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| Northwest Power and Conservation Council |
| RPM Technical Appendix |
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| **Council Staff** |
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# RPM Future Distribution Simulation

RPM uses several statistical modeling approaches to generate a distribution of forecast time series from a set of reference forecasts. The distribution of forecasts is then used to assess the risk of different potential “futures”.

Note: this document is intended to act as a compact reference for the RPM methodology anticipated to be applied in the Draft 7th Plan. To get a much more exhaustive description of the methodology and the intent see appendices L and P in the 5th Power Plan. To get more information on the capabilities of the redeveloped RPM look at the documentation contained within that model.

## Risk Models

### RPM Load Risk Model

The RPM load model modifies a reference forecast that is input into the model. Let be the forecast for flat (aMW) electric load at time (or period) . Then the forecast for future or game is modified by three terms. The first is

where ; , and are parameters; and , that is they are independent standard normal random variables. The second is

where are parameters that change by quarter and a normal random variable.

Given these terms, the load risk for future at time , is

Similarly the reference forecast for the weather-normalized load at time for future is modified as

### RPM Natural Gas Price Risk Model

The RPM natural gas price model modifies a reference forecast that in input into the model. Let be the forecast at time . The forecast for future is modified by three terms. The first is

where ; , and are parameters; and , that is they are independent standard normal random variables. The second is

where are parameters that change by quarter and a standard normal random variable. The third takes several factors that define start and end times where a “jump” factor is applied. For the factors take

Then the third term is given by

Where are parameters, , , and and are scaling factors. Given these three terms, the natural gas price for future at time is

### RPM Carbon Tax Risk Model

The RPM carbon tax risk model uses a few parameters to estimate a CO2 tax for the model.

where represents the first period in which the tax is applied and and and are parameters.

### RPM Electricity Price Risk Model

The RPM electricity price model modifies a reference forecast that in input into the model. Let be the on-peak electricity price forecast and be the off-peak electricity price forecast at time . The forecast for future is modified by two terms. The first is

where ; , and are parameters; and , that is they are independent standard normal random variables. The second takes several factors that define start and end times where a “jump” factor is applied. For the factors take

The second term is given by

where are parameters that change by quarter and a standard normal random variable. Then the third term is given by

Where are parameters, , , and and are scaling factors.

The fourth term scales the distribution according to the forecasts of gas , load and hydro . It also uses a systematic sampling of hydro as well as the risk model outputs for the natural gas price and the load .

Where are parameters. Given these four terms and the carbon tax price , the on-peak electricity price for the east zone for future at time is

and the off-peak electricity price for the east zone for future at time is

where is a parameter representing the CO2 emissions associated with market power.

### RPM REC Risk Model

The RPM REC risk model modifies a reference forecast that is input into the model. It is similar to the other risk models. The forecast, , for future is modified by two terms. The first is

where ; , and are parameters; and , that is they are independent normal random variables. The second is

where are parameters that change by quarter and a standard normal random variable. Given these two terms, the REC price for future at time , , is

### RPM PTC Risk Model

The RPM PTC risk model uses a few parameters and modifies the carbon tax risk model. That is, given a baseline PTC of the PTC for future at time is

where and are parameters and .

## Futures Functions

### Load

With the above risk model there are four risk-informed load time series that are calculated for use in RPM. The flat electric load forecast and the weather normalized load forecast both for on-peak and off-peak periods.

The flat electric on-peak load at time for future for is

where is a forecast multiplier based on the ratio of the on-peak load to the flat load. Similarly the flat electric off-peak load at time for future is

where is a forecast multiplier based on the ratio of the off-peak load to the flat load.

The weather-normalized on-peak load at time for future is

and the weather-normalized off-peak load at time for future is

### Natural Gas

With the above risk model there are two risk-informed natural gas time series that are calculated for use in the RPM. The natural gas prices for the west zone and the natural gas prices for the east zone. The price for the west zone is simply the price calculated by the risk model that is

The price for the east zone is

where is a parameter representing the minimum price for natural gas and is a forecast of the difference in price between the east and the west zones.

### Electricity Price

With the above risk model there are four risk-informed electricity market price time series. Two are from the east zone and are given above, that is for on-peak

And for off-peak in the east zone

For the west zone there is an adder for both on-peak and off-peak, and respectively. That is, for the west zone the on-peak electricity price is

And for the west zone the off-peak electricity price is

### Hydro Generation

The hydro generation time series is a function of the 80 water years. RPM is setup to select a random water year and then proceed sequentially from that water year through the 20 year run time. That is, if is the hydro generation for quarter of the historic record, for the 80 water years. And , and are defined similarly, then the time series for on-peak hydro generation for future at time is

where . Similarly

# Estimating Parameters for RPM

RPM has many parameters that drive the model results as well as inputs. These parameters are based on a variety of sources including forecasts, historic data and expert input. This section documents the process of estimating these parameters.

## Load Model

The primary component used for scaling the load model is of the form

If you consider that the random variables do not depend on time then this equation can be seen as only depending on time through the year of the simulation. The load forecast for the 7th plan has a high, medium and low forecast. To get this risk model to have a spread based on that forecast, regression is used. That is, if , and are the high, medium and low load forecasts respective then use regression to find , and in

Use the same procedure for . This can be done as if the random variables are fixed values because they do not depend on time. Take an average or weighted average of the variables to get a single parameter because the model assumes log-symmetry. The problem is how to alter these values to give the desired range.

While it may be possible to use a more complicated model with multiplicative errors, the easier thing is to recognize that in simple regression there is normally error around the estimation of the coefficients. If we assume that the distribution for has zero expectation, we can take the value from the regression to be a measure of the spread. Now since

We want a value where the probability of exceeding it is .85, which is the probability associated with the high load forecast. Since we have normality

Thus we set

Which implies

So taking from the regression above it is possible to construct an estimate for with a specified probability of exceeding a range.

The same method applies to the values for and above. This allows for RPM to be directly tied to the range implied by the load forecast.

The seasonal component adds some variability based on the quarter. The factor only depends on the quarter since it is of the form

The best way to accomplish this is to estimate seasonality based on the historic volatility. Because of the DSIs we need to adjust history to avoid carrying forward volatility that would not occur in the future. If we assume the seasonal factor is not intended to shape, then we know the expectation for each quarter should be zero. Thus

where is a standard normal distribution with zero expectation and is a scaling factor. So taking the adjusted history first normalize each quarter by the annual average and then normalize the resulting shapes by the average quarterly shape. That creates a sample similar to which can be used to estimate the standard deviation for each quarter.

## Natural Gas Price Model

Similar to the load model, regression is used to estimate the annual growth component. The seasonal factor is estimated using the historic record. The difference for the natural gas model is the jump factor. The magnitude of the jump is based on the largest historic deviation. The length of the jump goes from 1 quarter (period) up to 8 years based on input from the advisory committees. Price recovery is scaled at 1/10th of the magnitude of the jump in log space.

## Electricity Price Model

# RPM Dispatch Methodology

The Regional Portfolio Model uses a distributional dispatch methodology that calculates given a price determined in the model the frequency and the value of the dispatch.

Note: this document is intended to act as a compact reference for the RPM dispatch methodology. To get a much more exhaustive description of the methodology and the intent see appendices L and P in the 5th Power Plan.

## Thermal Model Derivation

The premise of the dispatch in RPM is that the market price compared to the variable cost to dispatch a resource determines how often it will be dispatched. To determine this over multiple prices and costs, a distributional dispatch calculation is required.

The equations for dispatch are derived based on the value of energy. The following equation gives a mathematical expression of the value if the generator is dispatched whenever the market price exceeds the generators variable cost, in this case represented as the price of natural gas.



Rearrangement gives the value in terms of the expected return from the market.



Solving the expectation takes some statistical derivation assuming is a random variable and is constant notice that

In the last expression, the first integral is partial expectation and the second is a survival function. Assuming has a lognormal distribution with and then both of these can be expressed in terms of the standard normal distribution , thus

A little rearrangement then gives

E

where

Unfortunately, this works for a constant but it takes some more work to get to the case where you are taking the difference of distributions. So assume is a random variable and is a random variable, then this follows a similar derivation to Margrabe’s formula. The basic idea is as follows, since these are both lognormal it follows that is also a lognormal and thus

follows the above result. So using a similar approach with equation for value above



The preceding equation may be evaluated explicitly and adapted for forced outages, CO2 costs and VOM:

