September 9, 2020

MEMORANDUM

TO: **Power Committee Members**

FROM: **Ben Kujala**

SUBJECT: **Challenges with the RPM Methodology**

BACKGROUND:

Presenters: Ben Kujala and John Ollis

Summary:

The Council has used the Regional Portfolio Model (RPM) since the Fifth Power Plan. While we redeveloped the model for the Seventh Power Plan, much of the underlying theory carried over from the original model. During the development of the 2021 Plan, we have encountered challenges with the theory behind the model.

Relevance:

There are two components to the theory that I want to focus on to illustrate the challenges we're encountering. First, there is an assumption that the distribution of the load, natural gas price, and electricity price follow a lognormal distribution. This is a common assumption in financial literature for commodity pricing and is fundamental to the Black-Scholes equation used in pricing options and the subsequent work by Black applied to pricing future contracts. This is not obscure theory; this work was awarded the Nobel Prize in Economic in 1997 and has been applied in many different settings. Second, the model assumes the dispatch of the existing and new thermal fleet is based on the market price of electricity.

Looking at the first assumption, the important thing to know about the lognormal distribution is that it was used to represent pricing because the value of stock traded on the open market (or perhaps more accurately a derivative product based on the stock price) could not go below zero and the potential value had a "long-tail" or said another way there was a small probability of the value being very large. The distribution is also used because it's easy to manipulate mathematically. Black eventually applied this to futures contracts from commodity markets. Forward markets for natural gas and electricity have very similar structure to the markets Black studied. However, even in the stock market product that Black and Scholes studied, there have been questions about the convenience of this distribution.

While the underlying theory seems sufficient to describe the price of natural gas (e.g. EIA uses this assumption for the Short-Term Energy Outlook: https://www.eia.gov/outlooks/steo/special/pdf/2009_sp_05.pdf), the electricity market has always had a tentative connection to this assumption at best. When the electricity market price is set by natural-gas-fired generation, the electricity price by virtue of association with the gas price can have a distribution that would be reasonably approximated by the lognormal distribution (especially when looking at the distribution of the expected average quarterly price of electricity). However, when electricity prices fall below the price implied by having natural gas generation on the margin, this assumption becomes questionable. When electricity prices become persistently negative, the assumption is clearly false. With a forecast that has frequent low prices and infrequent price spikes to extremely high prices, it follows that the forecast is for a market that does not follow well-behaved commodity market theory.

This leads to the second assumption I want to examine. The dispatch of thermal resources in the RPM is based on the market price. That is, regardless of if the resource is owned or contracted for by an independent power producer or a utility, the model assumes the resource dispatches when the market price exceeds the variable cost of running the unit. Market prices below the lowest variable-cost thermal resource result in the entire new and existing thermal generation fleet to be dispatched down to zero for a quarter. RPM simulates a quarterly price, then it uses the underlying log-normal assumption to create a distribution of hourly prices within that quarter. Looking at the number of hours that exceed the variable cost of the thermal resource gives the assumed capacity factor – or number of hours that thermal would be dispatched. This is described in Appendix L of the Seventh Plan as follows:

> *The premise in the RPM is that the dispatch of a resource is determined by how often the market price is above its variable cost. 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 always dispatched when the market price exceeds its variable cost, in this case represented as the price of natural gas.*
>
> *[…]*

Consequently, if the electricity price distribution is not correctly represented in the model, then the thermal dispatch is incorrect as well.

Fundamentally, gas plants can dispatch when the market price is below their variable cost for short periods of time. This is because some gas plants are unable to turn on and shut down from one hour to the next. This commitment logic is captured in the dispatch decision of our hourly models. Unfortunately, that commitment decision requires simulated hourly dispatch of resources (which is computationally slow) and a simulated decision (which is computationally more complex). The current RPM methodology simplifies that for speed, and to focus more computational time on looking at the risk associated with many different resource strategies. In the past, when gas-fired generation was on the margin for most hours of the year, the approximation of dispatch used by RPM was not substantially different than calculated capacity factor from the Aurora or Genesys dispatch. However, now it is possible that gas plants will run out of the money a great many hours to provide flexibility during a few hours of the day. The question is how to keep the speed of the current dispatch without significantly misrepresenting system dispatch, which will likely be large driver of system costs.

There is no doubt that in the past, starting from the Fifth Power Plan, these assumptions were not perfect. However, it is likely given some of the early electricity price forecasts we have looked at in this plan, that these underlying assumptions will be demonstrably wrong. And these assumptions are fundamental and intwined in the RPM logic, which makes changing them difficult at best.

This is not to say that there is an alternative portfolio modeling approach that has pristine theory and no issues. It is very likely that no portfolio model, commercial or developed in-house, is equipped to deal with an electricity market with extremely limited hours of thermal generation being on the margin and pricing driven more by model constraints than fuel prices.

More Info:

Black-Scholes model:
https://en.wikipedia.org/wiki/Black%E2%80%93Scholes_model

EIA Short-term Energy Outlook:
https://www.eia.gov/outlooks/steo/

Appendix L of the Seventh Plan:
https://www.nwcouncil.org/sites/default/files/7thplanfinal_appdixl_rpm_3.pdf

Challenges with the RPM Methodology

THE 2021
NORTHWEST
POWER PLAN

FOR A SECURE & AFFORDABLE
ENERGY FUTURE

The Value of an Option

- Theory originally applied to pricing stock options has been embedded in many financial models – including RPM

Press release

KUNGL. VETENSKAPSAKADEMIEN
THE ROYAL SWEDISH ACADEMY OF SCIENCES

English
Swedish

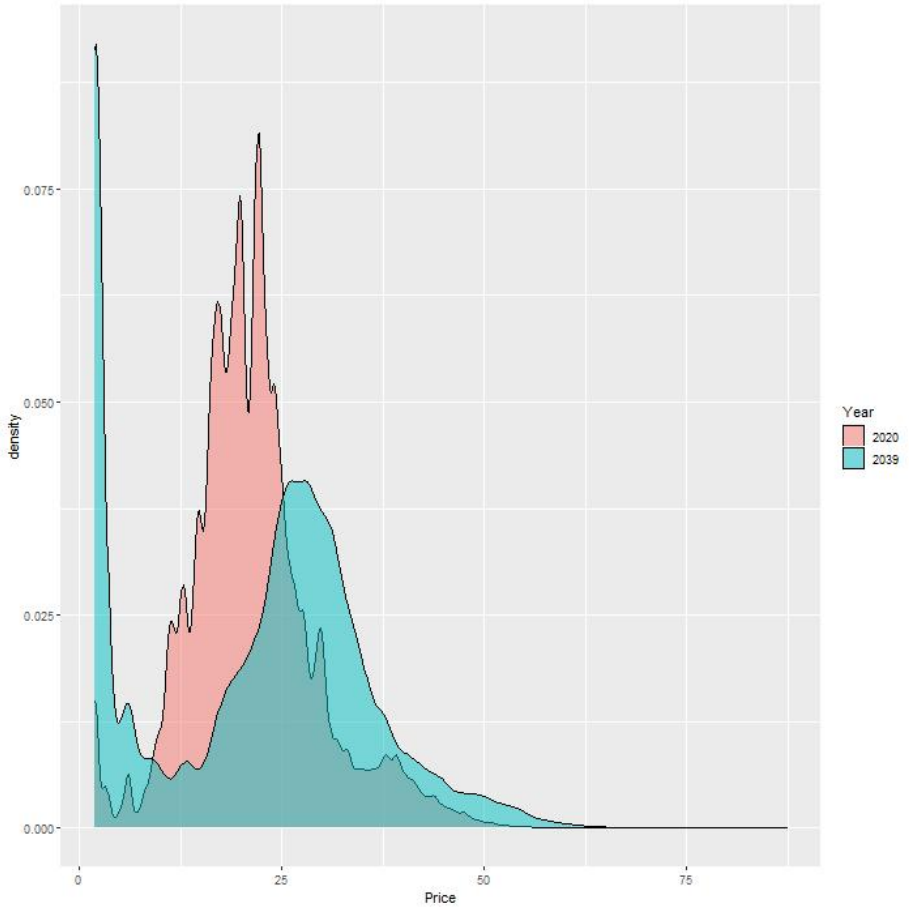
14 October 1997

The Royal Swedish Academy of Sciences has decided to award **the Bank of Sweden Prize in Economic Sciences in Memory of Alfred Nobel, 1997,** to

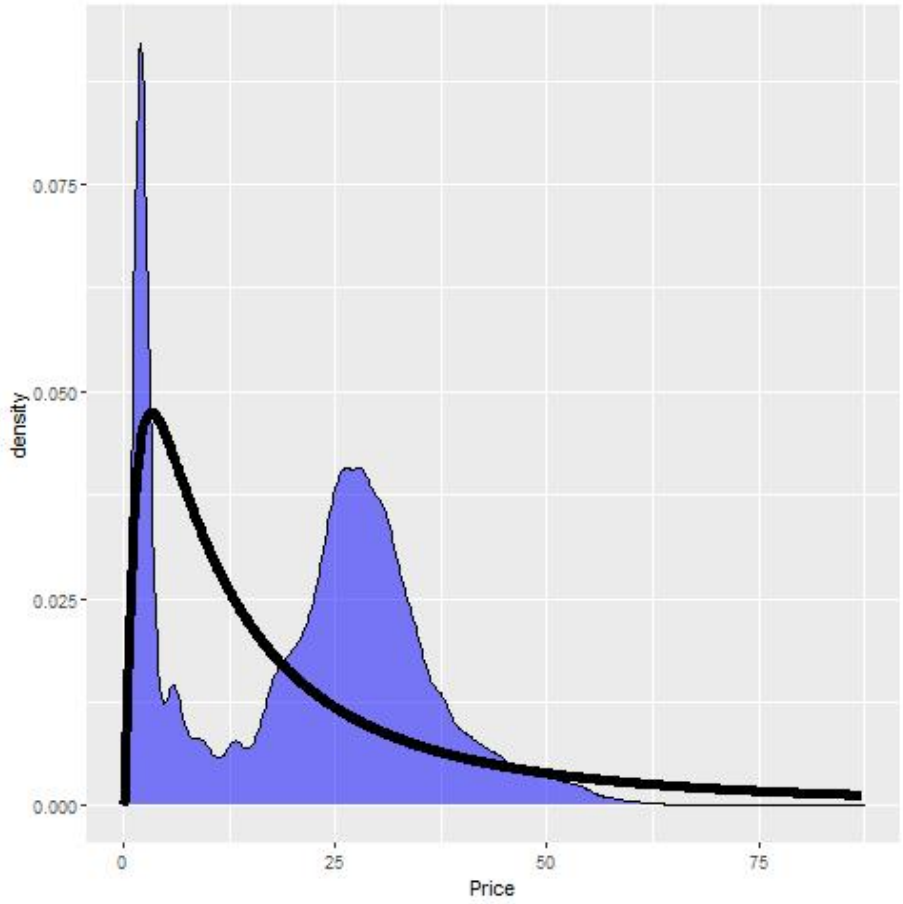
Professor **Robert C. Merton**, Harvard University, Cambridge, USA and
Professor **Myron S. Scholes**, Stanford University, Stanford, USA

for a new method to determine the value of derivatives.

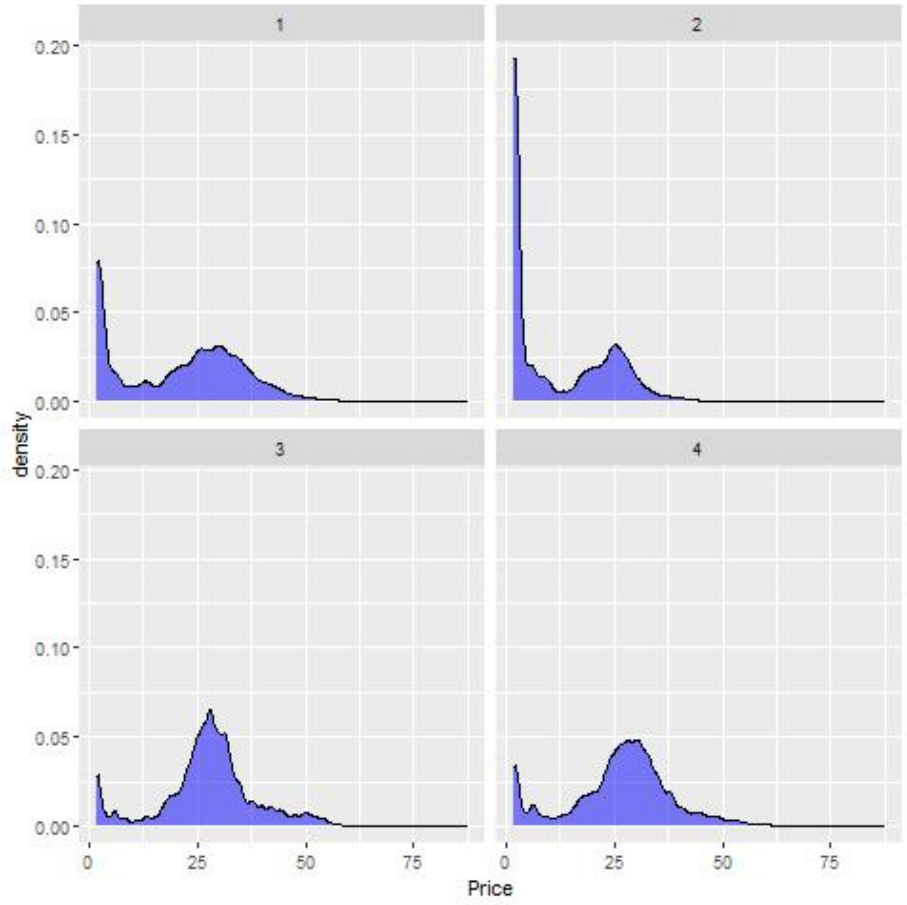
Hourly Price Distributions from Oct 2019 Price Forecast



Comparing 2039 Prices to Lognormal Assumption



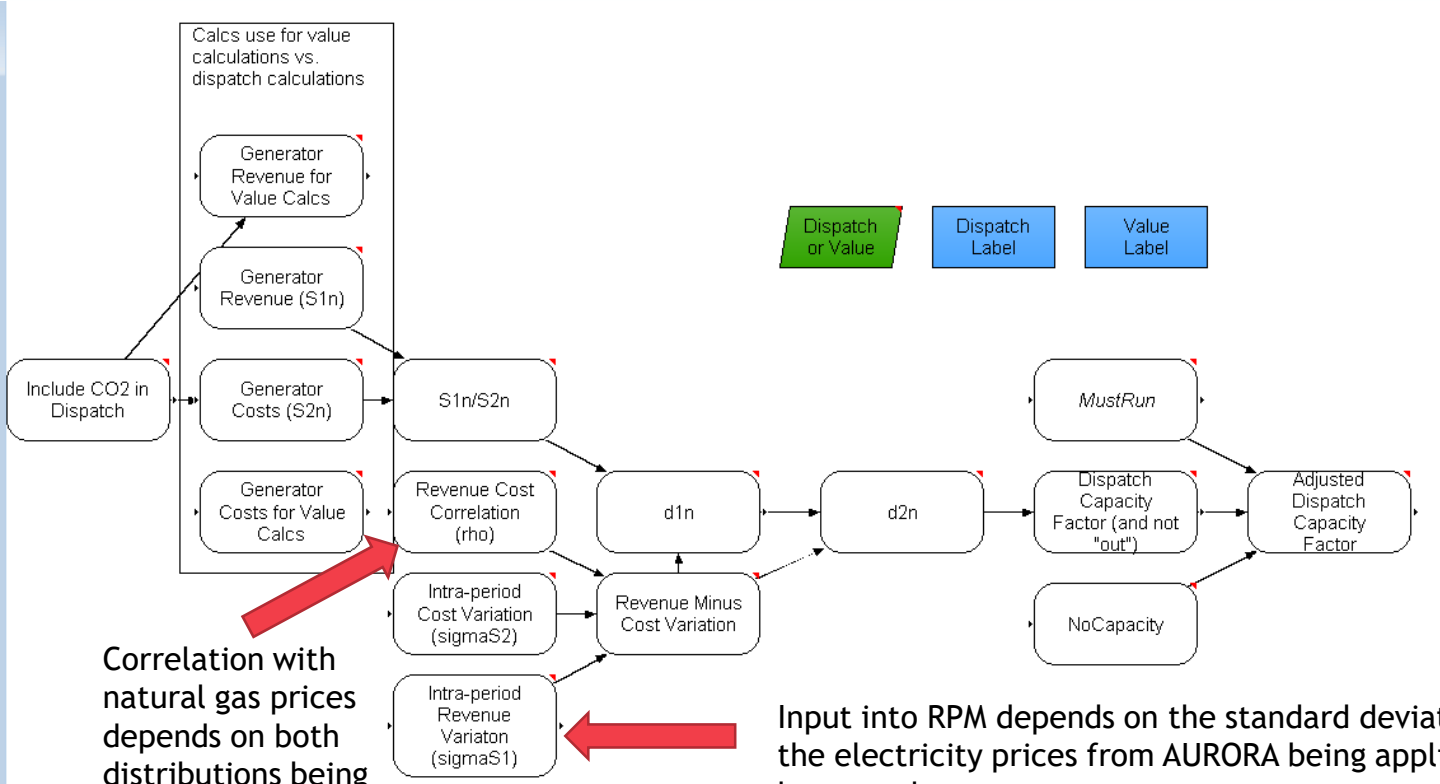
Price Distributions by Quarter



Implications for RPM

- Lognormal assumptions are embedded throughout the model
- Changing to different assumptions would involve substantial overhaul of the model
- Underlying theory used in past evaluation of regional and utility portfolios may not apply for future conditions

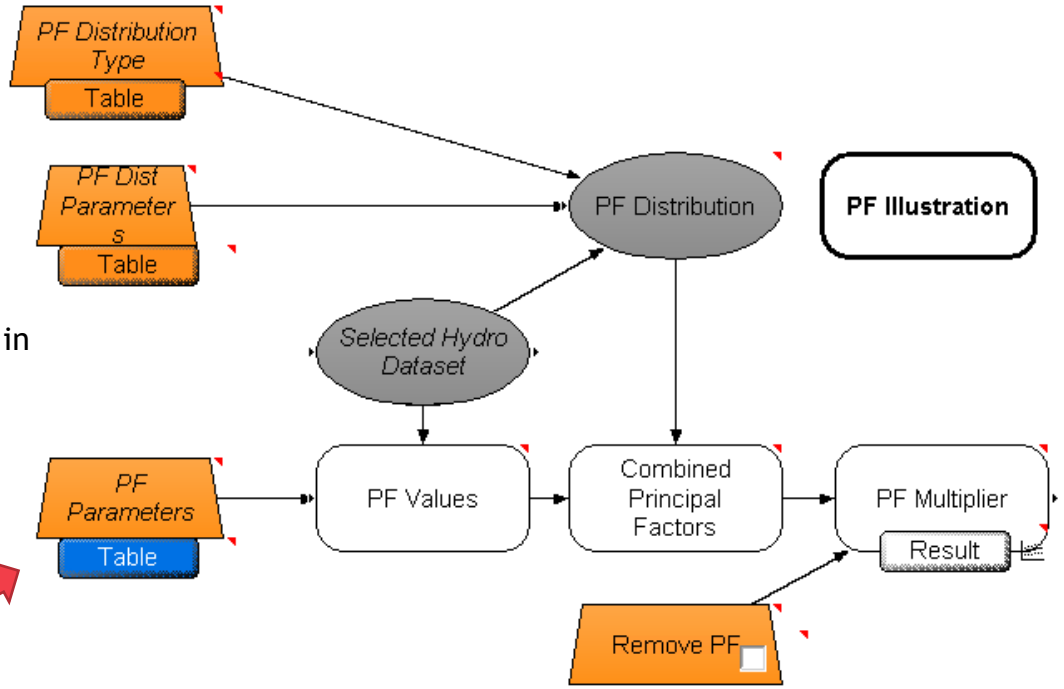
Intra-Quarter RPM Assumptions



Correlation with natural gas prices depends on both distributions being lognormal

Input into RPM depends on the standard deviation of the electricity prices from AURORA being applied as lognormal parameters

Distribution of Possible Quarterly Prices



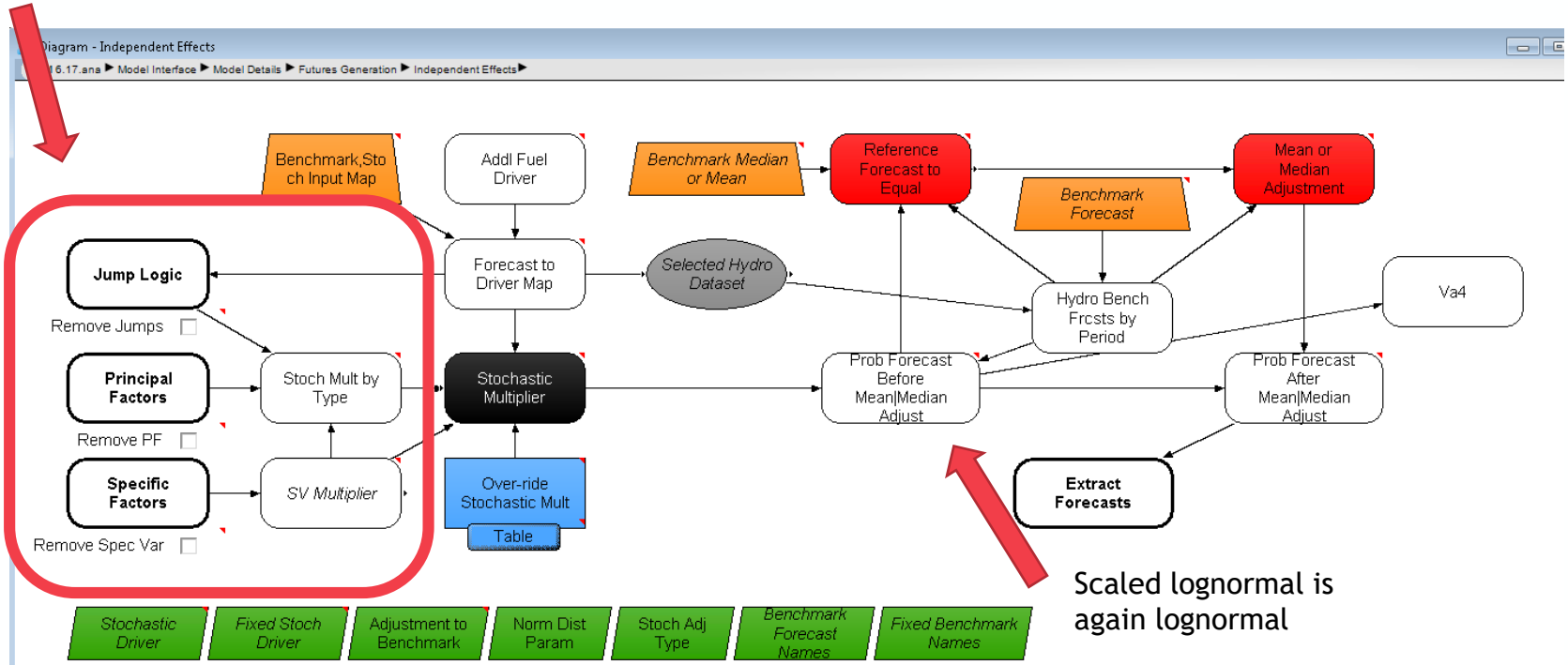
Parameters input in the RPM give a range based on medium and high price forecasts from AURORA

Principal risk distribution formed by creating a lognormal multiplier that is applied to external forecasts

Principal Factor Name | PF Param Name | PF Dist Name | Princ Factors Dist Input

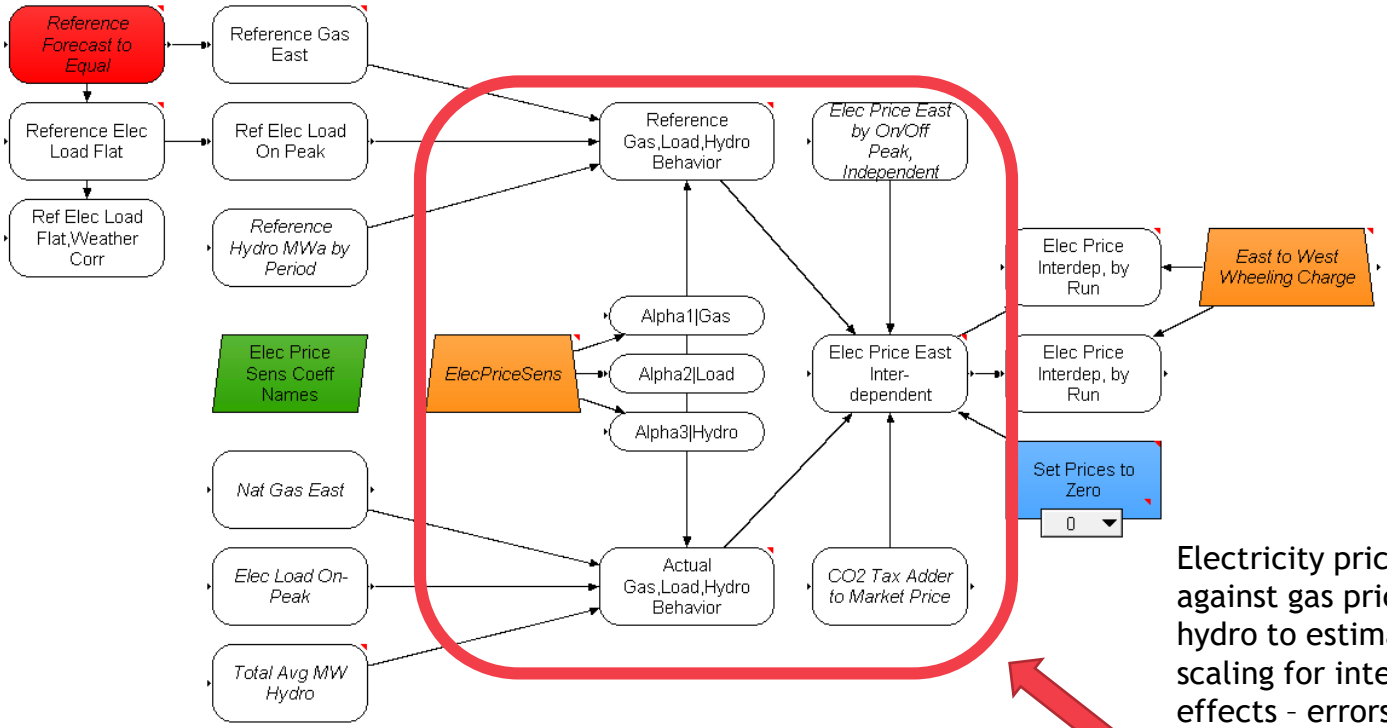
Distribution of Possible Quarterly Prices

Product of independent lognormal distributions is again lognormal



Scaled lognormal is again lognormal

Correlation of Quarterly Prices



Electricity price is regressed against gas price, load, and hydro to estimate needed scaling for inter-dependent effects – errors would be assumed normal and not autocorrelated

The Perfect Model

"…the statistician knows…that in nature there never was a normal distribution, there never was a straight line, yet with normal and linear assumptions, known to be false, he can often derive results which match, to a useful approximation, those found in the real world." – George E. P. Box