Leading the field in
Energy Market Modelling

Risk Constrained Integrated Resource Planning with LT Plan

Executive Summary

This paper explores and demonstrates the capabilities of PLEXOS to exploit Modern Portfolio Theory[1] in an Integrated Resource Plan (IRP) or Capacity Expansion Planning (CEP) and identify the factors that have a high impact on risk versus those that don't. The approach allows the analyst to explore the impact of variability in key decisions, such as the type of generation technology built, on the overall solution giving a deeper insight into the resource planning problem.

We establish the efficient frontier[2] by running a series of risk-constrained stochastic simulations minimizing the mean risk for a given variance.

The Challenge

Stochastic IRP in PLEXOS aims to minimize the Net Present Value (NPV) of investment and production costs over a given horizon.

A single capacity expansion decision is optimised followed by *S* realisations of stochastic variables and the associated optimal production scenarios and optional recourse expansion decisions.

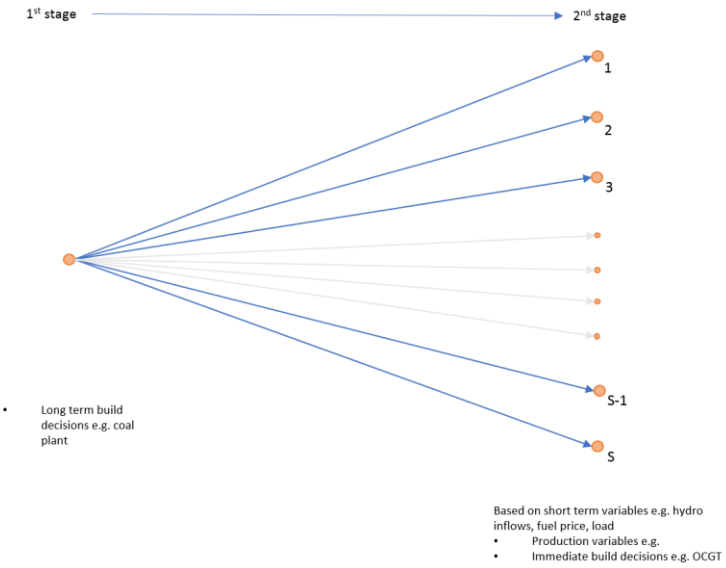

Figure 1: Scenario Tree for 2-stage Stochastic Optimization

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[1] http://en.wikipedia.org/wiki/Modern_portfolio_theory
[2] http://en.wikipedia.org/wiki/Efficient_frontier

Using scenario-wise decomposition PLEXOS formulates the deterministic equivalent of the original stochastic problem and solves using MIP (mixed integer programming). This will yield an optimal solution based on the expected NPV of costs. However there are many near optimal solutions that have different characteristics that would very beneficial to find *e.g.* lower risk but with somewhat higher total expected cost.

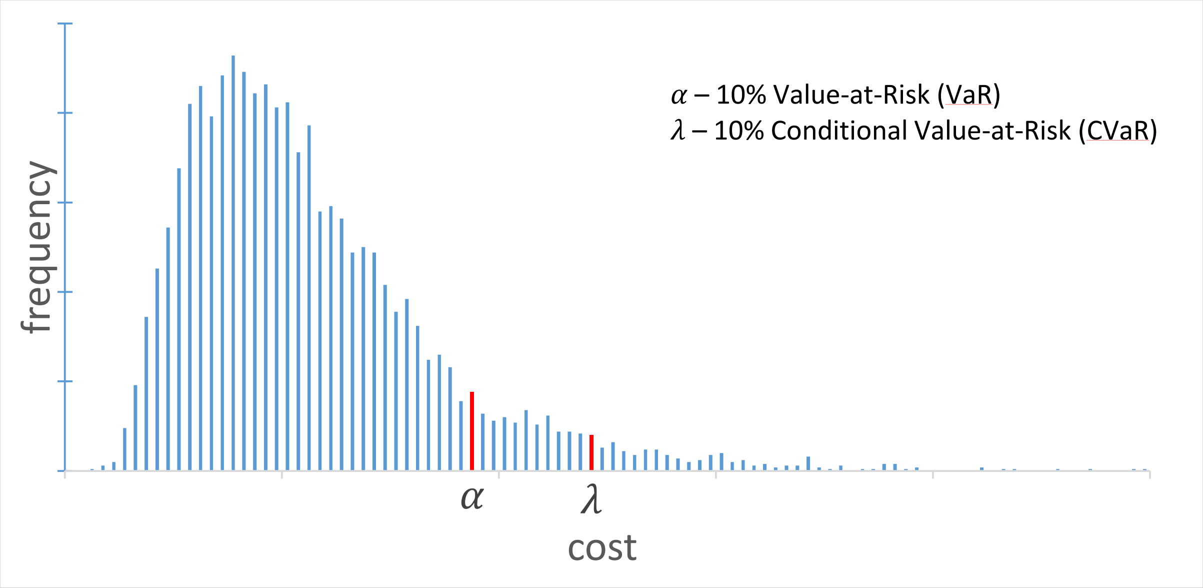

Figure 2: Histogram of System Costs

The Formulation

Value at Risk (VaR) is a commonly used standard to measure the probability that an investment portfolio will fall by a given amount in a defined horizon. The issue with VaR is it does not explore scenarios that exceed VaR *i.e.* the magnitude of risk beyond α.

Conditional Value-at-Risk (CVaR) accounts for the losses which exceed VaR *i.e.* CVaR considers scenarios up to λ, most notably scenarios that have a lower associated risk and a higher cost.

Integrating CVaR in the optimization problem in PLEXOS allows us to generate an efficient frontier of solutions that vary on whether the user tends towards high risk–low cost or low risk–high cost scenarios. This approach allows the user to investigate the tradeoff between the types of capacity built versus risk or the amount of capacity built versus risk, also what decisions yield the greatest impact.

The CVaR constraint is formulated as follows:

$minimize$

$$\sum_{s} w_s c_s(x)$$

$subject\ to$

$$\alpha + \frac{1}{1-\beta} \sum_{s} w_s r_s \leq \lambda$$

$$r_s \geq c_s(x) - \alpha, \qquad r_s \geq 0$$

…

The CVaR constraints are linear which dramatically improves the optimization efficiency.

Results

Creating a test system

Our demonstration model has the following characteristics:

- 40GW peak load
- 20 thermal generators
- One large hydro generator with storage
- Build candidates options of three new technology types: OCGT, CCGT and renewable.
- Twenty samples of hydro inflows stochastically driven
- 20 year horizon
- Load growth with a compound index factor of 5%

We evaluate CVaR, the expected costs in the 10th percentile.

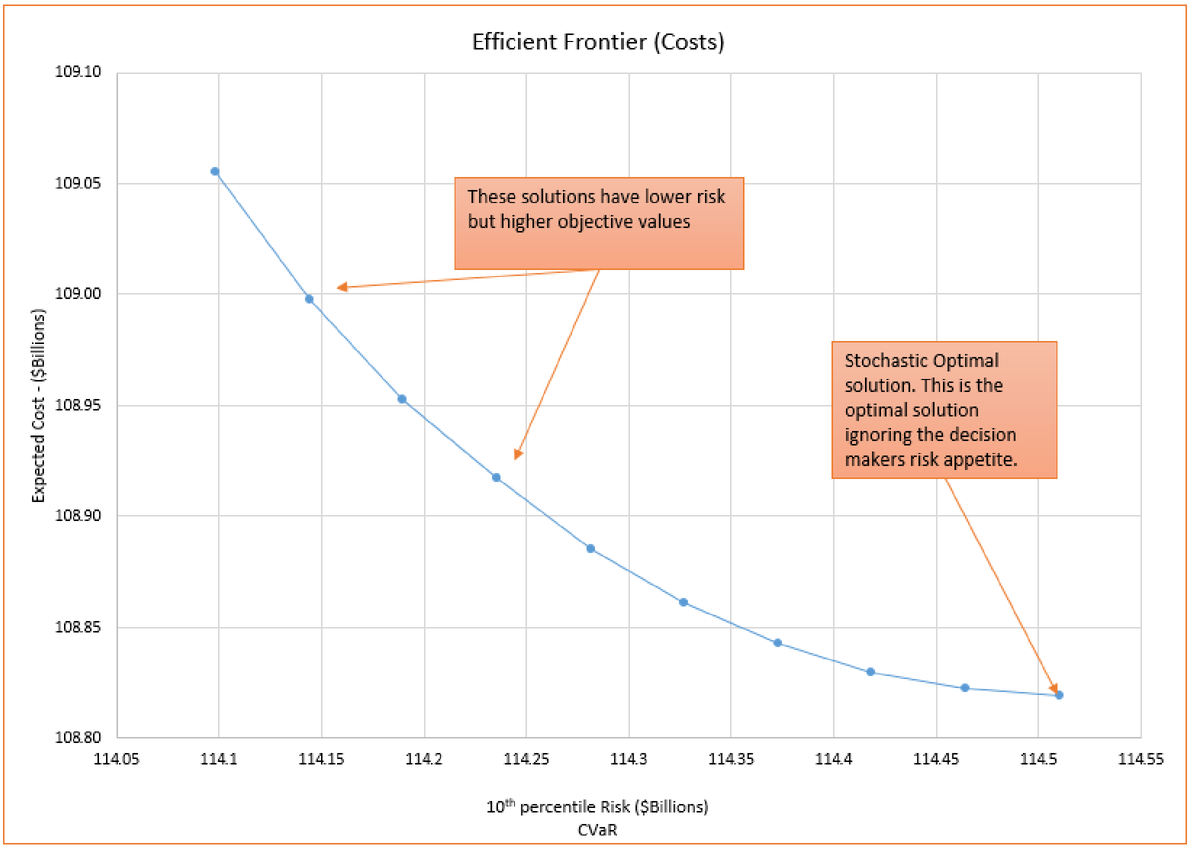

Figure 3: Efficient Frontier

Here is our Efficient Frontier of optimal solutions. Each point represents the outcome of one PLEXOS risk-constrained stochastic LT Plan optimization with a unique level of “acceptable risk”.

The stochastic optimal solution to the far right has the baseline level of risk and the lowest expected NPV cost *i.e.* lowest objective value. The solutions to the left are more risk adverse, more expensive but still feasible.

This approach to modelling risk needs the following parameters to be provided:

β – The confidence level, e.g. 90%[3].

λ – The CVaR limit at β confidence level (the Company [Acceptable Risk] property)

These inputs give the user complete control over how risk adverse they choose to be. Equally by modelling several confidence levels and CVaR limits, the user can identify the key decisions that impact risk.

The following two charts demonstrate the different build decisions and technologies selected based on the level of risk the user is willing to tolerate.

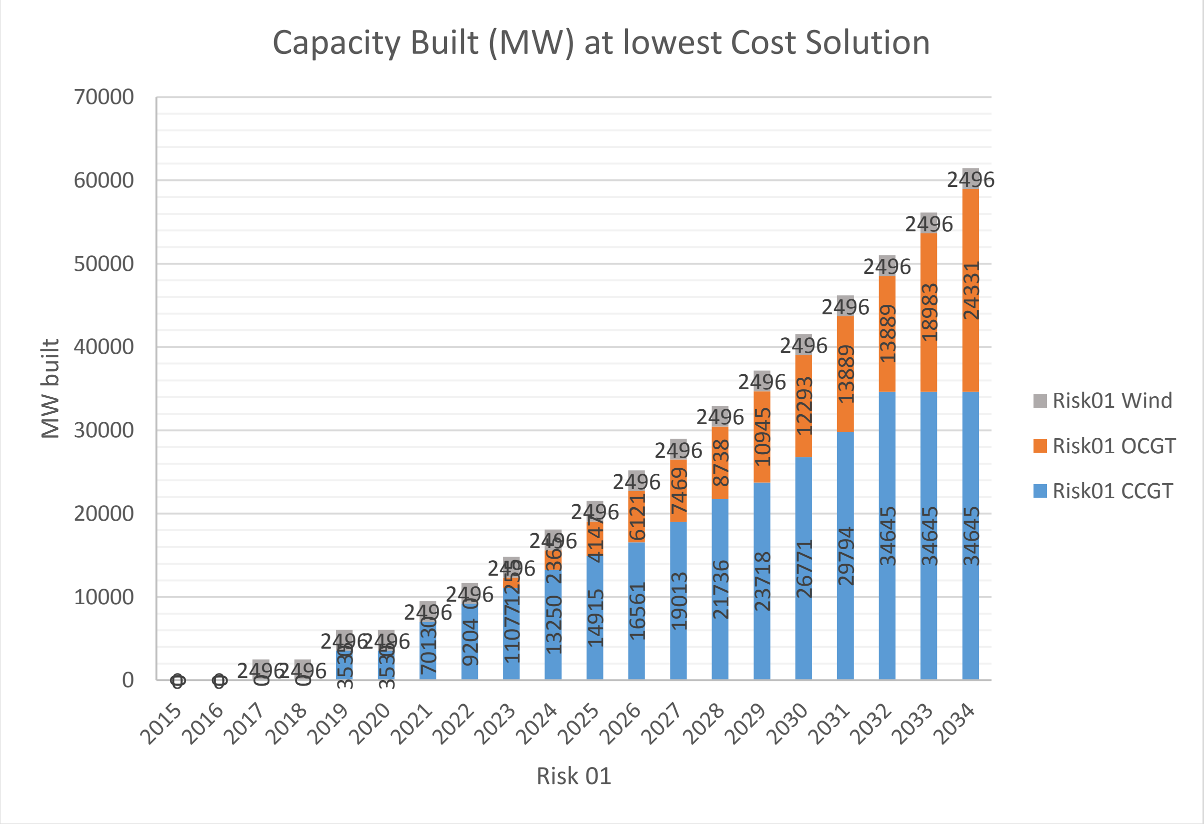

Figure 4: Capacity Solution for Stochastic Optimal Solution

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[3] At the time of writing the current release of PLEXOS is 6.302. In this version it is an undocumented parameter called [Risk Level]. See http://wiki.energyexemplar.com/index.php?n=Main.Undocumented for implementation.

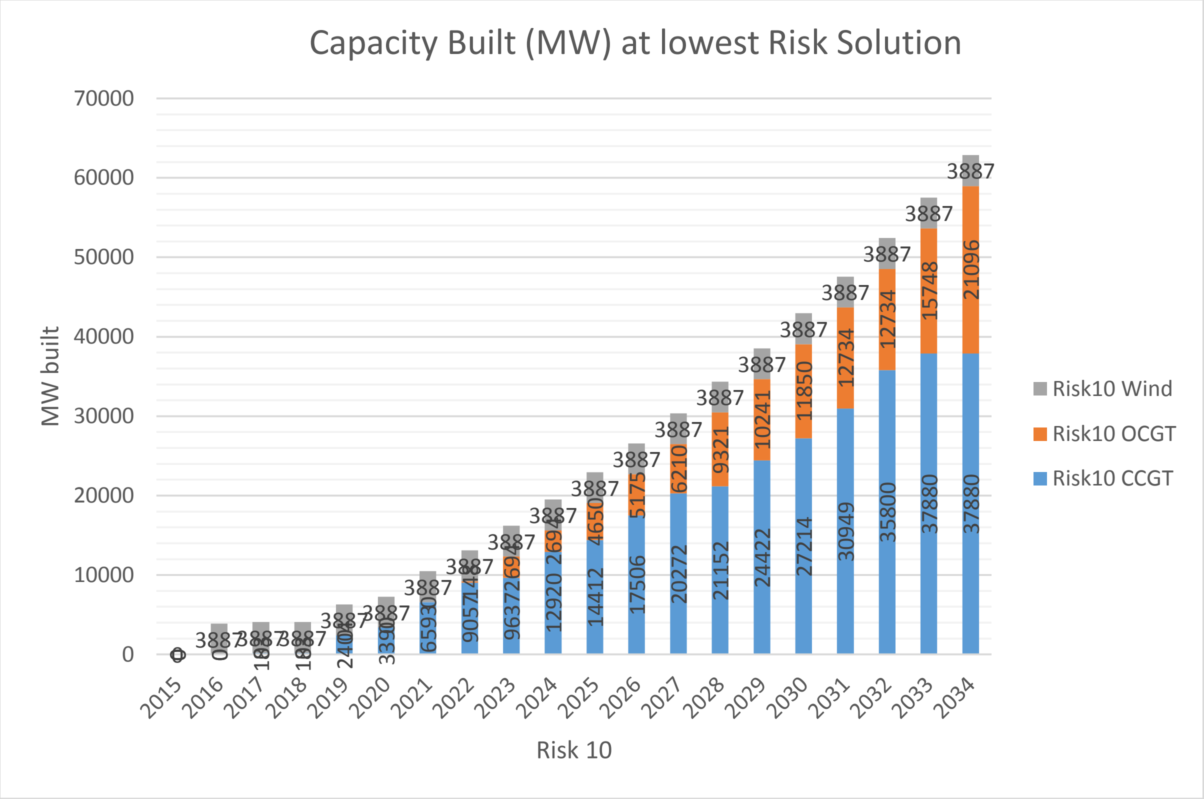

Figure 5: Capacity Solution for More Risk Averse Solution

Conclusion

Risk-constrained stochastic LT Plan is providing our users with more risk analysis information extending the capabilities of traditional IRP or CEP. With this technique, we can explore solutions from minimum cost on a portfolio with comparatively high CVaR through to solutions with higher costs but lowest risk. We can identify the key investment decisions, whether the amount of generation built, retired or the type of technology used that will have the greatest impact on risk.