council staff may find that it is appropriate to make some changes to the document to provide additional clarity or functional description - especially related to tasks that are to be delivered in later phases.

MEMORANDUM

August 1, 2014

TO: John Fazio, Ben Kujala, Chad Madron, Steve Simmons

FROM: Doug Logan

SUBJECT: Review of the Navigant approach document

At your request, I have reviewed "Regional Portfolio Model Redevelopment, Functional Approach Document." The approach outlined in this document incorporates all of the features identified as important in the existing implementation of RPM in the December 4, 2012, report, "Assessment of the Regional Portfolio Model." It also incorporates functionality covering the "priority 1" components recommended for the RPM reimplementation in the December 18, 2013, report, "RPM Implementation Review," except for various output reports, which will be specified later.

Therefore, I conclude that the approach document addresses the essential elements required at this time for the current RPM redevelopment project.

DML

Regional Portfolio Model Redevelopment

Functional Approach Document

DRAFT

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Northwest Power and Conservation Council

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Draft Date: August 7, 2014

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NAVIGANT

1. Document Purpose and Overview

This document is intended to serve as guidance for the functional approach to the RPM Redevelopment effort. This project is actually "model development," not "software development," and thus some degree of flexibility and iteration will be required throughout the entire development process. This document represents the level of detail required for Navigant to proceed with this flexible model development. This document is further envisioned to be a "living" document that will be updated as key decisions are made regarding various approaches that may be used in the final model. At the end of the last phase of development, this document will have evolved into a documentation of the approach used for each of the key features of the model. Maintaining this level of flexibility is critical to maximizing the opportunity to improve/streamline the model.

1.1 Revision History

Revision history for this document is provided in the table below.

Revision #	Description	Date	Owner
Rev 1.0	Initial Working Version	6-30-2014	Cory Welch
Rev 1.1	Incorporated Council Comments	7-10-2014	Cory Welch
Rev 1.2	Incorporated Additional Council Comments	7-21-2014	Cory Welch
Rev 2.0	Incorporated Additional Council Comments	7-31-2014	Cory Welch
Rev 2.1	First Public Release Version	8-7-2014	Cory Welch

2. Optimization Approach and Decision Criteria

2.1 Approach

2.1.1 Summary

The redeveloped RPM model will endeavor to replicate the existing model structure (as close as practicable) with optimization determining the 20 year plan for the Northwest power system. The 20 year *plan* is defined as a set of options to construct new generating resources as well as value adders applied to energy efficiency resources.

Optimization Problem

An optimization problem can be characterized by defining three items, as described below:

- Objective Function: The value that the optimization algorithm is seeking to maximize (or minimize).

- Decision Variables: The only values that the optimization algorithm is able to change to assess the impact on the objective function of changing those values. This term was chosen for consistency with most optimization literature, recognizing that the existing RPM literature alternately uses the expression "decision cell," which was an expression used by the previously employed software.
- Constraints: A set of equalities and/or inequalities that determine whether the set of decision variables chosen by the optimization algorithm is deemed to result in a "feasible" solution to the problem.

These three items are detailed in the context of the RPM in the paragraphs below.

Objective Function – Minimize the *expected (i.e., the mean)* net present value of *cost to serve the region* over a 20-year time horizon across a set of uncertain (i.e., probabilistic) futures.

Note: Council staff indicate that variable costs for existing resources are included in the cost to serve, but fixed capital and O&M for those resources would be excluded, as they are sunk costs. However, an input field for fixed O&M for each existing resource will be included (even if populated with zero values) for possible consideration in future phases. Actual contract prices will not be included in the model (as those data are typically unavailable); rather, contracts will be valued at the equilibrium electricity price as determined in the dispatch algorithm (discussed later in this document).

The cost of a plan is given by: the initial planning cost incurred to purchase an option to procure a resource (as determined by the optimization's decision variables); the costs incurred to operate existing resources and new resources if acquired (which may vary in each future); and the average simulated cost of serving the region across all futures. The simulated cost to serve the region is calculated by simulating variable and fixed system costs, among other factors described below.

Cost to serve the region: Cost to serve the region over the simulated 20-year forecast horizon will include the following:

- Planning costs incurred to purchase an option to acquire a new generating resource
- Cumulative *fixed*, real, levelized capital and O&M costs incurred for newly acquired generating resources,
- Cumulative *variable* O&M and variable dispatch costs to operate the system, including the costs for existing resources and newly acquired resources,
- Cost to import (adds to costs) or export (subtracts from costs) electricity from outside the region (determined by the dispatch algorithm, as differentiated from the costs associated with pre-existing contracts, whose costs would not be tracked),
- Cost to purchase power from generating resources not dedicated to the region (e.g., independent power producers), at equilibrium electricity prices.
- CO2 emission costs
- Other emissions/regulatory costs (TBD)

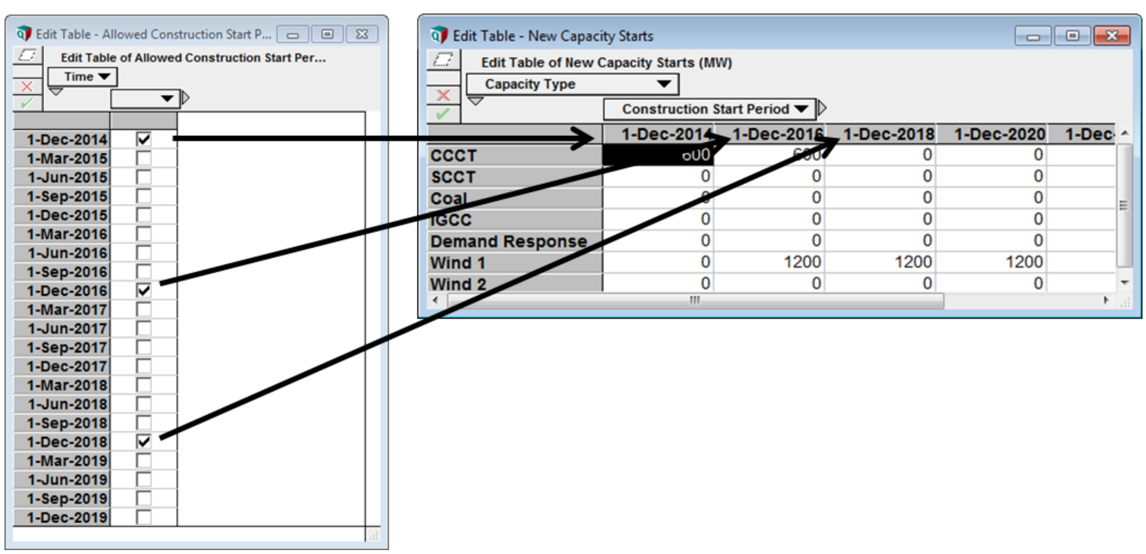
Decision Variables

The optimization problem is set up with two distinct types of decision variables, as described below:

- *Option to Acquire Resources*:

  These decision variables represent the option, but not the obligation, to acquire new generation resources. Whether these optioned resources are actually acquired will be determined by "decision criteria" (described in more detail below), which depend on the trajectory of loads, prices and other factors for any given future (these decision criteria are not under the control of the optimization algorithm). These decision variables are currently integer multiples of a specified generating resource size, which will vary depending on the type of generating resource to be added. During model development, we will explore both integer and continuous formulations for these decision variables.

  In the current RPM, for each resource, there is a decision variable for every new resource type roughly every two years (though this periodicity can vary over the simulated time horizon). Similarly, the redeveloped RPM will permit the frequency between decision variables for acquiring new capacity to vary through a user input. For simplicity, the same frequency between decision variables will apply to all new generating resources, though the frequency will be permitted to vary over the simulated time horizon (e.g., every 2 years for all resources). See illustration below for an example of how this might be implemented in the Analytica modeling platform. In this figure, the "New Capacity Starts" would represent the decision variables to provide the option to build new capacity. The table on the left would permit varying the number of time periods in the simulation where these decision variables apply.



- *Conservation Value Adder*: The Conservation Value Adder represents a price premium above the wholesale market price for electricity where energy efficiency would be assumed to be acquired. There are two decision variables of this type: one for lost opportunity conservation and one for discretionary conservation. These decision variables are each a single value that is held constant over all of the simulated futures. The purpose of this decision variable is to serve as a proxy to properly value the flexibility and forward looking cost-effectiveness of conservation resources.

Constraints

The redeveloped RPM would have the following constraints[1] imposed on the optimization solution:

- Resource adequacy (on energy only[2]) must be met (i.e., sufficient energy must exist to serve the forecasted load);
- Renewable portfolio standards must be met;
- The risk metric (see section below on the Efficient Frontier) must be met (i.e., risk metric must be less than or equal to the prescribed risk constraint).

Efficient Frontier

In addition to finding plans that minimize the expected cost to serve the region, the redeveloped RPM will identify the "efficient frontier" of the solution space, similar to the approach of the existing RPM. The risk metric to be used for creating the efficient frontier will be the TailVARxx (Tail Value at Risk at the XXth percentile, where the XX will be a user input value).

The current RPM creates the efficient frontier by running thousands of plans and inspecting the feasible solution space to determine whether it appears sufficient plans have been run in the neighborhood of a visually inspected efficient frontier. If there have been insufficient plans run, the risk constraint is increased and more plans are run in an attempt to better fill out the efficient frontier. An example of a plot of the solutions for thousands of plans (for two different scenarios) is illustrated below.

[1] In the actual optimization formulation, we may instead elect to have a failure to meet resource adequacy or RPS return an infinite cost, as opposed to enforcing a true "constraint" in the optimization algorithm. The final approach will depend on each approach's impact on run times and solve-ability.
[2] Phases 2 and 3 will explore the possibility/feasibility of adding a peak demand capacity resource constraint as well.

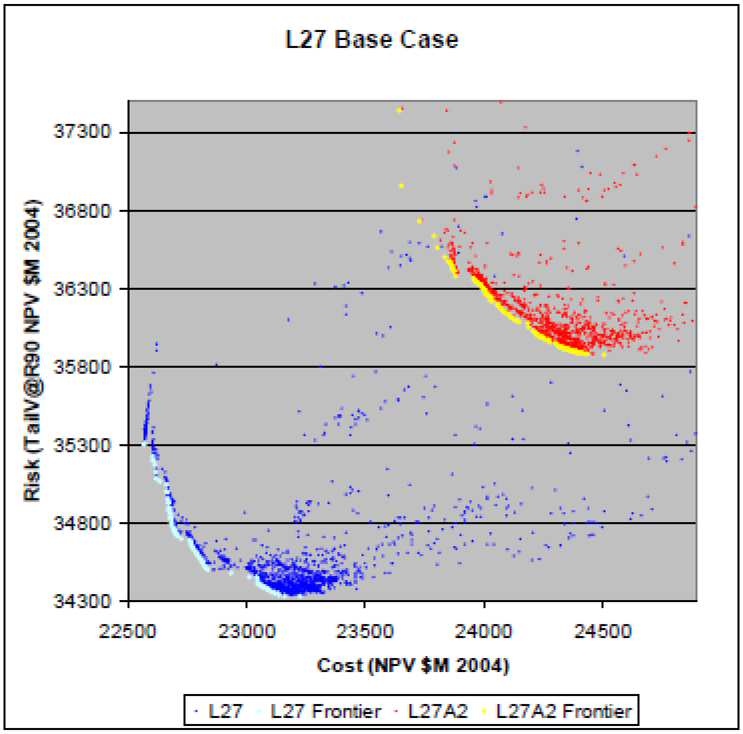


Figure L-107: Comparison of Feasibility Spaces

Source: PNW 5th Power Plan: Appendix L.

The redeveloped RPM may employ a similar approach to developing the efficient frontier. However, anticipated improvements in run-time may afford the opportunity for a more elegant solution. For instance, we may be able to solve for the least cost solution for a given risk metric for each of X prescribed levels of risk (e.g., generating, for instance, 4-10 different "optimal" plans along the efficient frontier). This would permit automated calculation of the entire efficient frontier without the manual manipulation of setting various risk levels and re-running the model, as is currently done (and also would take advantage of Analytica's "Intelligent Array" algorithm, which facilitates automated optimization for various constraint scenarios). An illustration is provided below of the difference in output. For instance, one could first run the optimization to minimize the expected net present value, and then run the optimization again to minimize the risk metric. Those two plans would bookend the efficient frontier. Then, a user defined number of points along the efficient frontier could be solved (e.g., either by solving for the least cost plan for a specified level of risk or by solving for the least risk plan for a specified level of cost).

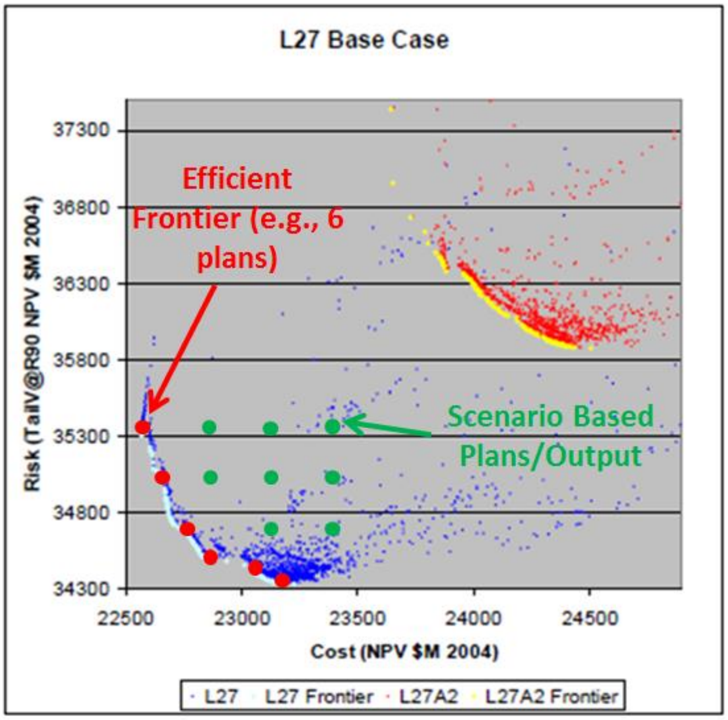


Figure L-107: Comparison of Feasibility Spaces

Source: Adapted from PNW 5th Power Plan: Appendix L.

This approach may be preferable to generating solutions and storing data for thousands of plans that are never envisioned to be implemented. This approach would be especially fruitful if the optimization algorithm can find the optimal solution with fewer than the thousands of plans currently calculated. Additionally, this approach would address stakeholder comments that too many similar plans are generated along the efficient frontier. Finally, since Council staff tend to consider a much smaller subset of plans along the efficient frontier (e.g., four or five) when generating its action plans, this modified approach may be preferable and easier to communicate.

That said, Navigant recognizes that Council staff also find value in seeing the results of plans that are *not* along the efficient frontier. Inspection of these plans, for instance, can help to explain model behavior (e.g., why a particular plan was *not* selected or does not fall along the efficient frontier). However, Navigant feels it can meet this objective while avoiding the need to store and plot data for thousands of plans that will never be inspected. We propose to work with Council staff to identify scenario based approaches for generating "non optimal" plans to facilitate understanding of model behavior, as illustrated above. We note that plans off the frontier can help Council staff to understand sensitivity to model inputs; Navigant will keep Council staff in the loop on the final approach on this issue.

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Decision Criteria and Market Simulation

As noted in the previous section, decision variables in the optimization only provide the option (not the obligation) to acquire generation of a particular resource type in the future. Whether those resources are actually acquired depends on the future in which you are in (i.e., which of the probabilistic trajectories for loads, prices, etc.) and on the pre-defined "decision criteria" employed by the model. These decision criteria are generically defined as:

- Decision Criteria: A decision heuristic (simple logic using trend analysis and adaptive expectations) to determine whether to "realize" the capacity option determined through the decision variables from the long-run capacity problem.

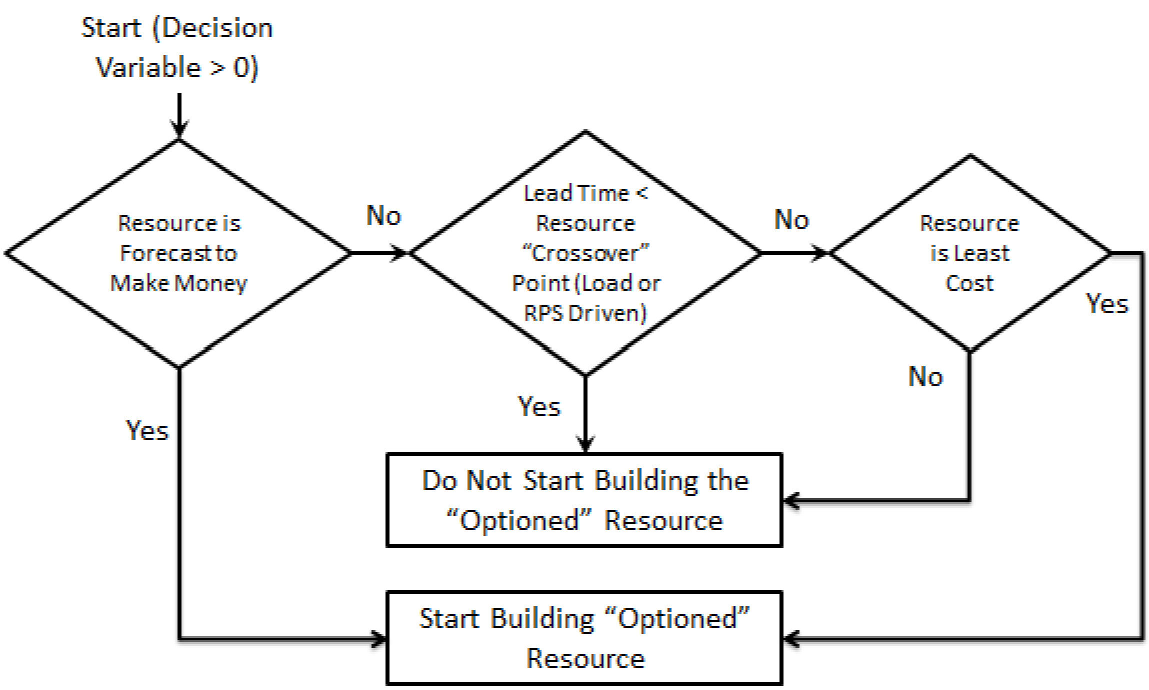
Once the decision variables have been set by the optimization algorithm, the Northwest power system is simulated over time across all futures. Resources that have been optioned via the decision variables can be realized and constructed according to decision criteria. These decision criteria currently calculate a go/no-go decision to build those resources. That decision is currently binary (meaning that if the decision variables optioned 2 of a particular resource of a predefined capacity, then either all or none (i.e., 0 or 2) of those resources would be acquired). The redeveloped RPM will endeavor to replicate this logic to the extent practicable in Phase 1, with some exceptions, as noted below.

- The current RPM includes a "multi-phase" construction cycle (e.g., siting and permitting, low cost construction, high cost construction). Discussions with Council staff indicated this is a lower priority feature for Phase 1 and probably even beyond Phase 1. Thus, Navigant will not include the multi-phase construction feature in Phase 1. We will consider whether it would add benefit relative to the additional complexity for future phases.

- As a result of the above, the decision criteria will be somewhat streamlined in the redeveloped RPM. The logic will be similar to that employed by the current RPM, with the exception of the permitting "delays" or "mothballing" of resources throughout a construction cycle. Rather, a single decision will be made in the year in which the decision variable afforded the option to build regarding whether to actually start constructing the resource or not. That decision will then be carried forward through the resource construction without re-examining the economics of the decision.

A schematic diagram of the expected decision criteria logic is provided below. This schematic is consistent with the logic described in the existing RPM, though it is somewhat streamlined. In addition to the logic depicted below, the decision criteria may also be used to implement a resource adequacy requirement by which resources are added in order to satisfy the constraint to maintain sufficient energy availability. Additionally, it may be used to enforce RPS mandates. Both resource adequacy and RPS mandates may alternately be enforced via the optimization constraints as opposed to the decision criteria. Which approach is more efficient will be determined in the coding and testing process.

Figure 1. Logic Diagram for Resource Acquisition "Decision Criteria"



2.2 *Options to Explore During Development*

- One issue with the current formulation is that the definition of a plan as a set of options to build resources is somewhat unrealistic when looking 10 – 20 years out. To have a valid option, there must be a purchase cost. While planning costs are currently incurred in the model whenever an option is included in a plan, developers do not actually incur such a cost 15 years before the resource would be constructed.

  We will consider, in coordination with Council staff, whether it would be advantageous to re-define a plan so that the first five years (or X years, perhaps a user input) of the plan are fixed (across all futures), and with decision beyond X years either not incurring an "option cost" (due to the lack of any real-world cost to have the potential for constructing resources past that time period) or incurring "option cost" during the simulation rather than at the beginning of the simulation period. This approach may benefit from more intelligent decision criteria (e.g., removing the binary characteristic of the existing criteria, and may not be appropriate for certain aspects of the plan (e.g., conservation logic)). Navigant will closely involve Council staff in this decision process.

The current EE adder is used to ensure that EE resources are added considering future value of the resources both in terms of flexibility and future market prices. An issue with this is that other resources do not have a method for being valued in the economic build decision at a price that differs from the market price. We will consider expanding the "decision criteria" to allow for the use of positive and negative adders (which would be decision variables) for resource acquisition as shown in Figure 1 when determining if a resource is forecast to make money. We anticipate that this would allow testing a positive or negative "risk premium" for resources using this logic which would likely favor more flexible resources over less flexible resources. Since this approach contains the case where the adders are all zero, this logic, if employed, would result in a superset that contains the possible plans in the 6th plan. However, adding decision variables to the problem could also possibly lead to unacceptable run times or solve-ability, which will be one of several considerations in whether this feature is employed.

- We will consider options to improve the decision criteria to relax some of the requirements that do not have real-world meaning such as the binary characteristic of them.

2.2.1 Phase 1 options/possibilities for consideration

- Consideration of alternate resource and EE modeling approaches
- Consideration of alternate "plan" definitions
- Consider improvement of decision criteria
- Include addressing RPS requirements

2.2.2 Phase 2 options/possibilities for consideration

- Add optimization, exclusive of the efficient frontier (required – not an "option")
- Further consideration of Phase 1 options, as appropriate
- Additional resource adequacy (e.g., peak demand) constraints
- Additional environmental/emissions constraints

2.2.3 Phase 3 options/possibilities for consideration

- Add efficient frontier as an output (required – not an "option")
- Consider alternative risk measures/metrics

2.3 Key Agreements to Date

- Multiphase construction is low priority, will not be included in Phase 1, and may be excluded in subsequent phases as well (TBD).
- Retirements will be exogenously determined.
- Phase 1 will not include optimization.
- Phase 2 will include optimization but not the efficient frontier.
- Phase 3 will include the efficient frontier.

3. Uncertainty

3.1 Approach

3.1.1 Summary

Uncertainty will be implemented in the same way that it was implemented in the existing RPM. Council staff will provide all the data associated with uncertain variables to Navigant for running the model. The model considers uncertainty as 750 independent futures, which are random draws of the various uncertain variables included in the model. The Phase 1 model will explicitly consider those 750 futures to facilitate comparison with 6th plan results; however, future phases will incorporate the logic required to generate the futures (as opposed to being provided the futures as a set of data from Council staff). Thus, future phases may permit making the number of futures an input variable, if deemed appropriate (e.g., 400 futures or some other number, versus a fixed 750 futures).
The following inputs are currently treated as random (i.e., uncertain) variables. Some of these variables (e.g., those in italics) will be modeled deterministically in Phase 1, but may be modeled stochastically in future phases, as desired by Council staff.

- Load
- Gas Price
- Electricity Price
- Hydro Generation
- *Commercial Availability*
- *Conservation Performance*
- *Forced Outage Rates*
- CO2 Tax
- Production Tax Credits
- *Green Tags*
- *Capital Costs*
- *Variable O&M*
- *Fixed O&M*

Hourly Data – Load and prices (e.g., electricity, natural gas) are provided for each scenario. These data are provided in quarterly and on/off-peak time periods, with an average value and, for electricity and natural gas prices, an assumed intra-period (e.g., hourly) variability around the average value. The calculated distribution of hourly prices is then used in the resource dispatch calculations. Hydro generation will also be provided by Council staff for each quarter for on/off peak periods. Correlations among the uncertain variables will be included in the data provided by Council staff (i.e., the 750 futures provided for prices will already include any assumed correlation among these uncertain variables).

3.2 Options to Explore During Development

Uncertainty in the input variables will differ for the model development phases as described below.

3.2.1 Phase 1 options/possibilities for consideration

See Summary discussion.

3.2.2 Phase 2 options/possibilities for consideration

- In Phase 2, we will incorporate the equations necessary to generate the distributions into the model; though, the coefficients for those equations, which drive the output, would be developed by Council staff.
- Additionally, we may make some of the variables that were modeled as deterministic in Phase 1 as probabilistic in subsequent phases (e.g., capital costs, outage rates).

3.2.3 Phase 3 options/possibilities for consideration

- TBD

3.3 Key Agreements to Date

- Council will provide all data for the 750 futures to be imported into the model
- Several variables that are currently probabilistic will be treated as deterministic in Phase 1 to facilitate early data development by Council staff, including:
    - Capital Costs
    - Variable O&M
    - Fixed O&M
    - Forced Outage Rates
    - Commercial Availability
    - Conservation Performance

4. Resource Modeling

4.1 Approach

4.1.1 Summary

Resource characteristics will be modeled in a similar fashion as the current RPM, with the primary exception being that multi-phase construction costs will be lumped into two parts – permitting and sitting, and full construction.

The items below provide a summary of the approach and key assumptions regarding modeling of individual resources:

Existing Generating Resources:

- Approximately 178 existing generators are currently aggregated into 21 surrogate groups, and a similar level of aggregation is expected for the redeveloped model (slight differences may be desired by Council staff, but material increases in the number of resources generated are not envisioned to be included since that would have an effect on computational requirements). Characteristics of each of the surrogate groups of resources will be provided by Council staff.

- Retirements of existing resources will be specified exogenously, with assumptions about retirements provided by Council staff. "Economic" retirements will not be modeled, but will be included as a possible "future feature" depending on priority, resources, and schedule. Any existing resource with a planned retirement will need to be modeled separately (i.e., not as part of a larger surrogate group) to permit proper accounting of the effect of the retirement.

- Many resources are simulated as "must run," including CHP, wind, geothermal, run of river hydro, most other renewables, and the Columbia Station nuclear power plant (because it has very low operating costs). The model will have the capability of specifying whether an existing resource is a must-run resource or whether it will be stacked up with other resources consistent with the dispatch algorithm (see section on Market Modeling).

- Forced outages and planned outages will be modeled as derations for each time period. Both will be modeled using exogenously specified derate factors in Phase 1. Future phases will calculate the forced outage rate as a function of mean-time-to-failure and mean-time-to-repair (in a fashion similar to the current RPM).

- The following characteristics of existing generation resources will be needed as model input, and will be provided by Council staff in an agreed-upon format (e.g., using a data input template to be developed by Navigant).

- Operating characteristics of generators
    - Heat rate
    - Forced outage rate & planned outage rate (for renewables, this appears to be 1-Annual_cap_factor) – Phase 1
        - Mean time to failure (for Phase 2 consideration)
        - Mean time to repair (for Phase 2 consideration)
    - Fuel type
    - Nameplate capacity
    - Capacity availability
    - Firm capacity value (for intermittent generation)
    - Integration cost (or flexibility penalty, for intermittent generation)
- Costs characteristics (to be provided in real levelized format, as with the current RPM)
    - Variable O&M costs
        - It is currently assumed that fixed costs for existing generators (e.g., Fixed O&M and Fixed Capital Costs) will not be included in the calculation of the NPV of Cost to serve the region, since these are effectively "sunk" costs whose expenditure is outside the control of the model. That said, we will need to discuss with Council staff whether inclusion of such costs is desired for future model versions where more detailed accounting of costs associated with retirements (and possibly economic retirements) may be desired.
        - Council staff note that sunk costs are used in calculating total revenue requirements and the retail rates for each future and plan combination. This is not currently a feature of RPM but will be included as a possible "future feature," to be considered depending on resource availability, schedule, and priority.
    - Variable integration costs are not considered in the current RPM but will be added to the "future features" list.
    - Etc. (some characteristics are TBD and will be determined in the modeling process)

- Generating resources within the region but "not dedicated to serve the region" (e.g., Independent Power Producers) will also be modeled, consistent with the current RPM. The accounting of costs for these resources will be at the equilibrium electricity price but the model will have the capability for the resource costs to be accounted at cost-of-service. Each resource will have the ability to be modeled as a "dedicated" or "not dedicated" resource, per a user input.

- New generating resource characteristics will be provided by Council staff and will include the same resources that were considered by the previous RPM.

New generators:

In addition to the data need for existing generating resources, the model will require the following additional inputs for new generators:

- Cost characteristics (to be provided in real levelized format, as with the current RPM)
  - Fixed O&M costs
  - Fixed integration costs
  - Siting and permitting costs
  - Fixed capital costs (aggregation of existing multi-phase construction costs)
  - Development costs
  - Etc. (some characteristics are TBD and will be determined in the modeling process)
- Planning characteristics
  - Earliest availability period
  - Economic life
  - Construction lead time (subsequent to siting and permitting)

- The following are new generation resources that can be built. As with the existing RPM, the model only considers technologies that have an economic chance of being built in order to reduce computational burden (e.g., Council staff exclude conventional coal plants as new resource candidates (see page J-32 of 6th plan)). Each new generator type will give a new class of resources in the dispatch. The constructed resources are not subsumed into an existing resource aggregation. Provided each resource conforms to the agreed upon input template for new resources, any technology type can be added (e.g., solar PV, storage, reciprocating engines).

  - Combined-cycle combustion turbine (CCCT)
  - Simple-cycle combustion turbine (SCCT)
  - Wind
  - Geothermal
  - Woody biomass
  - Advanced nuclear
  - Supercritical pulverized coal
  - Integrated gasified combined-cycle combustion with carbon capture and sequestration
  - Montana wind with transmission
  - Demand Response:
    - DR will be modeled as an exogenous input for Phase 1 (per discussions with Council staff).
    - Dispatch costs will be modeled on a $/kWh basis (as with the existing RPM), though with a limited (model input) number of assumed operating hours per year, which affects the calculated dispatch costs, which will be included in the model.
    - Future phases will consider whether to incorporate an endogenous calculation of the addition of DR as a resource.

4.2 *Options to Explore During Development*

4.2.1 Phase 1 options/possibilities for consideration

See summary section above.

4.2.2 Phase 2 options/possibilities for consideration

- Stochastic calculation of forced outage rates, using
    - Mean time to failure
    - Mean time to repair
- Consider modeling additional inputs stochastically (e.g., construction costs, etc.) that were modeled deterministically in Phase 1.
- Multiple types of wind resources with differing costs and profiles
- Wind resource energy output might be represented as a distribution within the dispatch period rather than as a flat average energy output
- Seasonal profile to capacity and forced outages for all resources
- Tracking and/or additional constraints regarding other emissions (e.g., particulate matter)
- Incorporation of DR as an endogenously calculated capacity addition

4.2.3 Phase 3 options/possibilities for consideration

- Consideration of incorporation of a peak demand capacity tracking and adequacy constraint (current RPM only models energy generation capacity and constraints)

4.3 *Key Agreements to Date*

- Retirements will be exogenously specified.
- Multi-phase construction is low priority and will not be included in Phase 1 (or likely in future phases).
- The model will have the capability to specify for each existing generating resource whether the cost of dispatch will be the market electricity price or whether it will be the cost of service.
- DR will be modeled as an exogenous input for Phase 1, but will be considered in future phases for endogenous calculation of capacity additions (possibly in coordination with a peak demand resource adequacy constraint).

5. Market Modeling

5.1 Approach

5.1.1 Summary

The existing RPM models resource dispatch and northwest region prices by taking an exogenous market price, calculating regional supply based upon that price, and then adjusting the price as necessary to balance imports/exports and resource dispatch. The redeveloped model will be implemented with a similar structure, though the algorithm for solving for the equilibrium price with consideration of import/export constraints may differ.

Time Periods
Consistent with the current RPM, the redeveloped model will solve resource dispatch, price balancing, and import/exports, for each quarter of the 20 year simulation (resulting in 80 "periods"), including on-peak and off-peak solutions for each of the 80 periods. The number of sub-periods per year will be flexible (e.g., permitting monthly rather than quarterly); however, model run times, creation of new data by Council staff, and other factors may make changing the number of sub-periods undesirable.

Market Price
There is a single equilibrated price for the northwest region that is solved by balancing supply and demand with the external price, imports, exports, generation, and contracts.

- There is a shortage cost (e.g., an effective resource with very high capacity and very high cost) to provide a backstop and guarantee feasibility.

Resource Dispatch
Thermal resources are dispatched given a function of spark spread (both market electricity prices and commodity prices (e.g., natural gas prices are modeled with an assumed distribution around the mean value). This means that even if the equilibrated price is below the resource dispatch price, the capacity factor may not be zero. As the equilibrated price rises, the capacity factor for a given resource will rise as well. Hydro and wind resource dispatch is exogenously determined and provided to the RPM.

Dispatch calculations will be performed for peak and off-peak within each of the 80 time periods specified above, using option models. Hourly variations within subperiods will be represented by probability distributions.

Import/Export limits
Regional import and export limits are exogenously given and can vary over time.

Contracts
Contracts are exogenously assumed and are only considered if external to the region. The contracted amounts are subtracted/added to the import/export limits. Only existing contracts will be modeled and,

after the contract expires, will not be included in the dispatch calculations. New contracts will not be modeled, as with the existing RPM.

Market Balancing
In the existing RPM, the market is balanced using an algorithm including a binary search, with prices adjusted as required to ensure internal consistency considering regional generation capacity, transmission constraints, imports/exports, and prices. The redeveloped RPM will similarly balance the market, though the algorithm used to do so may differ (see below).

5.2 *Options to Explore During Development*

Navigant will explore alternative market balancing algorithms during the development process:

- Linear programming – allows for multiple time periods to be solved simultaneously. Allows additional dispatch constraints to be easily added. Allows multiple regions to be solved. However, this approach also comes with additional modeling complexity and may not be desirable or feasible in the redeveloped RPM. Though, Navigant will consider this option.
- Analytica dispatch function – might be faster than either of the other two options.

5.2.1 Phase 1 options/possibilities for consideration

- Various market balancing algorithms will be explored, as described above.

5.2.2 Phase 2 options/possibilities for consideration

- Monetize cost of emissions that are not currently regulated

5.2.3 Phase 3 options/possibilities for consideration

- TBD

5.3 *Key Agreements to Date*

- Price elasticity of demand calculations will not be included in the model. Rather, this interdependence would be assumed to be included in the future loads and prices provided by Council staff (for Phase 1). For future phases, this relationship may be incorporated into the algorithms used to generate price and load forecasts, but that interdependence will be specified at the beginning of the simulation, and will relate external market prices to load forecasts (as opposed to being calculated internal to the model with each time period as a function of "equilibrium" market prices).

6. Model Boundary and Input Data

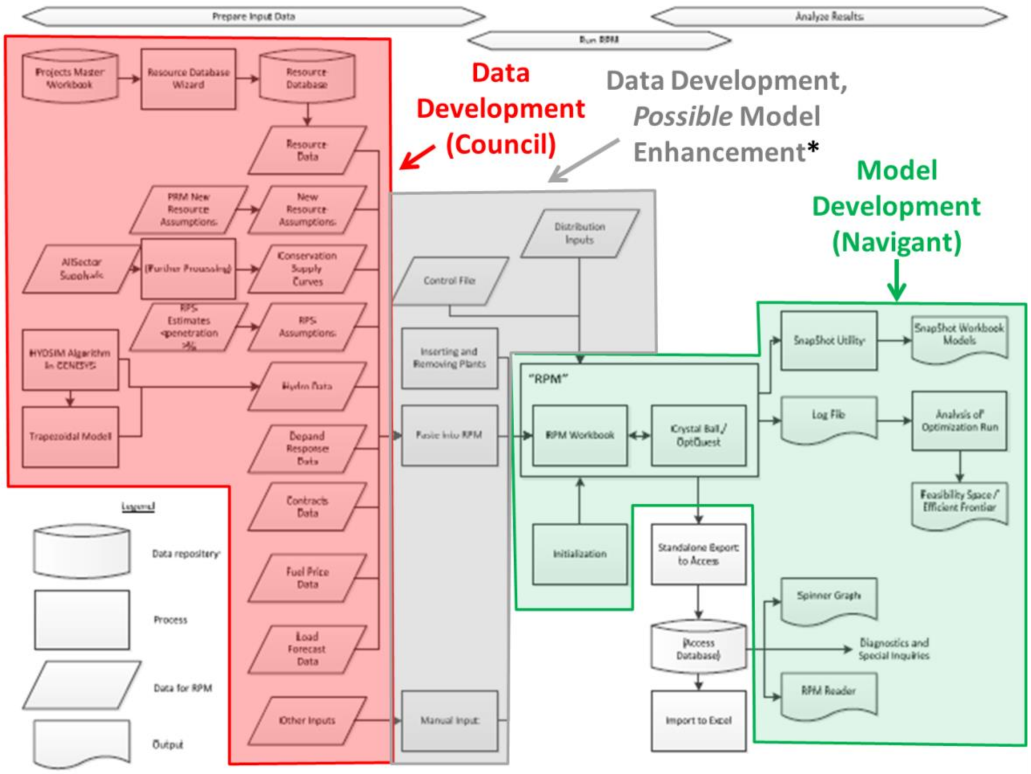
6.1 *Approach*

6.1.1 Summary

It is important in the development of the RPM to distinguish between model development, which is included in Navigant's statement of work, and data development and processing, which is not within Navigant's scope of work. Navigant understands that there are many steps required to process and develop data input to the RPM, including many files and steps required to translate, for instance, output from one model (e.g., the GENESYS model) to a format suitable for use in the "RPM Workbook." Developing and processing those input data, per the statement of work, is under the purview of Council staff, whereas development of the model acting on those data is under the purview of Navigant.

As part of the external review of the RPM by independent third parties, a process flow diagram was developed that we have adapted to clarify the boundary between Navigant's model development role and Council staff's data development role. In the figure below, steps outlined in the red box are considered to be data development and/or processing, whereas steps outlined in the green box are considered to be model development. The format of data provided at the boundary will require mutual agreement between Navigant and Council staff.

Figure 2. Boundary of Responsibility



Source: Adapted from "RPM Implementation Review," Douglas M. Logan, PhD, PE. December 18, 2013.
*Whether we will be able to incorporate some current data development steps (illustrated symbolically as the gray area) into the model development phase will depend on schedule and remaining Navigant budget. Currently, these are viewed as data development activities.

6.2 Options to Explore During Development

6.2.1 Phase 1 options/possibilities for consideration

- Data will be provided by Council staff at a level of granularity consistent with how the current *process* pastes data into the actual development.

Phase 1 Exceptions:

- The current RPM creates a set of futures for variables such as market electricity prices, gas prices, etc., using a set of algorithms and random variables to create correlated distributions. In discussions with Council staff, an agreement was made that for Phase 1, rather than provide the coefficients to "RPM Workbook" (an Excel file with embedded Visual Basic code, Council staff would simply provide the actual resultant distributions to Navigant, in the form of 750 data streams (futures) for each uncertain variable. Futures data will be provided for each of the 80 simulation periods. This approach was chosen at the request of Council staff to a) avoid the need for staff to fully integrate data management for the model prior to any development activity, and b) ensure that for testing purposes (and comparison with 6th plan output), the actual distributions used in the 6th plan are input to the model.

6.2.2 Phase 2 and 3 possibilities for consideration

- In Phase 2 (and possibly again in Phase 3, as appropriate), Navigant agrees to collaborate with Council staff to determine whether it would be advantageous to move the data input boundary further upstream in *select* instances. For instances, we will explore whether importing the characteristics for all existing generating resources (as opposed to the "surrogate," aggregated, resources currently imported into the RPM) would make sense. The decision of where the final data/model development boundary is drawn will have to consider:
    - schedule and remaining Navigant budget available to incorporate upstream *data processing* steps into the final model,
    - the degree to which moving this boundary would simplify the process and improve transparency, and
    - competing priorities regarding inclusion of other model features.

6.3 Key Agreements to Date

- For Phase 1, Council staff will provide the 750 futures for all stochastic inputs (as opposed to providing the coefficients of equations used to generate as input data for the model).
- As discussed in the in-person meetings on June 3-5, the boundary between data development and model development for Phase 1 will be at the location where data are "pasted" (or otherwise input) into the "RPM Workbook."
- In future phases, Navigant will work with Council staff to determine whether it makes sense to move the data processing boundary further upstream in the process (illustrated symbolically in gray in the figure above), subject to the limitations and considerations described above.

7. Use of Real Levelized Costs

7.1 Approach

Consistent with the current RPM, all generating resource costs (e.g., fixed capital, fixed O&M, variable O&M, etc.) will be annualized instead of using cash flows because annualized costs have better properties when comparing assets of different lifetimes.

7.1.1 Summary

Fixed capital (e.g., $/kW-year) and O&M costs ($/kW-year) for each new generating resource will be provided as an input to the model, and can vary depending on the *year of installation* of the generating resource. Once the resource is installed, however, those fixed capital costs and fixed O&M costs are assumed to remain constant over the entire operating life of the resource. For Phase 1, these costs will be assumed to be the same regardless of the future one is in, though future phases may include the modeling of uncertainty around these variables in a fashion similar to that of the existing RPM.

While the actual fixed capital and O&M costs (on a $/kW-year basis) are predetermined (and possibly a function of the future one is on, if modeled stochastically), the expectation of these costs on a $/kWh basis (which is used by the model's decision criteria of whether to realize the capacity addition afforded to it by the decision variables) will change depending on the trajectory of historic equilibrium prices.

In the current RPM, the expectations are purely backward-looking and use the average of past realized values, over an input time horizon. The redeveloped RPM will employ similar logic. Variable costs will vary by time and future.

To handle issues related to end effects, unequal asset lifetimes, and replacements, a perpetuity factor will be applied to all costs. The perpetuity factor will consider the expectations about the resource costs in the final two years of the study horizon, and it will extend those two years into perpetuity. In order for this perpetuity factor to be valid and appropriately applied, emission penalties cannot be enacted in the last two years nor can new resources be built.

7.2 Options to Explore During Development

7.2.1 Phase 1 options/possibilities for consideration

- None.

7.2.2 Phase 2 options/possibilities for consideration

- Navigant will consider including some upstream calculations to the levelized fixed capital and fixed O&M costs instead of relying entirely on exogenous values used in Phase 1.

- Inclusion of uncertainty around fixed capital and O&M costs.
- Instead of formulating expectations of variable costs as a flat trend into the future, we could use information from previous periods to change the variable costs based on a trended real growth rate. This formulation would require that growth rates revert to some long-run rate after a user-specified number of years to prevent unrealistic growth or decline in projected variable costs. There may be complications that arise with this formulation if costs are evaluated into perpetuity.

7.2.3 Phase 3 options/possibilities for consideration

- TBD

7.3 Key Agreements to Date

- Council will provide real levelized cost data as an input to Phase 1.

8. Hydro Generation

8.1 Approach

8.1.1 Summary

The current RPM takes hydro generation inputs from the Genesys model by time period. There is some ability to shift generation between seasons, though the capability is limited. The redeveloped RPM will take all hydro generation exogenously from Genesys. For Phase 1, we will not model any ability to shift hydro generation between off-peak and on-peak, though this capability will be explored in Phase 2.

8.2 Options to Explore During Development

8.2.1 Phase 1 options/possibilities for consideration

- None (see above).

8.2.2 Phase 2 options/possibilities for consideration

- Potential shifting of generation between off-peak and on-peak on a quarterly basis.

8.2.3 Phase 3 options/possibilities for consideration

- TBD

8.3 Key Agreements to Date

- There is no need to implement seasonal shifting of hydro generation at this time. Discussion with Council staff revealed this effect is small, and its inclusion is low priority.
- Hydro generation by period will be provided by Council staff as an input to the model.

9. EE/DSM

9.1 Approach

9.1.1 Summary

The redeveloped RPM will include two types of energy efficiency (EE) conservation: lost opportunity and discretionary. The approach to modeling each is described below.

Lost Opportunity (a.k.a., Replace on Burnout, New Construction)

- Each period (i.e., 4 quarters x 20 years = 80 periods) will have its own lost opportunity supply curve
- Each period's supply curve will be independent of prior period supply curves
- Supply curves are MWa vs. $/MWh (real-levelized).
- Pre-processing of supply curves would be done by Council staff. Data would be provided to the RPM in its final format for Phase 1.
    - Consistent with the current RPM, Phase 1 supply curves will use a piecewise approximation (currently 5 segments).
      The redeveloped RPM will receive annual prices and quantities for incremental conservation potential, as well as a "shape factor" that divides the annual quantities into 8 periods per year (on-peak, off-peak for each of four quarters).
    - Phase 1 would input data in same format as existing RPM (i.e., 5 piecewise segments for each quarter and for each on/off peak period, each with an assumed quantity and price).
- The current RPM uses a 60-month moving average of historical market prices for determining whether to acquire EE. EE is acquired if its cost is less than the moving average plus an "Long Term Value Adjustment" (discussed below), which is a decision variable in the model. The redeveloped model will similarly employ a moving average price for comparison with the EE supply curve; though, the redeveloped model will make the averaging period (e.g., 60 months) an input that the user can change.
    - The "initial" moving average market electricity price for comparison with the EE resource acquisition price will be a user defined input (required since there is no moving average calculable at the beginning of the simulation).
- The current RPM also employs a "high water mark" concept, whereby EE would be added at the price of the EE resource if the moving average market price for electricity ever exceeds this value (to account for inertia in EE programs and/or the implementation of codes/standards). In other words, if a resource were previously added at a given price, it would continue to be added in out-years at that same price.
    - The redeveloped RPM will also include this "high water mark" capability, but will also include a "switch" that would permit turning off this feature to explore model sensitivity to this approach.
    - Navigant will also explore other possible features to simulate the inertia in the design of EE programs (e.g., maximum % change in resource selection, adjusting the averaging time, etc.).

Discretionary (a.k.a, Retrofit):

- A single discretionary supply curve (over the entire simulation horizon) will be used that represents the total "bucket" of potential from which efficiency could be acquired.
- The model will permit a user-defined constraint on the maximum EE that can be acquired per quarter (otherwise all potential could theoretically be acquired in one quarter, which is not realistic).
- As with Lost Opportunity Conservation, a "shape factor" will also be needed as an input to permit splitting annual conservation quantities and prices into on-peak, off-peak, and quarterly values.
- Since discretionary potential is "drawn down" from the single supply curve, potential in future quarters will be affected by that acquired in previous quarters (as differentiated from lost opportunity supply curves, which are independent of EE acquired in previous quarters).
- Supply curves that have been provided to Navigant by Council staff already include the effect of not simply drawing down the cheapest resource first (using a sampling without replacement method). That is, the supply curves used as input to the RPM, use the assumption that conservation programs purchase a mix of resources and not just the cheapest ones first. Phase 1 will continue to employ supply curves as delivered by Council staff for input. Future phases will consider whether incorporation of the sampling without replacement for conservation into the RPM model logic rather than as an input, is practicable considering resources, budget, and priority.

Long Term Value Adjustment:

The current RPM includes two decision variables related to energy efficiency – one for lost opportunity EE and one for discretionary EE. Those decision variables represent the *additional price above the market price* for electricity where one would still be assumed to acquire EE. Once selected by the optimizer, the adder remains constant throughout the entire time horizon.

The rationale for this adjustment (which was tested as both positive and negative values in the Sixth Plan RPM) is that acquisition of EE beyond that calculated to be "cost effective" (as determined via comparison of the EE resource price with the moving average market price) may result in lower cost and/or risk for a given 20-year forecast. Thus, the optimization formulation would select a value for the adjustment that serves to minimize cost (or risk) for a given risk (or cost).

The redeveloped RPM will also include this decision variable in its optimization formulation. However, it will also include a switch that would permit the user to turn off this feature so that model sensitivity to this approach can be tested.

Other EE Modeling Considerations:

The current RPM appears to tie the amount of EE conservation to the actual future's load forecast (e.g., a 1% reduction in the load forecast relative to an assumed baseline would also reduce the supply curve MW by 1%). For simplicity in Phase 1, this feature will be excluded, but will be included in some manner in subsequent phases.

9.2 Options to Explore During Development

9.2.1 Phase 1 options/possibilities for consideration

- Alternate formulations for the "high water mark" concept (e.g., constraints on the % change in EE acquired from period to period, adjustment to the moving average filtering time to gauge whether that provides sufficient inertia, etc.)
- Alternate formulations for drawing down resources from the discretionary EE supply curve (e.g., simple weighted averages vs. random sampling without replacement, etc.)
- Possible alternate treatments of EE, including decision variables and optimization constraints imposed to enforce EE inertia requirements.

9.2.2 Phase 2 options/possibilities for consideration

- Inclusion of elasticity of EE resources to changes in the load forecast

9.2.3 Phase 3 options/possibilities for consideration

- TBD

9.3 Key Agreements to Date

- Incorporation for discretionary conservation of the feature that accounts for EE program designs that include resources with multiple prices (i.e., as opposed to simply acquiring the cheapest resources first) is a high priority for Council staff.

10. Output Data and Displays

This section is added as a place-holder for a future listing of output data files and displays.

11. Glossary

Constraints: A set of equalities and/or inequalities that determine whether the set of decision variables chosen by the optimization algorithm is deemed to result in a "feasible" solution to the problem.

Decision Criteria: A decision heuristic (simple logic using trend analysis and adaptive expectations) to determine whether to "realize" the capacity option determined through the decision variables from the long-run capacity problem.

Decision Variables: The only values that the optimization algorithm is able to change to assess the impact on the objective function of changing those values. This term was chosen for consistency with most optimization literature, recognizing that the existing RPM literature alternately uses the expression "decision cell," which was an expression used by the previously employed software.

Future: A set assumed trajectories over the simulation period for each random variable. The current RPM has 750 futures, though the redeveloped RPM may vary the number of assumed futures. The term "futures" has been adopted for consistency with existing RPM literature. In Monte Carlo analysis, the term "random draw" is also sometimes used.

Market Electricity Price: An assumed price for electricity for a simulated adjacent region. This is an exogenous input that plays a large part in driving model behavior.

Objective Function: The value that the optimization algorithm is seeking to maximize (or minimize).

Option: In the context of this model, it describes the right, but not the obligation, to acquire a resource.

Equilibrium Electricity Price: The equilibrium price within the simulated NW region that results from a balancing of generation, loads, and prices considering the market electricity price, transmission constraints, and cost to generate electricity within the region.

Plan: The values for each of the decision variables in the model. For this model, the plan consists of the option to acquire generating resources of a given type, of a specified quantity, and in a given time period. Whether the model actually acquires those resources is dependent on the decision criteria. Additionally, a plan currently consists of a value for the assumed "adder" for energy efficiency.

Random Variable: A random variable refers to any input that is modeled as a probability distribution rather than a point estimate.

Simulation Period: The time horizon over which the optimization will be run. In the current model, the time horizon is 20 years, with 4 quarters per year (for a total of 80 periods).