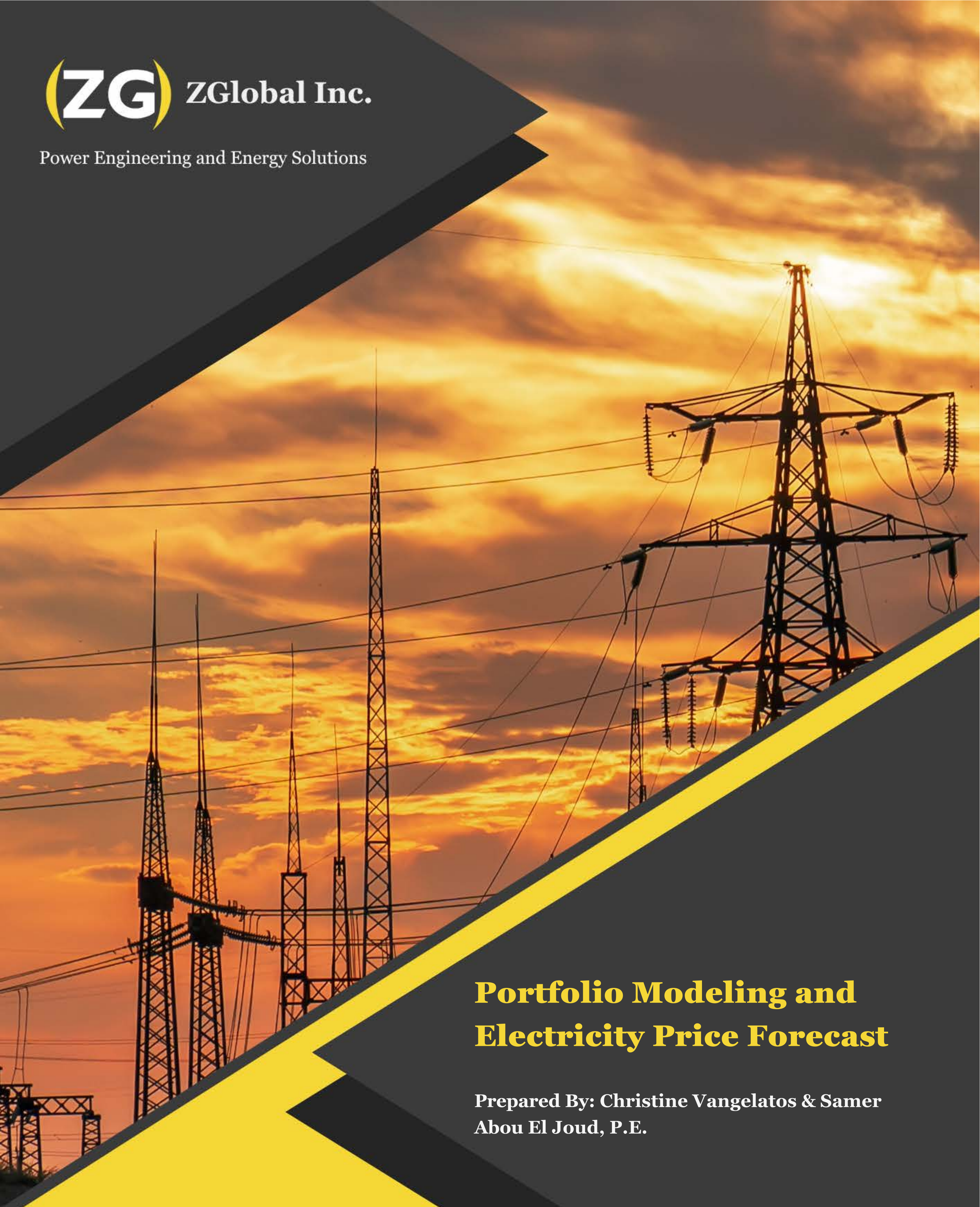
ZGlobal Inc.

Power Engineering and Energy Solutions



Portfolio Modeling and Electricity Price Forecast

Prepared By: Christine Vangelatos & Samer Abou El Joud, P.E.

Abstract:

This case study delves into the application and the use of ZGlobal eGrid Analytical process to conduct energy portfolio modeling, optimization, and the computation of both short-term and long-term electricity costs to consumers or revenue to energy suppliers for various grid locations. These calculations are meticulously derived from input assumptions employing Production Cost modeling techniques. These techniques represent a set of optimization procedures designed to predict the electricity costs necessary to meet specific demand scenarios. The forecasted electricity cost spans a time horizon ranging from hourly assessments to projections extending up to a 20-year horizon.

Introduction:

In energy management and grid optimization, ZGlobal eGrid Analytics emerges as an indispensable tool, facilitating the intricate processes of energy portfolio modeling and electricity price forecasting. This case study elucidates the core methodologies and key considerations employed in applying this robust tool for critical decision-making within the energy sector.

Production Cost Modeling Techniques:

Production cost modeling, employed within the ZGlobal eGrid Analytics framework, encompasses a suite of optimization procedures aimed at anticipating the electricity costs imperative for meeting distinct demand scenarios. These models are characterized by their ability to forecast electricity costs across diverse timeframes, ranging from hourly to a considerable 20-year horizon.

Production cost models, founded on deterministic methodologies, have been the cornerstone of energy forecasting and optimization for several decades. They rely upon a well-defined set of assumptions underpinning the modeling results' accuracy and precision. The deterministic approach primarily comprises the following key components:

1. **Accurate Generation Modeling:** This entails the precise modeling of various generation capabilities including imports and exports of energy, encompassing generation capacity factors, heat rates, ramp rate variables, incremental costs, startup times, energy storage modeling and other pertinent factors. Ensuring the accuracy of these parameters is paramount for accurate electricity cost projections.

2. **Demand Characteristics:** The comprehensive modeling of demand characteristics forms an essential component of the production cost modeling process. Anticipating fluctuations in demand patterns and their impact on electricity costs is integral to the overall modeling framework.

3. **Constraint Modeling:** A critical aspect of production cost modeling is the consideration of diverse constraints that govern the energy grid's operation. These constraints encompass transmission limitations, losses, network topology, fuel availability, pollution allowances, transmission rates, and associated costs. Incorporating these constraints into the model ensures that the forecasts remain cognizant of the real-world operational and environmental factors that influence electricity costs.

Applying ZGlobal eGrid Analytics, underpinned by robust production cost modeling techniques, provides a comprehensive platform for modeling energy portfolios and forecasting electricity prices across diverse temporal horizons. The deterministic approach, relying on accurate generation modeling, demand characterization, and constraint considerations, ensures that the forecasts remain grounded in the realities of operational, physical, and environmental constraints. Consequently, this methodology serves as a valuable resource for energy companies and decision-makers striving to optimize their energy portfolios and make informed cost-effective decisions within the complex energy landscape.

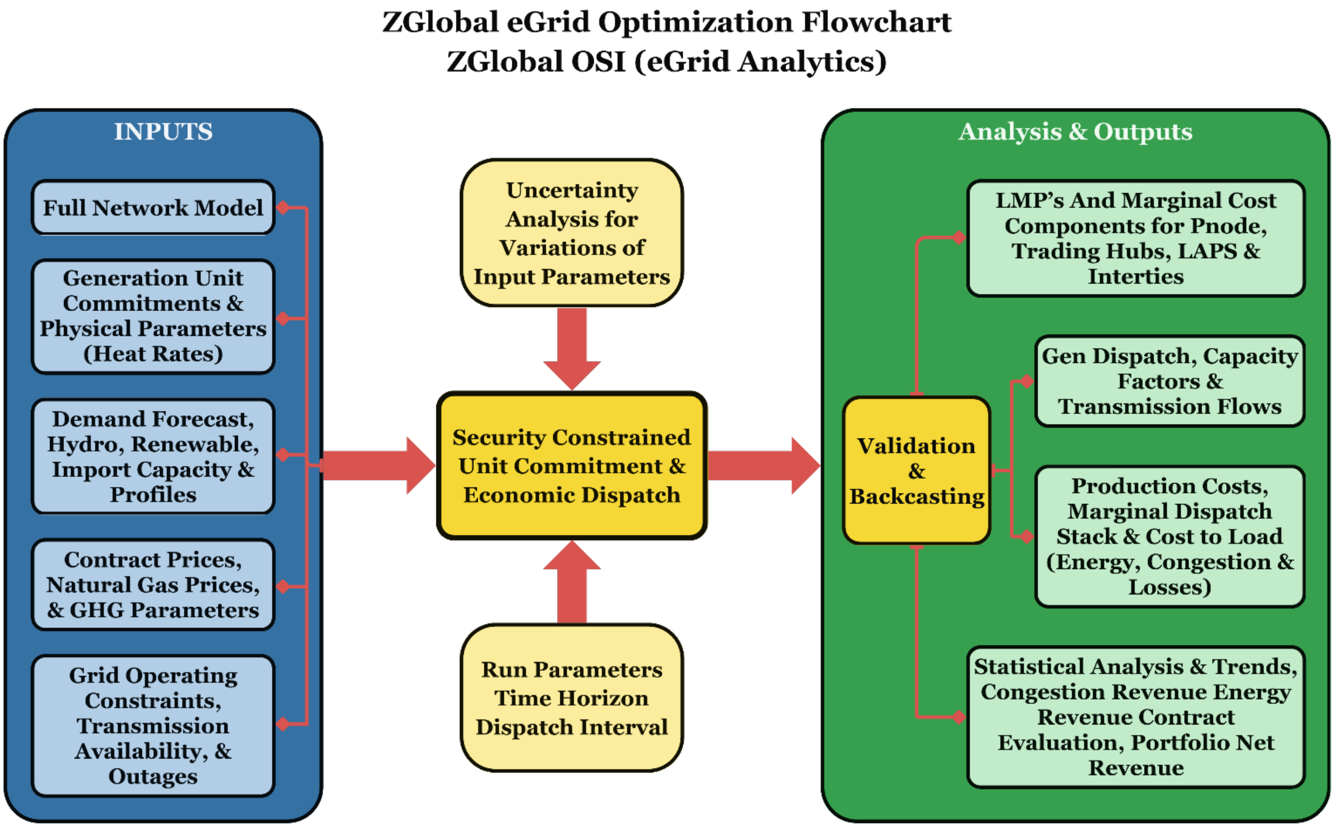


Figure 1: ZGlobal eGrid Optimization Flow Chart
ZGlobal OSI (eGrid Analytics)

ZGlobal's Approach of Optimization and Price Calculation:

ZGlobal leverages its expertise and cutting-edge optimization software to determine the optimal hourly electricity supply, transmission, and delivery necessary to align with client business objectives while adhering to the laws of physics. This process also encompasses identifying the most opportune times for energy storage and determining the optimal release schedule. The outcome of this process is a comprehensive electricity cost assessment at each node of the electric grid, inclusive of transmission costs, and the precise electricity generation requirements for each resource.

Deterministic Optimization:

ZGlobal employs deterministic optimization to calculate electricity prices at each grid node for each hour, providing a detailed representation of market operations. However, this method has a limitation, as it does not consider the uncertainties surrounding driving factors' futures. Relying solely on deterministic methodology, without accounting for changing fuel costs, weather conditions, or outages, can lead to inaccuracies in electricity price forecasts. Nevertheless, ZGlobal views the deterministic approach as a dependable baseline for estimating energy pricing, as it elucidates how various generation resources contribute to meeting demand. This energy stack analysis is instrumental in estimating implied heat rates, spark spreads, and marginal electricity costs.

Hybrid Method:

The Hybrid Method employed by ZGlobal combines deterministic and stochastic models. The deterministic model represents supply and demand relationships based on specific assumptions, while stochastic techniques model the evolution of underlying drivers. This approach aims to discern the factors influencing electricity price fluctuations and identify the primary variables describing these changes in a robust and consistent manner. In the stochastic approach, ZGlobal utilizes the Box & Cox method to transform a set of random variables, each described by a standard deviation distribution. Notably, the Hybrid Method excels in capturing and accounting for major sources of information that reflect the uncertainty associated with events or risks, such as the potential impact of heatwaves or heavy rains, which could lead to power outages and, consequently, fluctuations in electricity prices.

Acknowledging Uncertainty and Risk:

Recognizing uncertainty and risk underscores that there isn't a single anticipated outcome; instead, multiple potential outcomes exist. Decision-making processes must account for a range of values and quantifiable risks. ZGlobal integrates these quantifiable risks into its electricity price forecasts to enhance the management of demand and supply portfolios on behalf of its clients. The Hybrid method also calculates the Value at Risk for investors for a specific project.

Modeling Future Electricity Prices:

The Future Electricity Price (FEP) distribution, centered around the mean, is assumed to follow a normal distribution for each distinct time of the day (**periods**[1]). This distribution is mathematically expressed as:

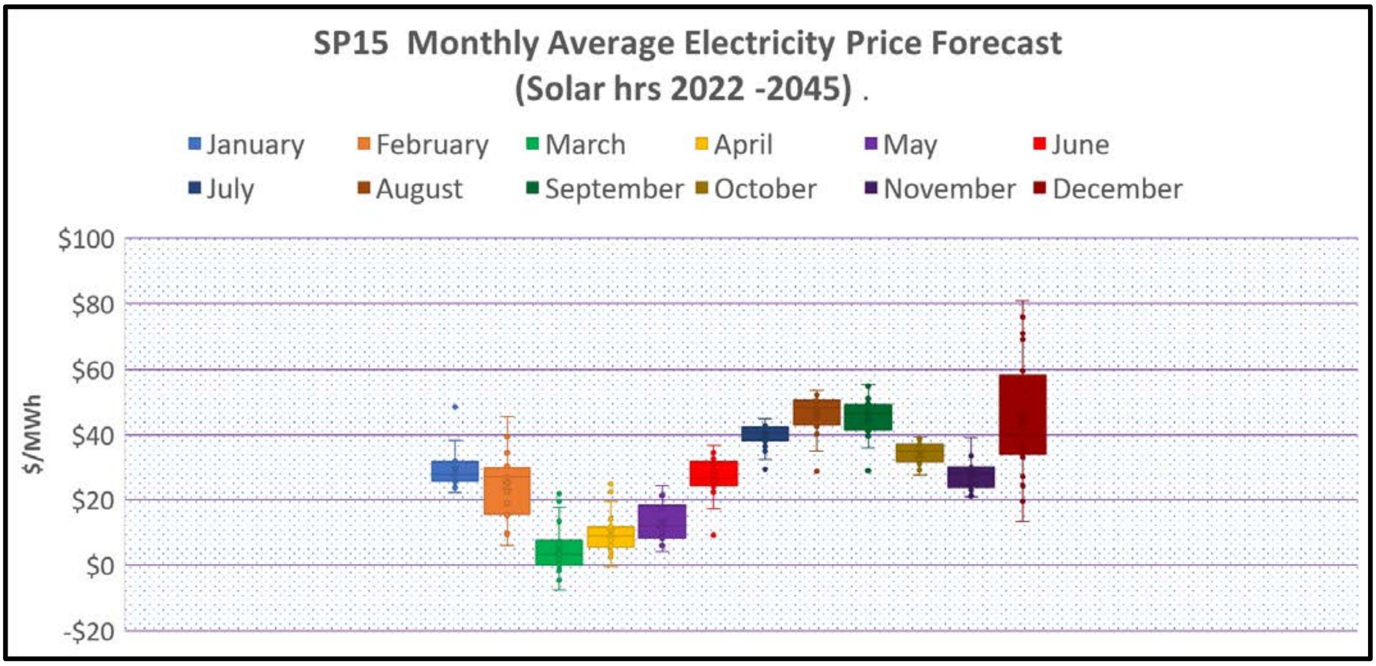
$$p(\chi) = \frac{1}{\sigma 2\pi} \exp\left(-\frac{(\chi-\mu)^2}{2\sigma^2}\right)$$

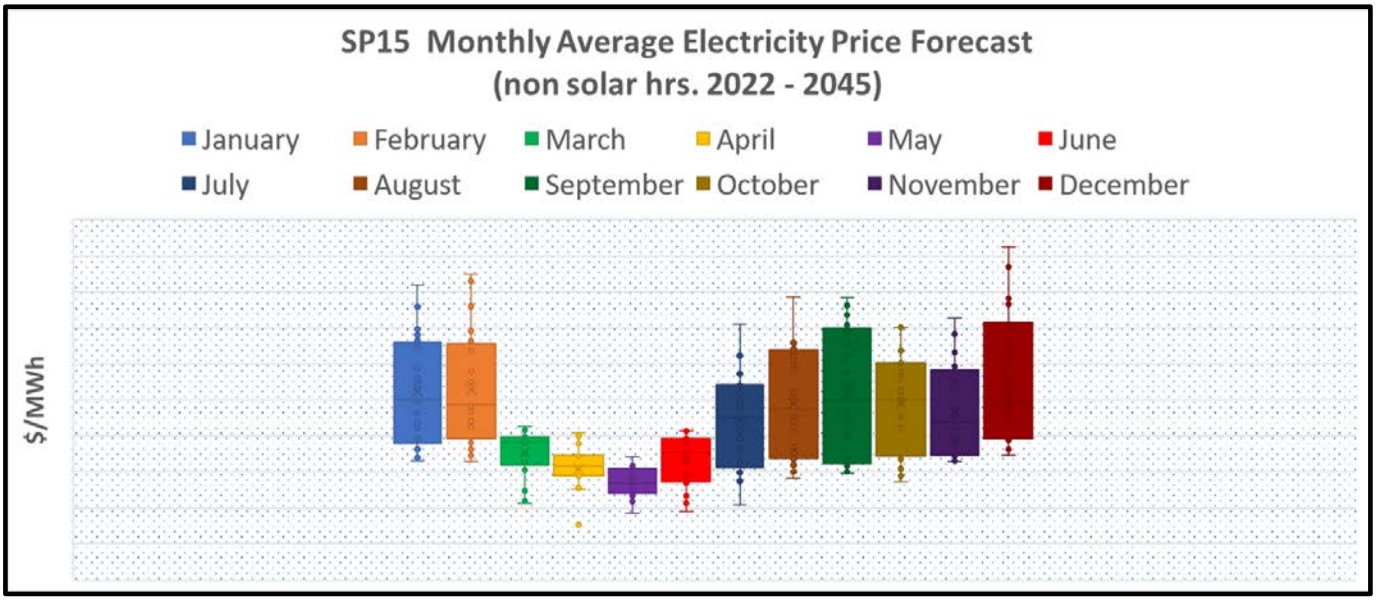
- μ represents the Mean of the FEP, calculated through deterministic optimization.
- σ signifies the standard deviation characterizing the distribution of the FEP, derived from stochastic analysis.
- P(χ) stands for the random probability density variable, a product of the stochastic analysis.

[1] **Time of the day periods are:**
Solar Hour; April to Oct:7am - 7pm (HE 8-20); Nov to March: 8am to 5pm (HE 9-18)
Non-Solar hour April to Oct: 8pm - 6am (HE 21-7) ; Nov to March 5pm to 7 am (HE 18-8)

Illustrative Example

To illustrate this concept, consider the monthly average electricity price forecasts for the Southern California region (SP15) during both solar and non-solar hours from 2022 to 2045. These forecasts are generated based on specific assumptions using the deterministic method. The resulting electricity price shapes are as follows:





The Deterministic Model predicts that the average electricity prices during non-solar hours will be twice the average electricity prices during solar hours.

Scenario Analysis (Deterministic and Stochastic Analysis)

Averages can often be misleading. ZGlobal possesses the capability to model the Western U.S. transmission system, while considering supply and demand dynamics, to calculate the electricity price at which the energy market achieves equilibrium. This calculation is based on specific assumptions and is referred to as the Deterministic Forecast.

In addition to the Deterministic Forecast, ZGlobal conducts Stochastic Analysis to evaluate the influence of key input assumptions, such as natural gas prices, on future energy prices. For instance, let's consider a week in June where the deterministic average electricity price during solar hours is $52 per megawatt-hour (MWh), and during non-solar hours is $59/MWh. In this scenario, ZGlobal systematically varies certain influential factors and reevaluates the electricity price, quantifying the impact these variables have on electricity prices.

As an illustrative example, we introduced variations in hydrological conditions and natural gas prices, which subsequently led to fluctuations in electricity prices, as demonstrated below:

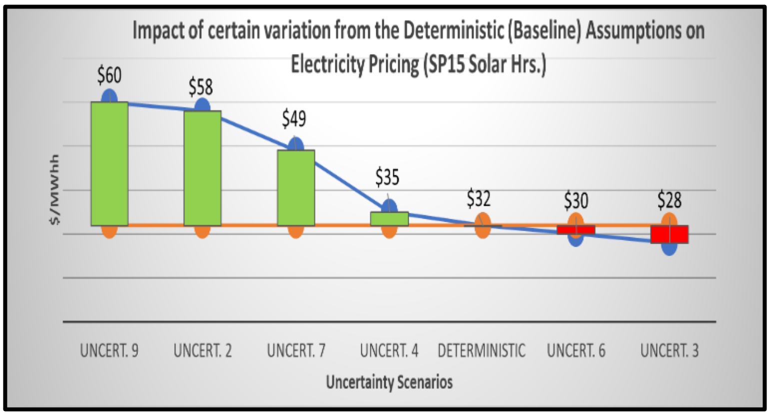
- ✓ **Uncertainty #9** depicts drought conditions coupled with high natural gas prices (NGP)
- ✓ **Deterministic** is the baseline forecast depicting average hydro and NGP.
- ✓ **Uncertainty #3** depicts average or baseline hydro and low NGP.
- ✓ **Uncertainty #8** depicts high hydro and low NGP.

Uncertainty Analysis	Hydro/Imports (H)	Natural Gas (NG)
Uncertain 9	L	H
Uncertain 2	B	H
Uncertain 7	H	H
Uncertain 4	L	B
Deterministic	**B**	**B**
Uncertain 6	L	L
Uncertain 3	B	L
Uncertain 5	H	B
Uncertain 8	H	L

The results reveal that under the deterministic assumption, the average weekly electricity price during solar hours for the week stands at $32 per megawatt-hour (MWh). Notably, it becomes evident that electricity prices exhibit a high degree of sensitivity to changes in both hydrological conditions and natural gas prices (NGP).

Apply uncertainty analysis during solar hours:

- ✓ **Uncertainty #9:**
  - o Depicts drought conditions coupled with high natural gas prices (25% over the baseline).
  - o The electricity price jumps from $32/MWh to $60/MWh.
- ✓ **Uncertainty #3:**
  - o Depicts average or baseline hydro and low NGP ($5 lower than the baseline).
  - o The electricity prices drop from $32 to $28/MWh

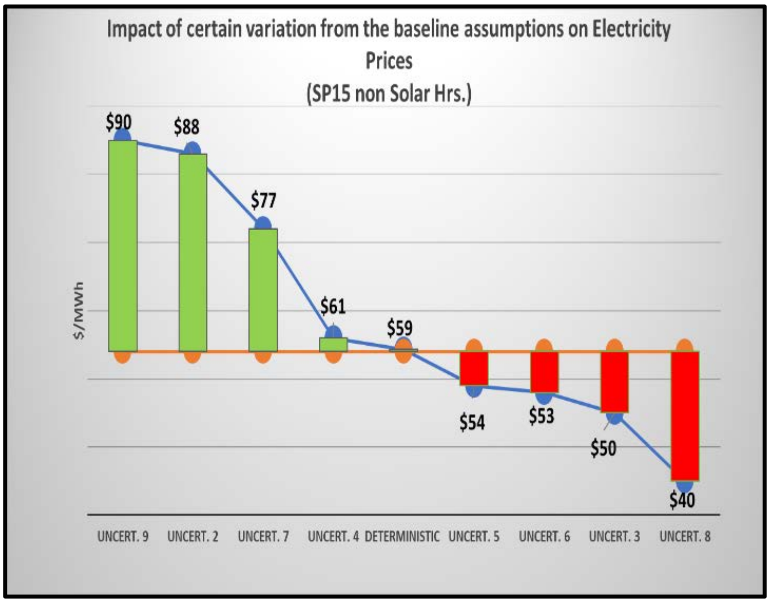


Conversely, when examining the same week for non-solar hours and applying identical changes in hydrological conditions and natural gas prices, the outcomes reveal that the average weekly electricity price, under the deterministic assumption, amounts to $59 per megawatt-hour (MWh) for that week. It is noteworthy that the electricity price exhibits a pronounced sensitivity to variations in both hydrological conditions and natural gas prices (NGP).

Moreover, under Uncertainty #3, the electricity price displays considerable volatility, surging from $59/MWh to $90/MWh, while under the same uncertainty, it may decrease from $59/MWh to $40/MWh. This underscores the significant volatility and sensitivity of electricity prices to factors such as the time of day, hydrological levels, and the supply of natural gas (NGP).

Apply uncertainty analysis during non-solar hours:

- ✓ **Uncertainty #9:**
  - Depicts drought conditions coupled with high natural gas prices (25% over the baseline).
  - The electricity price jumps from $59/MWh to $90/MWh.
- ✓ **Uncertainty #3:**
  - Depicts average or baseline hydro and low NG (25% lower than the baseline).
  - The electricity price drops from $59/MWh to $53/MWh.



Transmission Allocation and Auction

Transmission congestion arises when specific power lines operate at full capacity, potentially impeding the ability of other lines to carry additional loads to meet demand. This limitation, contingent on the load or demand pattern can restrict the insertion of generation at certain geographical points due to congestion on the transmission network, and resolution may not be straightforward, cost-effective, or prompt.

- **Transmission Capacity Allocation and Auction**
  Securing transmission capacity to mitigate congestion costs entails a two-step process for loads participating in the California Independent System Operator (CAISO) allocation and auction. In the case of generation, participating in the transmission auction with Congestion Revenue Rights (CRRs) represents the primary mechanism for hedging against congestion.

- **Securing Transmission and Congestion Hedging**
  Transmission lines, facilitating the long-distance movement of electricity across a high-voltage network, are indispensable for delivering electricity to loads with the lowest transmission cost. This is a critical function for generation and loads, both within and outside the CAISO's jurisdiction.

ZGlobal plays a pivotal role in aiding clients who engage in the allocation and auction process to secure financial protection against unforeseen congestion costs, which arise due to bottlenecks in the transmission system. Congestion management endeavors to determine the expenses associated with transporting electricity from its source to the end consumers, known as the sink. ZGlobal excels in identifying the optimal financial hedge for transmitting electricity over lines with designated capacity limits, accounting for both volume and specific conditions within an hour.

ZGlobal offers long-term and real-time transmission reservation services, facilitating the movement of energy from its point of generation to its destination, while also scheduling the quantity and timing of energy transmitted over specific transmission lines within and outside CAISO and ERCOT. Additionally, ZGlobal identifies the specific generators requiring transmission paths and specifies the locations of consumers benefiting from this generation. Any reduction in supply, demand, or transmission capacity due to weather, fires, malfunctions, or other disruptions is promptly reported, with adjustments made to the schedule.

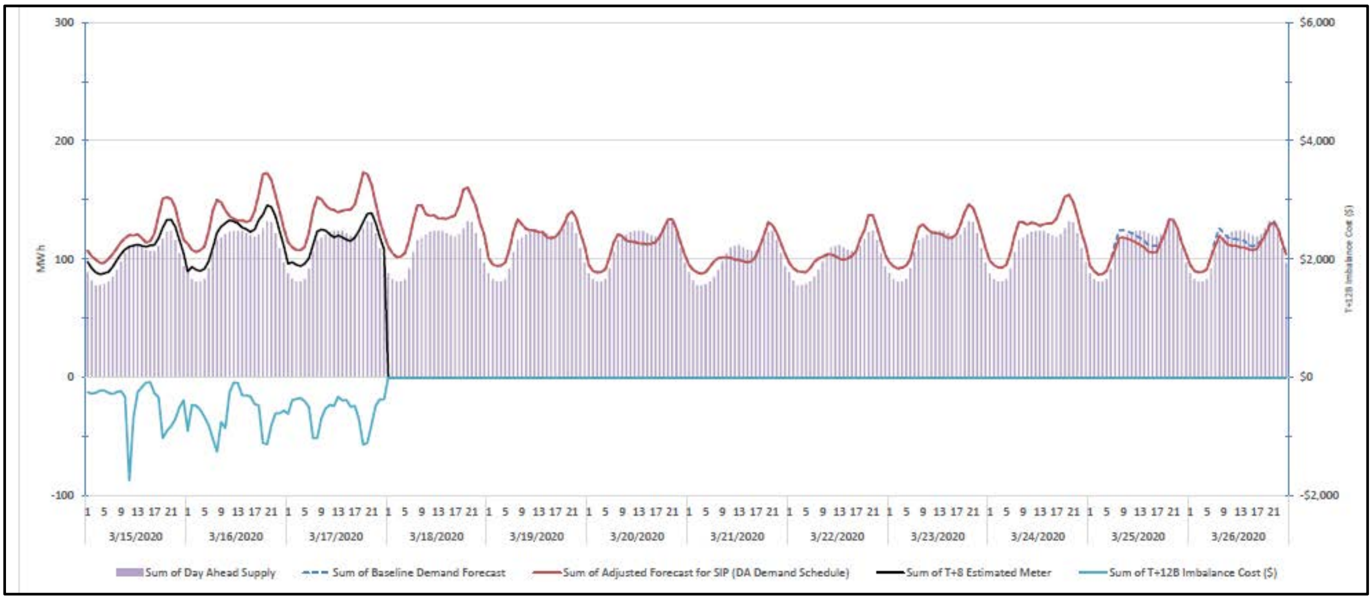
ZGlobal takes on the task of congestion management on behalf of its clients, aiming to minimize congestion costs while maximizing the delivery of cost-effective supplies to meet demand. The congestion management process involves the following steps:

1. Analyzing the inherent risk between supply and demand nodes.
2. Examining historical data to discern congestion patterns.
3. Estimating the necessary hedge amount based on the clients' generation portfolio.
4. Compiling a list of source-to-sink node pairs that mitigate risk between supply and demand nodes.
5. The selection of these sources is based on statistical and empirical analyses of historical data, encompassing price, revenue, and congestion patterns on the grid.
6. The chosen sources are highly correlated with the supply nodes and have a proven track record of generating congestion revenue based on historical data.

Despite the CRRs being obtained to cover the generation portfolio, it's important to note that, as financial instruments, they may not offer a comprehensive hedge for the entire portfolio.

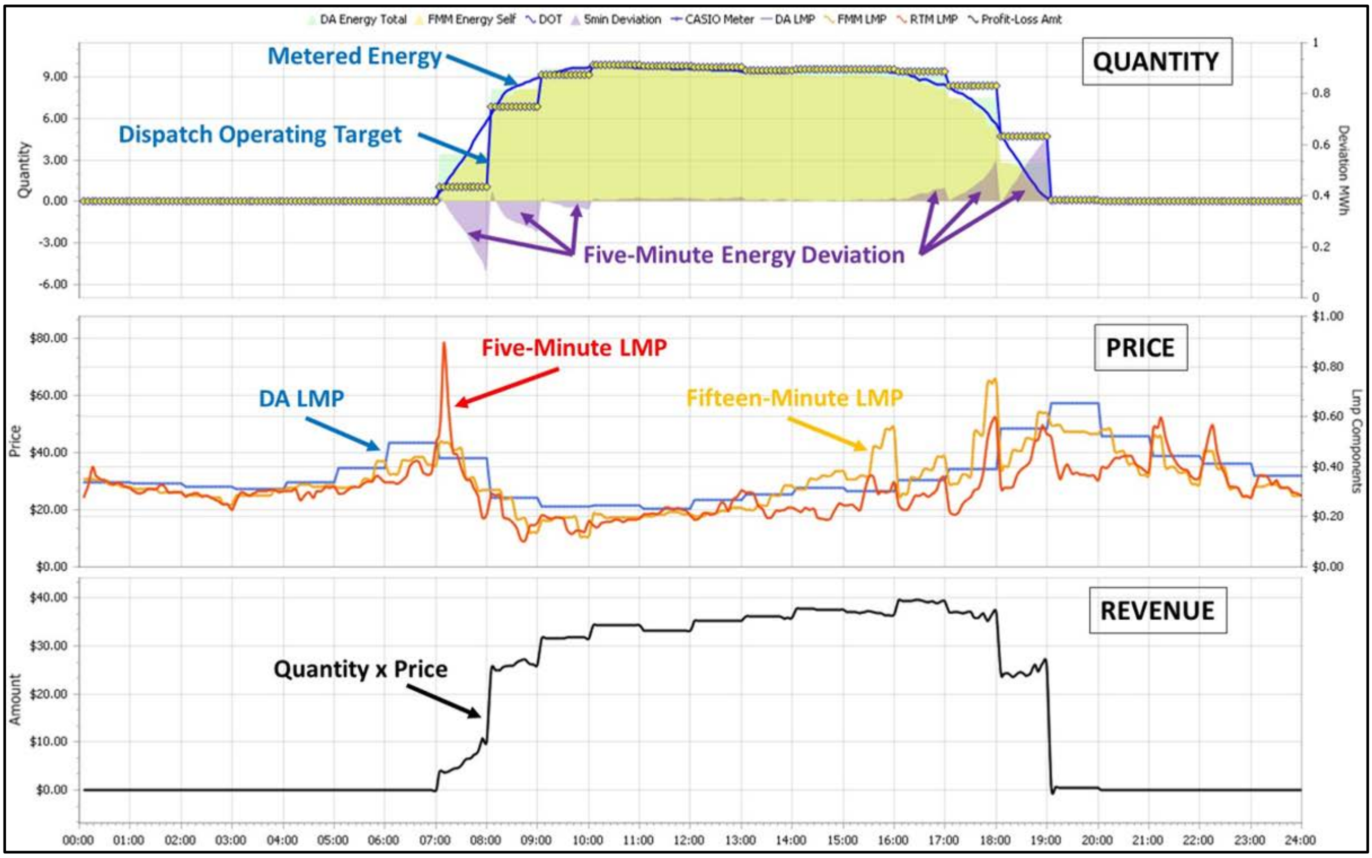
Portfolio Results

The chart presented below illustrates the operations of the past three days and provides expectations for the upcoming nine days. In the chart, the purple bars represent the aggregated supply for each respective hour. The red line signifies the short-term load forecast, while the black line offers an estimation of the meter data, as supplied by the meter service data management agent. Additionally, the blue line tracks the ISO portfolio's imbalance costs, which are computed based on the estimated meter data.



Visual Representation of Scheduling Effectiveness for Variable Energy Resources (VERs)

The figure displayed below serves as a visual tool employed by ZGlobal's schedulers and analysts to evaluate the efficiency of scheduling Variable Energy Resources throughout the day. This diagram is divided into three sections, each offering distinct insights:



- Upper Third: In this section, you will find data related to scheduled energy quantities, metered energy, and the resulting energy imbalance quantities.
- Middle Third: This portion of the diagram presents information on day-ahead, 15-minute, and 5-minute ISO market prices, which are crucial for assessing market dynamics and pricing trends.
- Lower Third: The lower third of the diagram portrays the resultant revenue, providing a concise summary of the daily performance of Variable Energy Resources (VERs).

This visual representation is invaluable for conducting a swift and comprehensive review of daily VER operations.