CASE STUDY

High resolution modeling captures €4.5 Billion in costs in the EU power system.

Looking ahead to the impact low-carbon and negative emissions will have on the EU power system, changing the resolution to 5-minute intervals showed up to 100% increase in some battery usage - a significant increase in accuracy when compared to using hourly resolution. Using this higher resolution also captured more system costs, with the annual total increasing by 3%. While this may seem small, it represents about €4.5 Billion for a large power system like the European Union.

How does one accurately model this commitment and dispatch? High-resolution modeling is important when it comes to understanding flexibility as the value of storage, power to gas and batteries, and these these are not adequately captured at hourly resolution.

While one methodology for running large annual simulations is to split it into monthly or weekly packets, solve with an overlap and then stitch the results back together (time domain partitioning), PLEXOS was able to run the full model without splitting it. The research was led by Fiac Gaffney working with Paul Deane, who had conducted similar modeling on the Irish system.

With sub-hourly, high-resolution modeling, everything is faster: solvers and solving techniques have improved, the PLEXOS architecture has evolved and, of course, the cloud is now available for running operations.

At higher temporal resolution, constraints start to bind; that is, they are captured in the model and impact the objective function. Constraints like ramp rates, run-up profiles and shutdown profiles may not get captured fully in hourly modeling. A 400MW CCGT that can ramp at 30MW/min will not be picked up at hourly resolution but at 5 minutes it will. When a constraint is captured in linear programming it produces a shadow price. This is a useful metric, for example, to understand how much to pay for an extra unit of ramping.

> **Since 1999, traditional methods for modeling have only seen a 25-times increase in improvement. PLEXOS has seen a 500-fold improvement and can handle far more sophisticated and complex environments/problems.**

Learn more about high-resolution modeling: **energyexemplar.com | info@energyexemplar.com**

CASE STUDY

MISO Energy uses PLEXOS to find wind-hydro synergy with Manitoba Hydro and unlock significant savings.

MISO Energy's simulations found the cost of expanding the transmission capacity between Manitoba Hydro and MISO Energy would enable greater wind participation in the MISO Energy market. Both line connection options offered production, modified production, load and reserve cost savings and wind curtailment reduction.

Fueled by wind, gas, oil, coal and nuclear, MISO Energy provides electricity across 15 US states as well as Canada's Manitoba province. Manitoba Hydro has a similar reach, providing electricity and natural gas to more than 500,000 electric and 250,000 natural gas customers.

MISO Energy faced integration challenges due to the intermittent and non-peak nature of wind generation. It was thought these challenges could be mitigated by Manitoba Hydro's large and flexible system, which included 15 hydroelectric generating stations, as well as some thermal, diesel and wind capacity.

The simulations found that significant benefits could be realized from the addition of either an eastern 500 kV line between Dorsey, Manitoba and Duluth, Minnesota, or a western 500 kV line between Dorsey, Manitoba and Fargo, North Dakota/Moorhead, Minnesota.

The organizations chose PLEXOS as the simulation platform to evaluate the benefits and costs of expanding the interface between them.

They found PLEXOS met the needs for:

- Intricacies in modeling Manitoba Hydro's resources
- Efficiently responding to wind variability
- Modeling ancillary services
- Computing the complexity of the study
- Generating the required reports

MISO Energy operates one of the world's largest energy markets with more than $29 billion in annual gross market energy transactions.

CASE STUDY

Precise and reliable fuel forecasting and reporting enables Nova Scotia Power to uncover fuel cost savings to justify transmission system upgrades.

Tightening emissions regulations drove NSP's need for greater sophistication in their fuel forecasting. Switching to PLEXOS from resource optimization software that could no longer handle their dispatch complexities, they uncovered considerable fuel cost savings.

Tightening emissions regulations, decreasing load and increasing variable generation were all causing NSP's dispatch modeling to become substantially more complex.

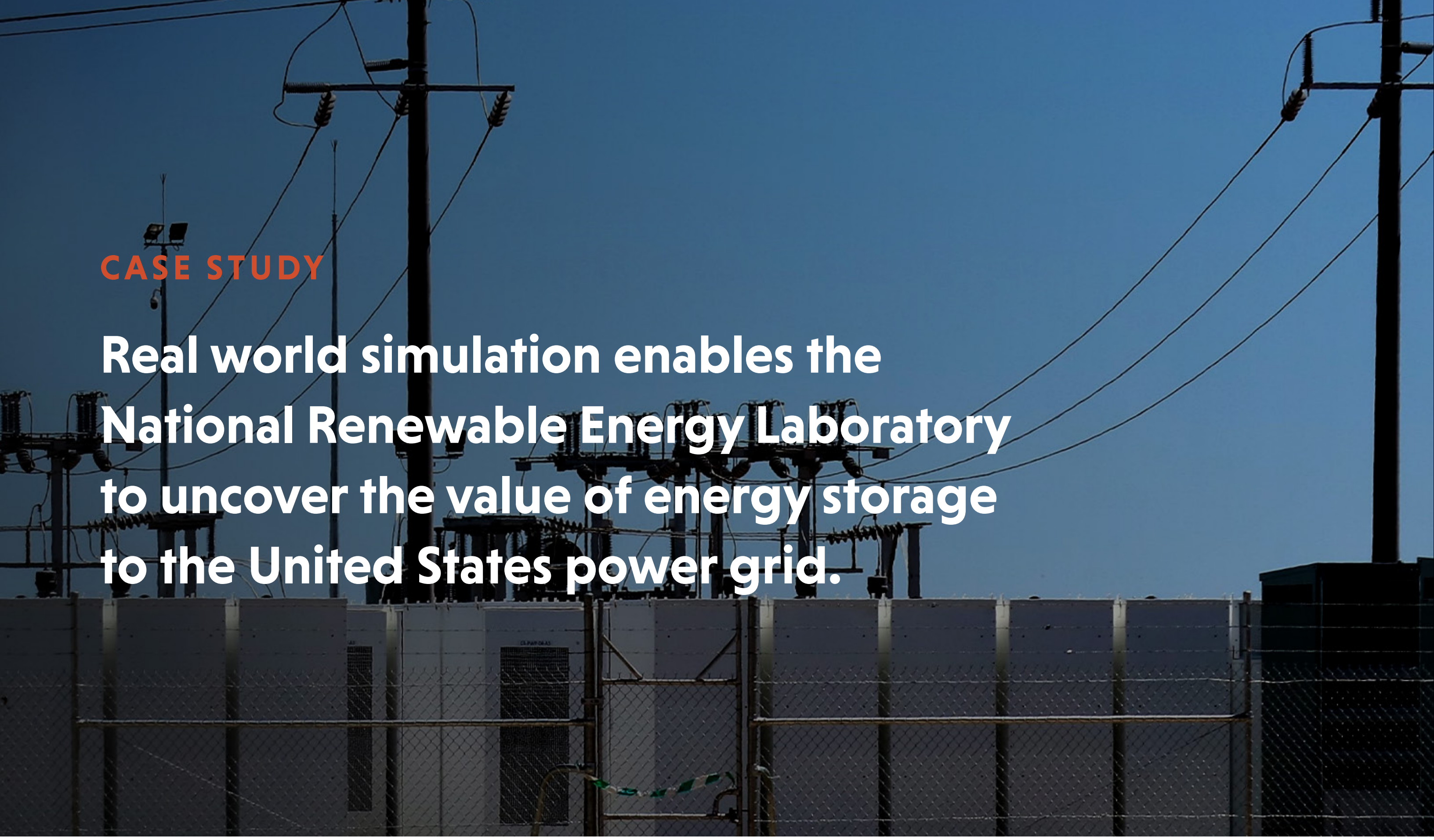
After a Fuel Adjustment Mechanism Audit completed by Liberty Consulting Group, NSP learned that its Modeling Dynamic Reactive Reserve (MDRR) dispatch model was limited. The tool was economically dispatching coal units ahead of the generators in a way that created an infeasible dispatch, and the model was under-forecasting the natural gas and HPO fuel requirement.

Based on the audit's recommendation, they chose PLEXOS to address the dispatch issue. In addition, the PLEXOS model was able to explicitly consider the sync condenser contribution to the system load.

Initially, PLEXOS and the previous tool ran in parallel for two quarterly fuel forecasts to validate the model. The team grew confident in the accuracy and PLEXOS became the tool for recording fuel forecasts.

PLEXOS accurately forecasted fuel and purchased power requirements from the start of the changeover and succeeded in forming the base case for all system studies and fuel forecasts. NSP was able to justify transmission system upgrades based on fuel cost savings. The organization now relies solely on PLEXOS to deliver accurate fuel forecasts and reports.

> **NSP provides power to around 500,000 customers in Nova Scotia, Canada. Its diverse generation mix includes HFO, gas, coal/petcoke, oil, hydro/tidal, wind and biomass.**



CASE STUDY

Real world simulation enables the National Renewable Energy Laboratory to uncover the value of energy storage to the United States power grid.

Using PLEXOS, the NREL was able to evaluate the sensitivity of reserve prices to a variety of operational constraints, fuel prices and other factors. In addition, they examined the value of energy storage devices as the sum of their operational and capacity values.

The NREL was preparing a report, "The Value of Energy Storage for Grid Applications," as part of the US Department of Energy's Demand Response and Energy Storage Integration Study. The report needed to address the issue that electricity storage technologies to date had limited deployment in the United States power grid, despite the multiple benefits they could provide.

The organization chose PLEXOS to simulate the operation of a power system that co-optimizes provision of energy and ancillary services.

The project's goal was to evaluate storage in a system that was large enough to represent a "real world" scenario, yet small enough to allow reasonable run times given the large number of sensitivities it needed to analyze. It also had to be able to isolate changes associated with the different sensitivity cases.

Successfully performing the simulations using PLEXOS, the NREL found that, overall, the value of energy storage is largely dependent on it obtaining a capacity value, even if the device is providing higher-value reserve services.

> The National Renewable Energy Laboratory is dedicated to research, development, commercialization and deployment of renewable energy and energy efficiency technologies.

CASE STUDY

Stochastic optimization offers South Australian policy makers a clear-cut, realistic solution to power and water co-optimization, minimizing the overall system cost.

Water processing and pumping stations run on energy from the electricity grid. Consequently, if their demand is large enough to change the system's marginal generator, it will directly affect the electricity price. This means water cannot be optimized alone and with additional variables of hydro inflows, wind generation, demand and forced outages, it may seem unlikely to find a real world simulation method.

Energy Exemplar conducted a study comparing two stochastic methods to run the co-optimized model for South Australia: PLEXOS vs Monte Carlo.

The stochastic variables of the study were: the water inflow into the state's main reservoir; South Australia's wind speed; and energy prices in the neighbouring state of Victoria.

Electricity and water demand were treated as deterministic inputs and included in PLEXOS using historical profiles. The stochastic methods to optimize the model were: Monte Carlo simulation with 14 historic samples; and two-stage stochastic optimization (non-recursive) with scenario reduction.

Initial results for a cost comparison showed the Monte Carlo simulation is less costly than the stochastic operation. ▶

Method	Avg Total Cost	Avg Pumped Water (1000m³)	Avg Pumping Cost ($/1000m³)
Monte Carlo	76,651.9	3,263.3	23.5
Stochastic optimization	93,247.7	3,244.4	28.7

This is expected, since the Monte Carlo method anticipates the future behavior of stochastic variables when making operational decisions at the present states; each of its independent samples run with perfect foresight throughout the entire simulation period.

In contrast, PLEXOS's stochastic optimization does not anticipate the variables. The variables stay uncertain at each stage, and the decision is based only on the probabilities of each distinct scenario. These results reflect more conservative and realistic operations.

The main advantage of stochastic optimization is that it provides the optimal decisions under uncertainty. This non-anticipatory method is the best policy over the simulation period – better than any of the samples of the Monte Carlo simulation or their averages.

Additional advantages of stochastic optimization are shown in Figures 1 and 2. The graphs show a one-day snapshot of the optimal operation of the water reservoir in the model.

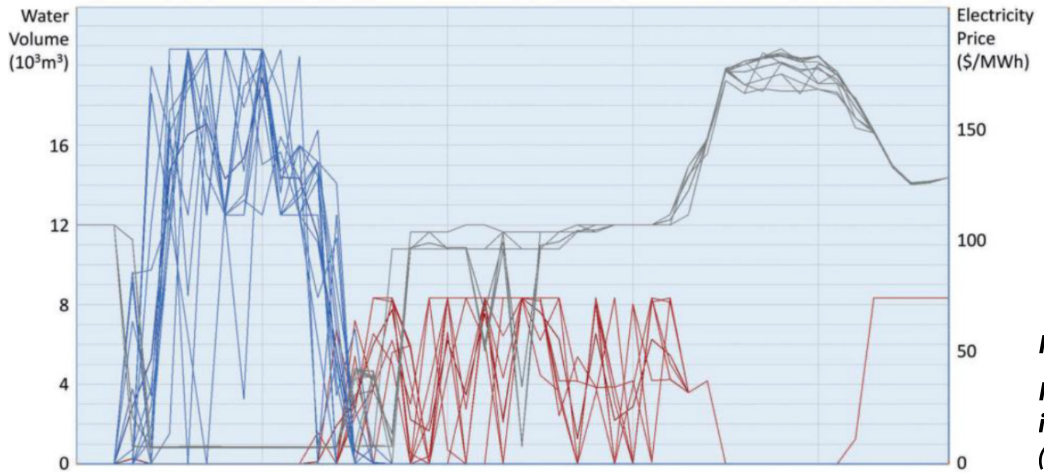


Figure 1:

Monte Carlo's optimal water injection (blue) and withdrawal (red) over electricity prices (grey)

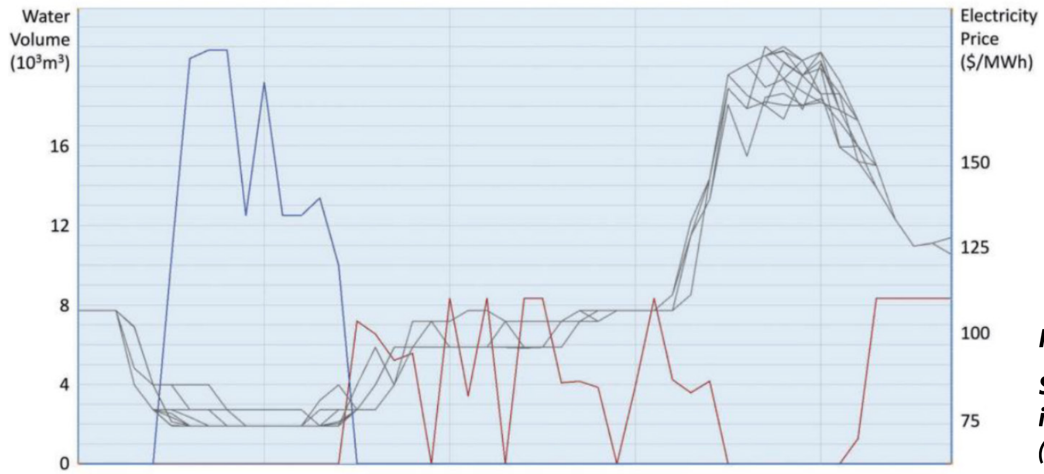


Figure 2:

Stochastic optimization's water injection (blue) and withdrawal (red) over electricity prices (grey)

Both solutions see water operation in periods of low electricity prices. However, stochastic optimization provides one clear solution over different price outcomes, while Monte Carlo gives a collection of 14 optimal decisions - one for each price outcome. The Monte Carlo method may be overwhelming for decision making, while stochastic optimization guides planners and operators with the best policy. ■

CASE STUDY

Leading power generator uncovers tens-of-millions of dollars in fuel savings, hidden within a complex energy mix.

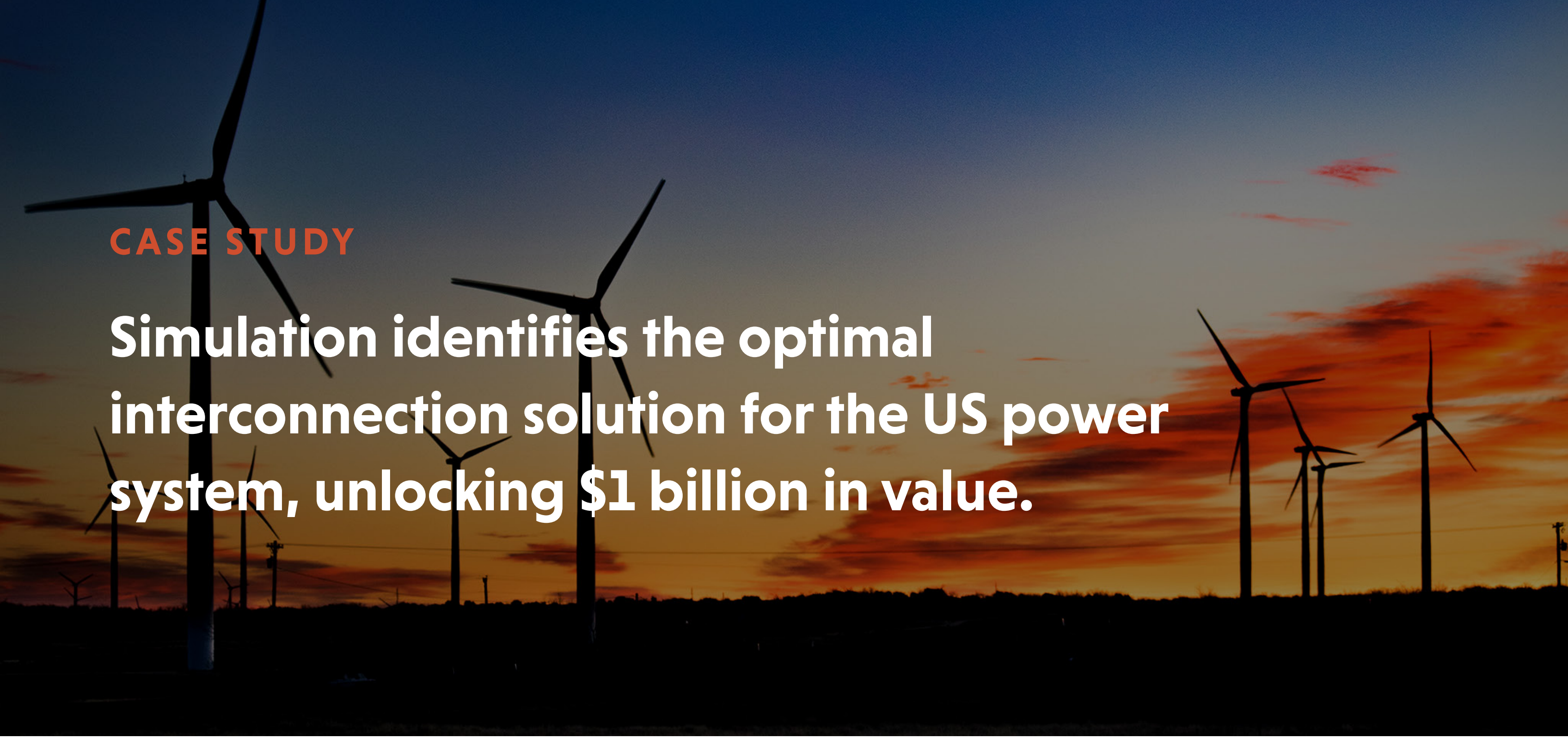
The very first use of PLEXOS yielded the power company significant annual fuel savings, by running "real world" simulations, including modeling over 300 unit commitment properties to emulate life-like dispatch.

The environment to simulate is complex, involving multiple fuel constraints including coal, port and different mix ratios for its coal plant in Hong Kong, nuclear imports from China and various gas supply contracts.

Powering the system is a number of different technologies, including steam turbines, CCGTs and GTs, which need to adhere to emission constraints.

Within the simulation model, the organization applied a variety of constraints using the "constraint class" as well as set up "if" statements using the "conditional classes." The model's "variable classes" also assigned relationships, and together with Mixed Integer Programming.

> The results were immediate, making the purchase of PLEXOS a large ROI multiplier with the very first use.



CASE STUDY

Simulation identifies the optimal interconnection solution for the US power system, unlocking $1 billion in value.

Using PLEXOS, an industry alliance led by the National Renewable Energy Laboratory was able to show that, despite very little electricity being transferred between the Western Interconnection, the Eastern Interconnection and the Electric Reliability Council of Texas (ERCOT), the financial benefits of their interconnection would be huge.

Representatives from more than 30 utilities, system operators (MISO, SPP, WECC, AESO, ERCOT, IESO) and industry organizations, including Energy Exemplar, developed a study to evaluate the optimal solution for joining the interconnections.

The team found more than $1 billion in value could be gained from strengthening the connections (or seams) to encourage efficient development and utilization, creating a more reliable, resilient, sustainable and affordable electricity system.

It also proved that proper modeling (extreme accuracy with minimal complexity) incorporating geographic diversity (wind, solar, hydro) increases the ability to integrate more renewables into a power system and deliver energy certainty.

PLEXOS was chosen because of its unprecedented resolution and Mixed Integer Programming. Ninety-eight thousand nodes, more than 100,000 transmission lines and 12,000 generators were fed into the model – the first to simulate the East and West Interconnections together.

> **The National Renewable Energy Laboratory (NREL) is dedicated to research, development, commercialization and deployment of renewable energy and energy efficiency technologies.**

CASE STUDY

Co-optimization helps the Middle East confidently meet electricity and water demands in a rapidly changing economic environment.

Throughout the region, changing technologies and renewable targets are driving the need for simulation studies to ensure organizations meet current and future demands for power generation and water production. Immediately proving its value, PLEXOS delivered a 6% annual fuel saving when the optimized plan was implemented.

With over 400 different system elements, the project represented a new step in the fully co-optimized world of energy systems. However, the software's unique architecture and fully integrated modules ensured all requirements were included in the objective function.

PLEXOS simultaneously solved for electricity generation, heat production and water desalination production processes. Modeling for electricity encompassed the region's changing energy mix of coal, solar PV, CSP and pumped storage hydro power plants.

The Energy Exemplar team ran three-year backcasts to calibrate the system model database and found close dispatch results which confirmed that the optimization was performing the same as the live system.

With a calibrated database, the customer has a flexible model for performing a wide range of studies. Now secure in their analysis, the customer can run many scenarios to determine the reliability of their co-generation and desalination system.

> **Given the complex nature of the code constraints involved, the project started with WSP UK, consultants with an intimate understanding of the local intricacies. The team used PLEXOS to model the co-generation plants and then collaborated with Energy Exemplar to develop the PLEXOS code. Once tested, the customer appointed the Energy Exemplar to team for the implementation.**