Simulating meaningful uncertainty for complex physical and financial portfolios

The meaningful uncertainty simulation framework can extract all relevant information contained in market and portfolio data to give energy firms the ability to make informed business decisions. By Gary Dorris and Carlos Blanco

Monte Carlo simulation is a tool used widely to assess the physical and financial uncertainty of energy portfolios due to changes in key risk drivers under different possible states of the world.

Despite significant methodological, computational and technological advances in market and portfolio energy risk modelling in recent years, many firms are still using 'first-generation' decision-support simulation models that suffer from known material deficiencies.

Traditional energy risk simulation models built on concepts borrowed from financial markets often produce unrealistic scenarios of potential future states due to the poor representation of physical market dynamics and their interaction with spot and market prices. Moreover, the way they handle certain portfolio components such as complex assets, loads and long-term contracts, which are often modelled as simple financial instruments such as forward contracts or strips of spread options, is not satisfactory. These approximations result in excessive simplification of key constraints and operating strategies that might introduce significant model risk and material errors in the valuation and risk assessment of these portfolios.

In this article, we introduce the concept of meaningful uncertainty simulation framework for energy risk modelling, valuation and risk analysis. Our risk-based framework ultimately attempts to extract all relevant information contained in market and portfolio data to inform intelligent business decisions that range from short-term operational actions to long-term planning choices. The building blocks of the framework are shown in figure 1.

Integrated, realistic and verifiable scenarios of key portfolio drivers

The forward-looking scenarios of key physical and financial drivers of the portfolio are the backbone of a simulation framework. The ability of the framework to produce verifiable, consistent and unbiased simulation results is a critical requirement.

Simulation models used by many energy companies often lack the coherent framework to link physical uncertainty related to extrinsic value with financial uncertainty related to intrinsic value. The reduced-form constrained models such Geometric Brownian Motion, with or without mean reversion and jumps, produce intrinsic valuations that are relatively simple to implement and calibrate. However, a rigorous validation analysis is likely to show that their use to support valuation and risk decisions can be dangerous, as unrealistic price scenarios will provide erroneous insights on portfolio value and risk. On the other side of the spectrum, the full-blown fundamental models produce extrinsic valuations that are overly complex, highly unstable, slow and unable to replicate forward-market price dynamics.

A better alternative is the use of structural state-space models that link the key drivers between the energy physical and financial markets (see Figure 2). By providing a coherent representation of the physical system through weather, load and other variables that drive physical markets, the state and time dependencies between the material portfolio risk drivers are preserved. This framework also maintains the necessary inter-temporal dependency between prior-to-delivery expectations of forward market simulations that are dynamically linked to the during-delivery conditions of spot price conditions and their physical drivers.

Structural state-space models use explanatory physical and market variables such as temperatures, net system load and spot gas prices to explain power prices, resulting in a more stable and transparent model to inform decisions. These models can account for non-linearity between variables and also ensure that the simulated dynamics are consistent with the observed physical and market data. For example, structural state-space models can maintain the persistence of shocks over time in a meaningful way, including rates of mean reversion based on key drivers such as weather, load and prices. These models can also be designed in order to ensure that equilibrium relationships such as spark spreads, heat rates, locational and calendar spreads are preserved over time and that no arbitrage conditions hold.

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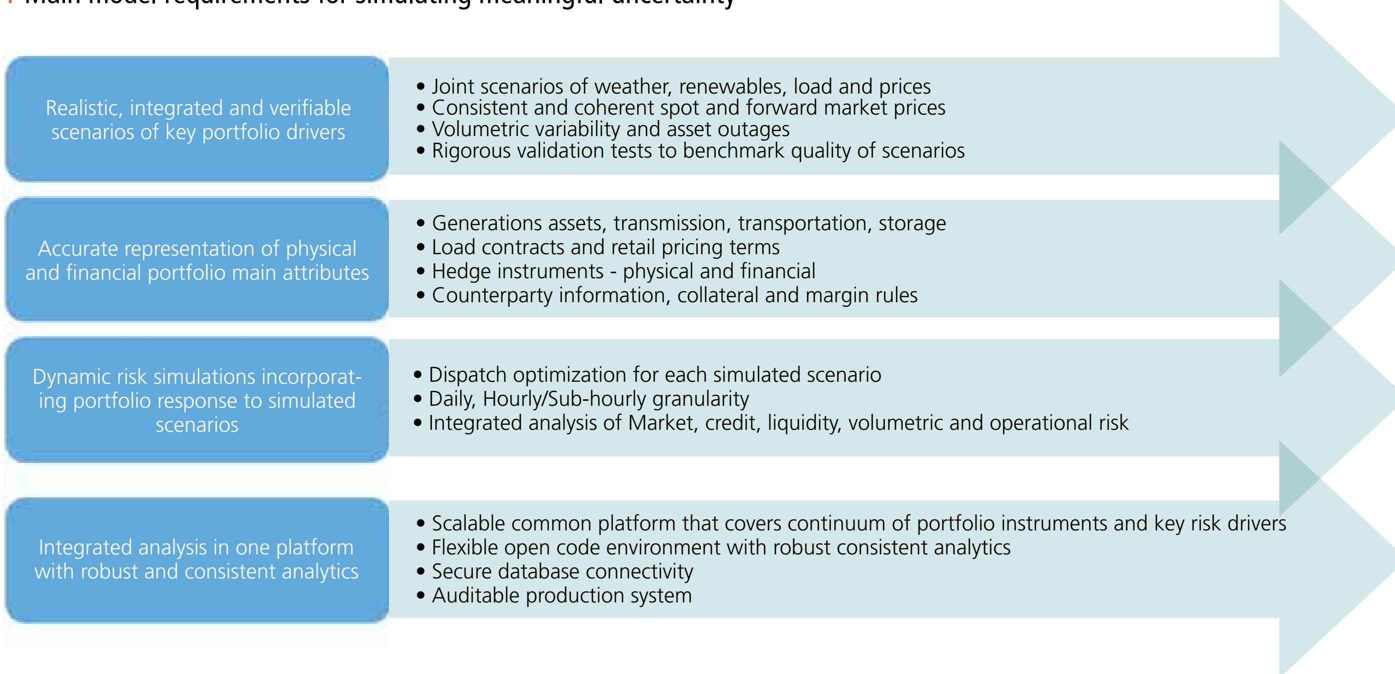
An energy risk simulation framework should address uncertainty as viewed through the sub-hourly, hourly and daily spot market dynamics, current market expectations (forward prices or forecasted prices) and the future realised delivery conditions for load, renewables, spot prices, generation and key physical market variables. For example, the growing contribution of

1 Main model requirements for simulating meaningful uncertainty



Source: Ascend Analytics

renewable generation and batteries are already changing the traditional market dynamics, but many energy risk models have not kept pace with those developments. The impact of renewable generation, particularly wind and sun, are being felt in the Western markets in North America and parts of Europe, while batteries are a new frontier and act as a physical hedge between day-ahead and real-time market prices and furnish ancillary services.

We will discuss the simulation process in more detail in future pieces, but at a high level, the process is divided into two separate components: prior-to-delivery and during-delivery.

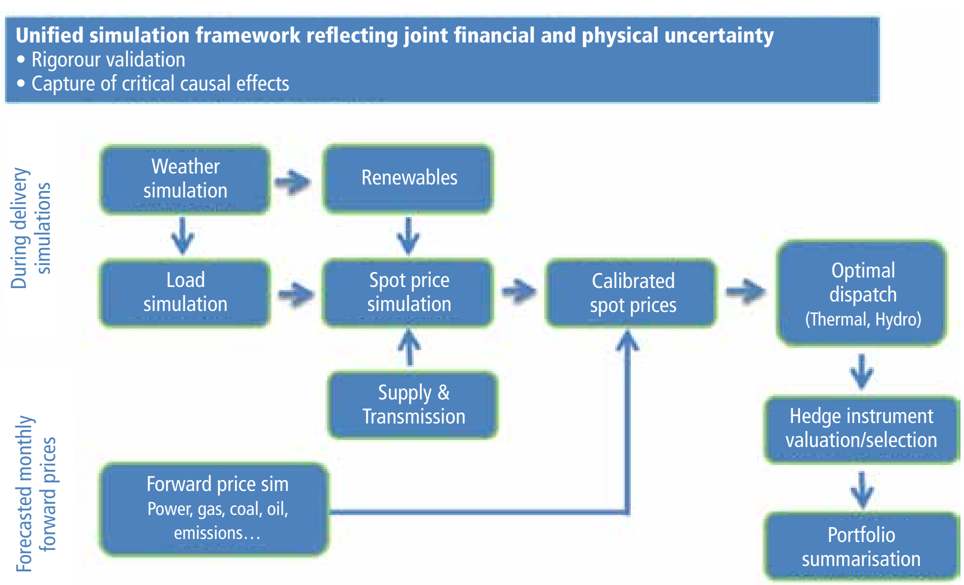
• The prior-to-delivery simulation of forward prices (or forecasted prices) evolves current expectations through time from the start date to the end of the simulation horizon. Prior-to-delivery conditions form the foundation of intrinsic valuation.

• The simulations during-delivery capture the relationship of physical system conditions (ie weather, load, fuel prices, wind, hydro, unit outages and transmission) on market prices. The during-delivery simulations form the foundation of extrinsic valuation.

The inter-relationship between prior-to-delivery and during-delivery simulations is central to linking expectations to realised observations that are either simulated or actual.

Regardless of the framework used to represent uncertainty, the results from any simulation engine should be benchmarked to determine whether the evolution of market conditions into the future are consistent with previously observed dynamics and forecasted expectations. A formal validation process to substantiate meaningful uncertainty will be introduced in a subsequent article.

2 Integrating physical and financial uncertainty



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Accurate representation of the main attributes of physical and financial portfolios

Energy portfolios often have a combination of physical assets such as generation assets, loads, physical purchase and sales contracts, as well as financial hedges. In order for the simulation analysis to provide meaningful and actionable information to management portfolio risk, each physical and financial exposure should be represented with enough detail to capture the main market, credit, margin, volumetric and operational risk exposures.

Physical assets can be particularly complex to describe in terms of operating constraints, but operational groups maintain detailed information on those constraints as well as planned outages and probabilities of forced outages.

Simplistic representations of the optionality and dispatch rules for the assets and volumetric exposures of those contracts is likely to result in a flawed analysis that could lead to wrong asset and contract valuations, biased hedge ratios and a misrepresentation of portfolio risks. For example, modelling generation units as strips of spread options fails to account for the impact of dispatch decisions on a given time period on the available set of operational decisions in subsequent periods. Similarly, modelling of retail load or renewable generation as linear instruments fails to account for volumetric uncertainty.

Dynamic risk simulations incorporating portfolio response

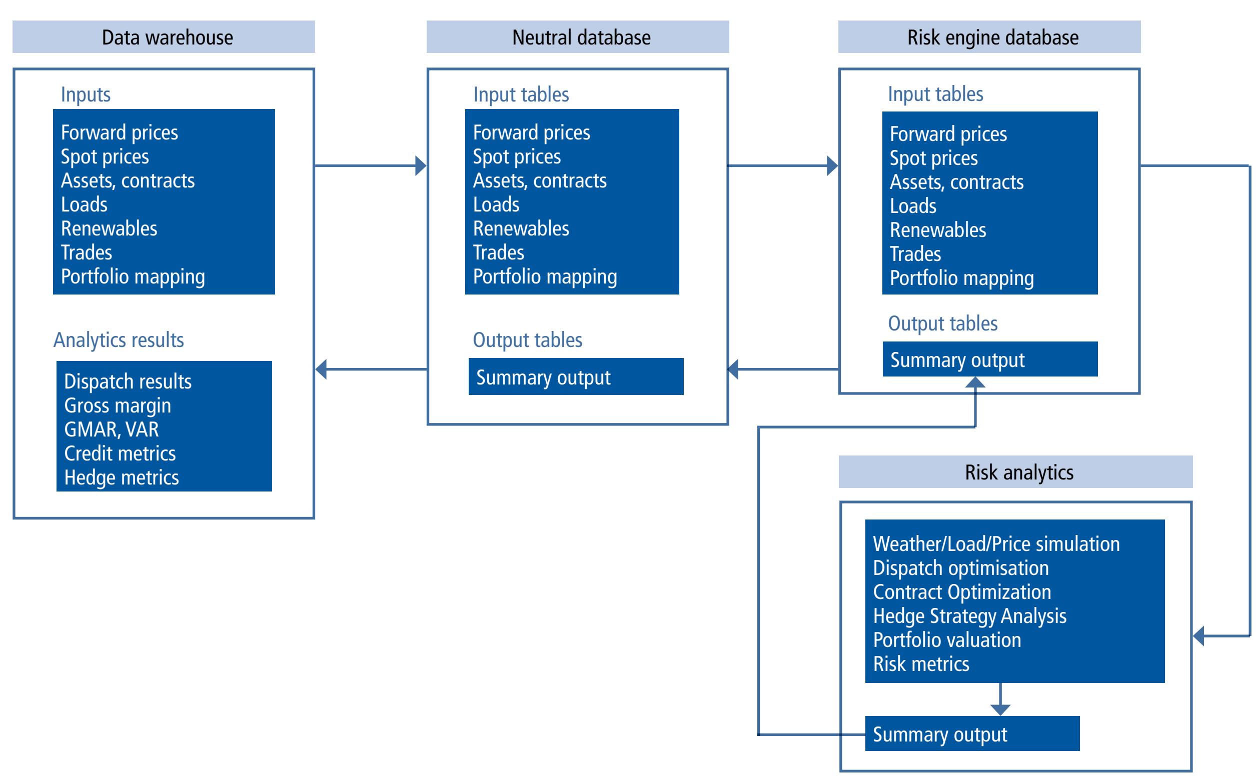
Modelling realistic possible states of the physical and financial markets at the required granularity is just the starting point to determine asset portfolio uncertainty under a meaningful simulation framework. The analysis should also model the likely response for each asset and instrument in the portfolio, such as the optimal dispatch for generation assets based on the simulated changes in market conditions.

The resolution of the simulation model should not dilute critical details of concern such as dispatchable asset operations, the exercise of volume tolerance or destination options, hydro operations, wind generation and volumetric variability in load-serving portfolios.

> Modelling the key physical and financial portfolio drivers in a coherent way is critical to analyse earnings variability, design hedging strategies and determine the optimal operating and hedging strategy

For example, to value and assess the risk of generation portfolios accurately, the simulation framework should capture how each asset will be optimised as a result of forward and spot market changes and the state of the generation asset (eg ramp up/down, maximum capacity, forced outage…) under each scenario. For the analysis to be meaningful, the simulation should preserve critical relationships among variables, such as implied heat rate distributions or structural relationships of weather, load, renewables and price relationships. Modelling the key physical and financial portfolio drivers in a coherent way is critical to analyse earnings variability, design hedging strategies and determine the optimal operating and hedging strategy.

3 High-level system overview – data flows



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Integrated analysis in one platform with robust and consistent analytics

When it comes to the valuation and risk management of assets and contracts such as storage, generation units, load-serving contracts or financial hedges, many energy firms use stand-alone models for valuation and risk.

The problem with this silo approach is that even if a company can capture the value and risk of different assets and exposures using independent models, the inability to account accurately for the interactions between the portfolio components leads to a suboptimal analysis of operating and hedging decisions and inaccurate portfolio risk metrics that fail to provide valuable insights on multiple risk dimensions combining physical and financial exposures.

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The data infrastructure is a critical component of the framework as the analysis requires the risk engine to interact with data that resides in multiple databases and communicate with other trade and risk management systems (see figure 3).

The integrated analysis can support portfolio-level risk metrics, which capture combined physical and financial positions, including market, credit, operational and volumetric risk, such as gross margin at risk, profit at risk, earnings at risk, cashflow at risk and potential future exposures. Another benefit of the unified framework is the ability of decision-makers to assess the impact of potential hedging strategies on the overall portfolio and also determine the optimal mix of physical and financial hedges based on the corporate risk appetite.

The production system should automate data processing in a secure, auditable and open code environment with robust analytics and advanced computational capabilities to achieve the goal of having a unified view of portfolio risks. Another benefit of an open and modular architecture is the ability for rapid integration with existing systems and/or proprietary analytical models.

We will discuss the computational and technological components of the framework, such as cloud computing, parallelisation of scenario calculations and the infrastructure required to store and report large amounts of data in a future piece.

Conclusion

We have provided an overview of a comprehensive, coherent and scalable energy risk-modelling framework, based on the concept of meaningful uncertainty and designed with the ultimate goal of providing valuable insights into the value and risk of the complex physical and financial portfolio to risk managers, long-term planners, traders, portfolio managers and structuring teams.

The framework bridges the gap between physical and financial markets by simulating physical variables to produce realistic and defensible scenarios of physical system and market conditions before and during the delivery period, at the relevant time granularity for multiple horizons.

In the following articles of this series, we will discuss the methodological, computational and technological building blocks of the framework. ■

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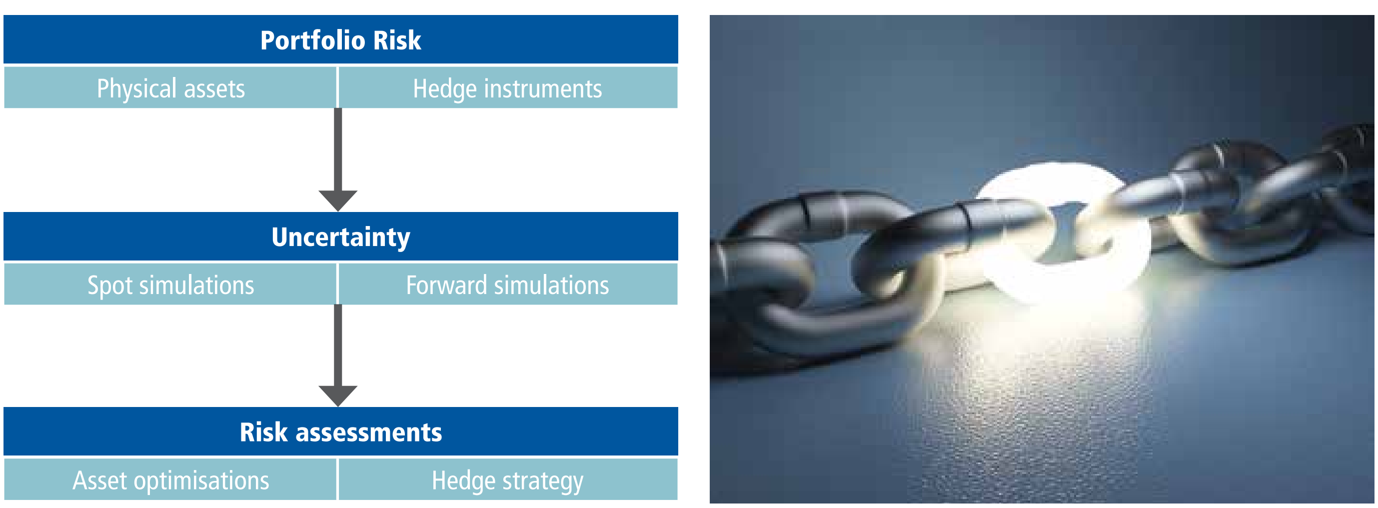
4 Bridging the gap the gap between the physical and financial energy markets. Meaningful uncertainty is the link that bridges physical assets to hedge instruments



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