PLEXOS

RENEWABLES

Leverage Every Opportunity
as the World Transitions to a
Lower Carbon Future

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LET PLEXOS OPTIMALLY GUIDE YOU TO A LOW CARBON FUTURE

Easy to use, life-like simulations achieved through high granularity modeling, advanced programming and stochastic optimization techniques.
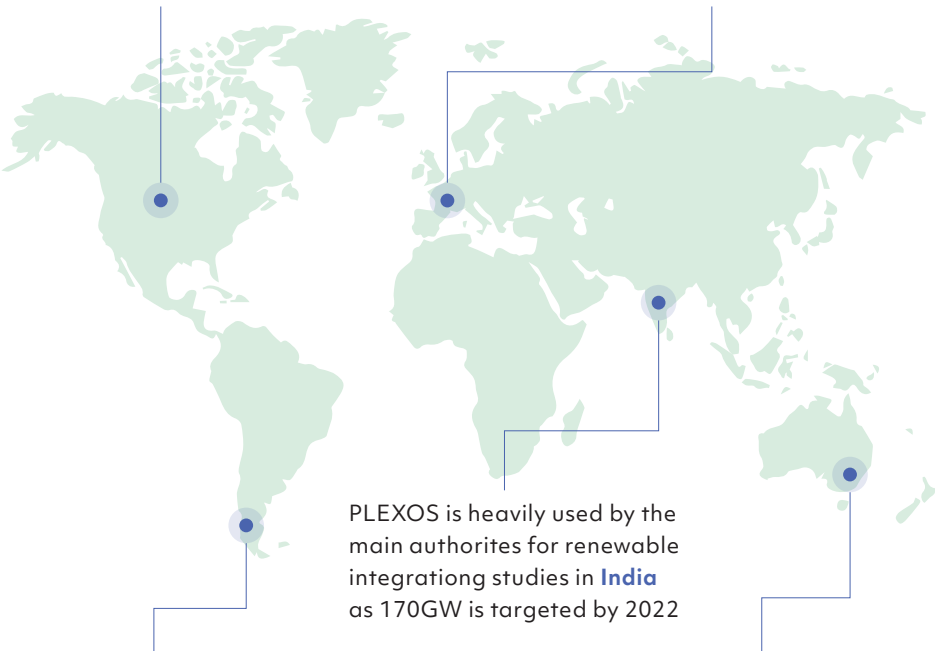
Plexos optimally times and positions investments of all renewable technology types. It guides trading decisions through price forecasting and highlights risks associated with things such as congestion analysis.

50+ countries rely on PLEXOS for renewable studies. The relevance is universal:

United States of America's PJM use PLEXOS for the Clean Power Plan

90% of **Europe's** utilities market relies on PLEXOS for carbon trading management

PLEXOS is heavily used by the main authorites for renewable integrationg studies in **India** as 170GW is targeted by 2022

Chile's Coordinador Electrico National relies on PLEXOS for long term national renewable plans

Australia's AEMO published national studies in PLEXOS format for download

The PLEXOS Platform

CRAFTED TO CATER FOR EVERYONE, EVEN BEGINNERS!

What is PLEXOS?

PLEXOS® is economic software that uses mathematics-based optimization techniques for forecasting.

PLEXOS is easy to use and offers the latest visualization features, data handling and distributed computing methods to provide a robust, high-performance simulation system

for electric power, water and gas.

Renewable modeling?

An investment in PLEXOS is a small outlay compared to the enormous benefits that are realized from savings in costs, better ways to maximize profits and from achieving more accurate planning results.

PLEXOS is not a Black Box and is highly configurable by the user. It offers cutting edge access to some of the most advanced algorithms and modeling techniques, thus giving the user peace of mind and a real-life simulation experience.

Who uses PLEXOS?

PLEXOS is relied upon by a global community of over 350 organizations in approximately 60 countries.

Current users include:

- Renewable Builders, Owners and Operators
- Departments of Energy and Ministries
- Market Operators, Regulators and Commissions
- Over 100 Utilities
- 40 of the world's system operators
- Power Plant Manufacturers and Construction Companies
- Gas Producers, Traders and Retailers
- LNG Operators and Traders
- Research institutions and consultants

It's more than software, it's a VIP gateway to a global community of users in approximately 60 countries.

Expand your network and join the rapidly growing community of PLEXOS users.

Services

SUPPORT

Providing the best support is our first priority at Energy Exemplar. Our philosophy is to staff well and keep employing ahead of the curve. We currently have PLEXOS experts in every regional office and full time developers across the US, Australia and India who are well placed to respond to your needs

TRAINING

PLEXOS comes with comprehensive help files and a built-in electronic Wiki. However, there is no substitute for taking one of our training courses. Select from a range of generic and customizable training courses which help new users get started or more intermediate and advanced modelers to improve their skills. Group training is also held in each region from time to time.

IMPLEMENTATION

The best forecasts come from a well calibrated and back-tested model. Energy Exemplar's PLEXOS analysts have a wealth of modeling experience from all over the world and undertake customized implementation projects very regularly.

Some examples include dataset builds and back-tests, assistance with modeling configurations for projects, software optimization for speed and accuracy, software installations, client-server configuration, automation of data entry and customized reports that link directly to simulation outputs.

DATASETS

Energy Exemplar has many datasets from all over the world in PLEXOS form and this number is growing, as we are always working on a new one! If we don't have a dataset for a certain country, we can build one on request.

Renewable Topics

Key Renewable Modeling Features

Sub-hourly modeling (down to 1 minute level) to represent intermittent generation

Multi-commodity optimization by integrating multiple models

Energy & ancillary services co-optimization with renewables

Interleaved simulation to optimize unit commitment and economic dispatch of Day-Ahead and Real-Time markets

Various autoregressive sampling models for wind speed, solar radiation and natural inflows

Representation of detailed real-life technical constraints

Stochastic simulation to model uncertainties using Monte Carlo simulation or Stochastic optimization
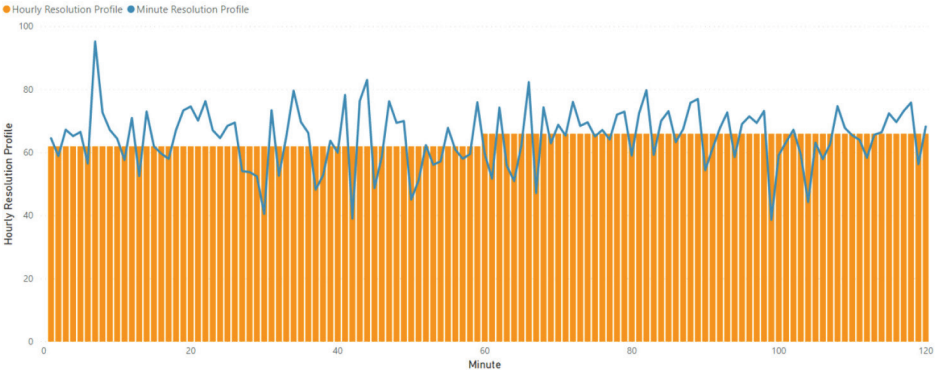
Demand Side Management

Accurate price forecasting

Hourly and Minute Resolution Profile by Minute

Investment Decision Analysis

COMPLEX PROBLEMS REQUIRE POWERFUL TOOLS

Let the advanced algorithms in PLEXOS provide the certainty of what, when, or where to optimally invest or retire assets from the point of view of considering generation and transmissions across electricity and gas.

> "PLEXOS has been the 'all in one tool' for us for such analysis, from market modelling to planning, forecasting and optimisation. With its perfectly designed gui, we have saved great effort in formulating complex problems as well as good amount of time with its fast and flexible simulations."
>
> – Mutlu Yildirim, ETRM, Turkey

WORKING TOWARDS A GREENER GRID

All over the world governments and regulators are putting in place measures to transition from the fossil fuel-based power systems of the 20th Century, to a new greener grid. The time frames and the mechanisms to get there differ from region to region but the challenges are the same:

What is the right technology mix to support an increasingly intermittent power supply?

How will subsidies, regulatory changes and market reform help to stimulate investment while supporting a core generation fleet needed to provide the security of supply?

In order to answer these questions, one needs to consider in parallel both the physical attributes of the generation and transmission assets, as well as the complexities of energy economics.

PLEXOS allows for a representation of every generating unit and transmission line in a given market and schedules the assets to meet system load at least cost based upon detailed technical operating characteristics and the economics that drive those decisions.

As well as representing the existing power system, PLEXOS allows the user to provide optionality to build new units along with retiring, refurbishing or retrofitting the existing fleet. In addition to the operating costs of these new assets, PLEXOS also considers all project costs associated with any capital investment decisions.

This allows PLEXOS to answer the key questions:

WHICH
technologies
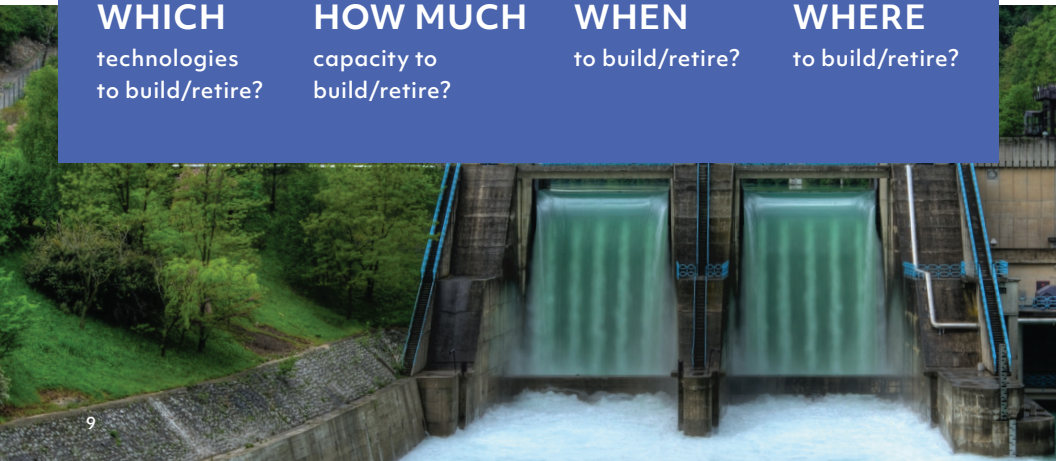to build/retire?

HOW MUCH
capacity to
build/retire?

WHEN
to build/retire?
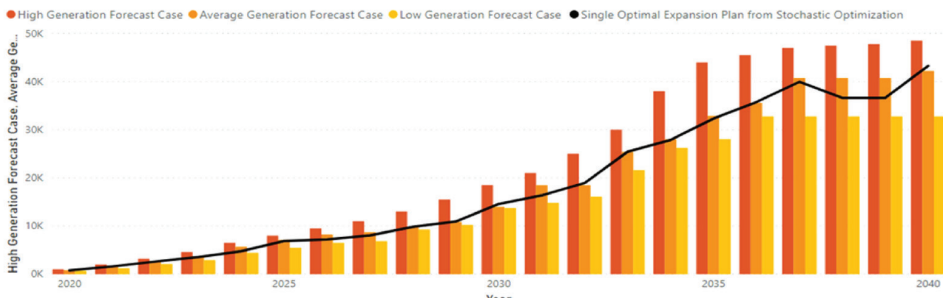
WHERE
to build/retire?

PLEXOS powerful scenario analysis allows the user to examine different versions of the future by reflecting possible policy and regulatory changes, such as:

Renewable Generation Targets

Emissions Targets/Markets

Technology Phase Out

Market Restructuring

While most long-term energy market models focus exclusively on the development of the traditional thermal assets, Energy Exemplar recognize that modern power systems are built with renewables at their core. PLEXOS is the only solution available which is able to capture hourly, and even sub hourly level detail, when determining the future power mix, and therefore unlocking the true renewable potential in a market, by combining investment decisions bet ween renewables, batteries and other flexible resources.

PLEXOS revolutionizes
renewable integration modeling

via the use of stochastic optimization techniques. Stochastic optimization allows PLEXOS to consider the uncer tainty associated with renewable generation forecasts when making build decisions. The result is a single, actionable, expansion plan which minimizes the cost of operating the power system, yet meets the system obligation across all possible futures.

● High Generation Forecast Case ● Average Generation Forecast Case ● Low Generation Forecast Case ● Single Optimal Expansion Plan from Stochastic Optimization

PLEXOS
LT PLAN

Demand Side Paticipation

Physical Generation and Load Contracts

Any Type of Generating Technologies

Capture Operation Constraints

Policies and Regulations

Transmission Dynamics

Multi-Stage Generation and Transmission Projects

ASSIGN PRACTICALLY ANY RULE WITH THE CONSTRAINT, DECISION VARIABLE AND CONDITIONAL CLASSES.

- Regional capacity reserve margins and ancillary services
- Maximum number of units built and retired
- Technical and financial life spans
- Fuel availability and maximum fuel usage

- Co-generation and other must-run conditions
- Emission production limits and renewable energy targets
- Minimum energy production
- Hydroelectric storage targets and releasing policies

Optimal Hedging

PLEXOS is the **tool of choice** for hedge funds and the world's leading utilities for making the best trading decisions. PLEXOS is **universally relevant** to any type of system, whether a market is present or not.

Apply physical and financial contracts and load obligations to dynamically modify generation in PLEXOS for **optimal dispatch decisions**.

- ✓ Set minimum profit targets

- ✓ Perform sensitivity analysis for generation asset valuation and risk analysis

- ✓ Better understand the sensitivity of price forecasts and resulting effects on dispatch decisions and cash flow variation

SHORT/MID TERM ENERGY PRICE FORECASTING

PLEXOS is used extensively by customers around the world to forecast energy market prices. Energy market price forecasting in PLEXOS is based upon a fundamental model in which both the supply side and demand sides are modeled. PLEXOS models in detail both the technical and commercial characteristics of the generating units and deploys an algorithm which simulates the market clearing engine.

PLEXOS does not hard code market rules, instead reflecting these rules by configuration, allowing PLEXOS to simulate any current or future market structure.

PLEXOS is used widely by market participants across Europe and has been deployed to analyze even the most complex European energy market frameworks, such as analysis of EUPHEMIA order types and flow based market coupling.

PROVEN ACCURACY

PLEXOS has a proven track record in the ability to accurately simulate energy markets.

In fact, market operators and regulatory authorities around the world choose to publish PLEXOS databases to allow market participants to make more informed decisions (for example Ireland, Australia). An example of a recent benchmarking exercise for the Iberian market for the full year 2018 is shown below:

Monthly Average Prices
Iberia 2018 Actual verses PLEXOS
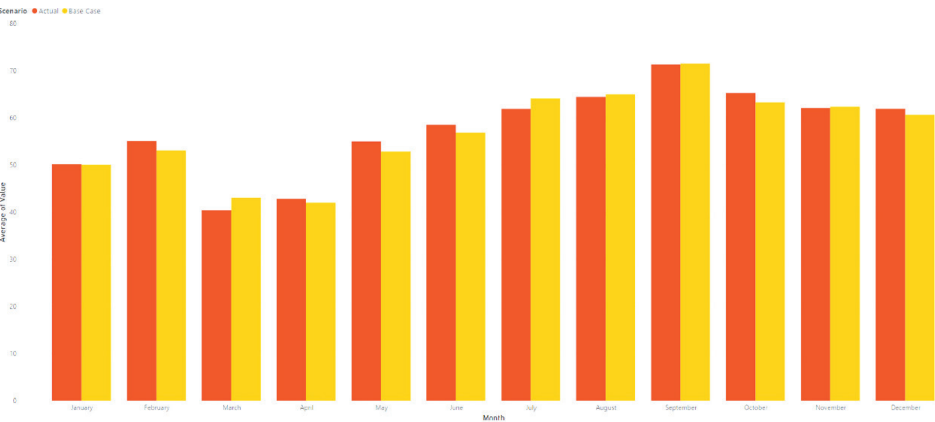
**Hourly Prices**
Iberia November 2018 Actual verses PLEXOS
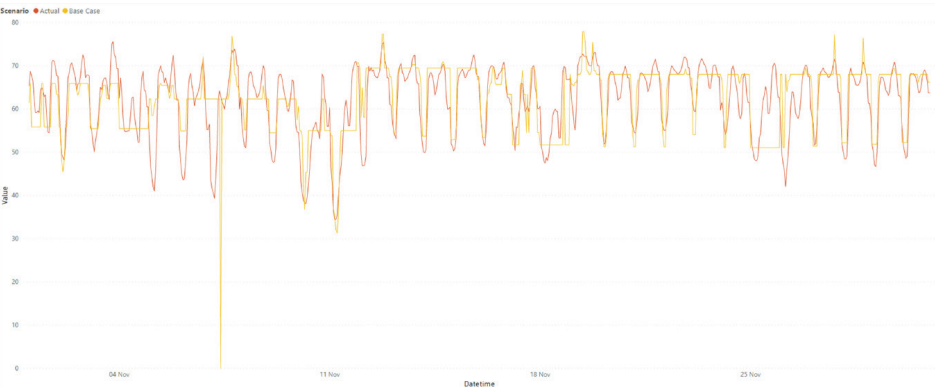
Trading & Risk Analysis

PLEXOS supports market traders to value their portfolio and analyze risk associated with uncertain conditions in the market. This is achieved via stochastic analysis, in which price drivers such as demand error, renewable forecast error, forced outage, fuel price volatility, etc. are captured as uncertain variables, with Monte Carlo draws simulating hundreds or even thousands of draws. PLEXOS parallel computing and cloud architecture allow for **large numbers of simulations to be executed within a timeframe** required to make operational decisions.

PLEXOS risk analysis can be under taken both at market level, providing a spread of possible market prices, as well as at portfolio level allowing computation of typical risk metrics such as VaR and PaR.

10-Day 5% Portfolio Value at Risk

5% VaR
$657,942

Probability Density

Portfolio Return (Millions)
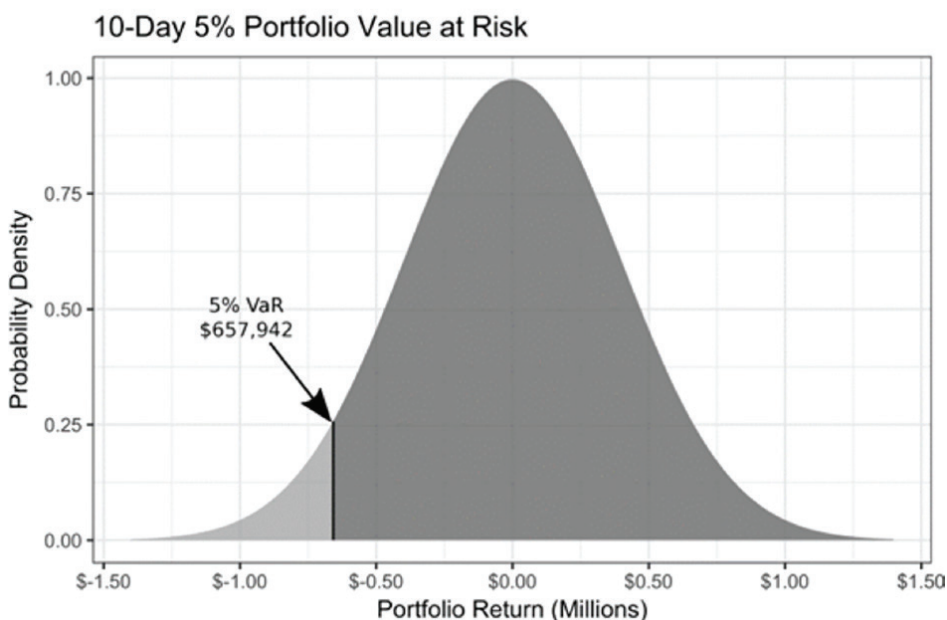
PPA Analysis

As the levelized cost of energy for renewable projects decreases, and the available support mechanisms become more competitive, **investors are turning towards alternative methods to fund renewable projects.** Very of ten, this is in the form of Power Purchase Agreements (PPA). As renewable PPAs become more common across the globe, the PPAs themselves are becoming more complex, with more and more underwriters placing provisions designed to protect against uncertainty associated with both generation output and electricity market prices. Each PPA has its own unique profile of value and risk and requires rigorous case-by-case analysis to properly understand the contractual implications to the buyer and seller.

Average Solar Generation and Energy Market Price
Spain 2018

PLEXOS enables renewable developers and operators to understand what a fair price for a power purchase agreement looks like, accounting for the uncertainty associated with the technology and the electricity market price.

Simulation of the entire market produces forecasted hourly market clearing prices, as well as capture prices fitted to the renewable investment project across the lifetime of the PPA .

Stochasticity, not only in the renewable generation forecast, but also other fundamental price drivers such as demand error, forced outage, fuel price volatility, are captured as uncertain variables. PLEXOS automatically simulates hundreds or even thousands of draws, providing a risk profile and visibility into spread of possible returns.
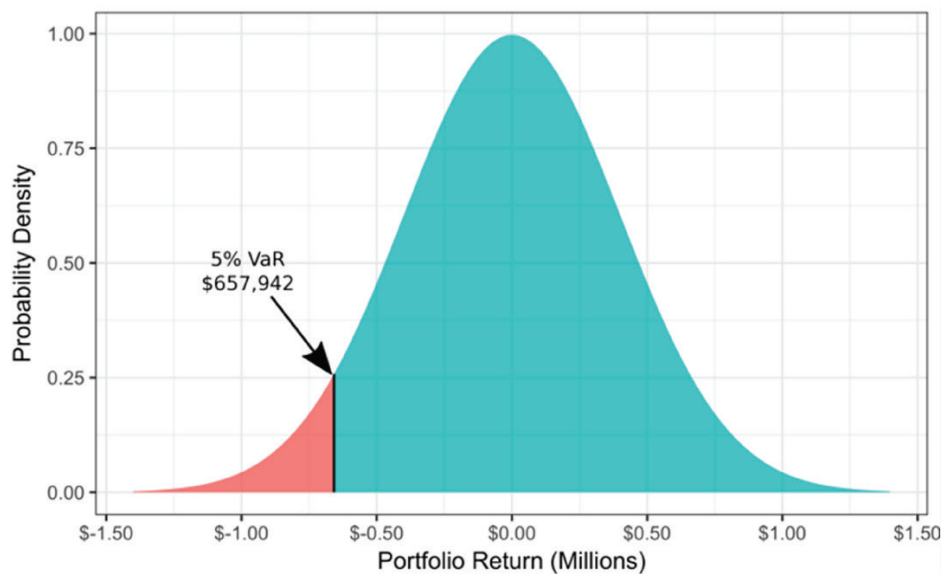
PLEXOS parallel computing and cloud architecture allow for large numbers of simulations to be executed quickly, even for large markets.

Analyzing Uncertainty

Stochastic Simulations Capture Intermittency Risk

✓ Analyze Curtailment Risk

✓ Evaluate Financial Transmission Rights

✓ Impact on Overall Value at Risk
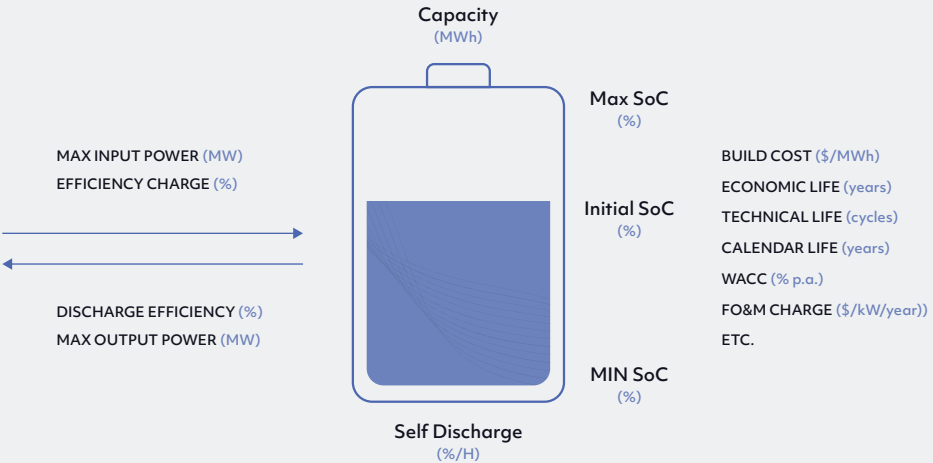

5% VaR
$657,942

Storage

PLEXOS represents
ALL TYPES OF ENERGY STORAGE TECHNOLOGY
for short and long term modeling. It allows
THE COMPUTATION OF SAVINGS
from production costs, congestion charges and reduction in losses.

The Battery Class

- Electric Vehicles
- Thermal Storage Systems
- CAES
- Flywheel Batteries
- Secondary Batteries
- Flowing Electrolyte Batteries

Capacity
(MWh)

Max SoC
(%)

Initial SoC
(%)

MIN SoC
(%)

MAX INPUT POWER (MW)
EFFICIENCY CHARGE (%)

DISCHARGE EFFICIENCY (%)
MAX OUTPUT POWER (MW)

Self Discharge
(%/H)

BUILD COST ($/MWh)
ECONOMIC LIFE (years)
TECHNICAL LIFE (cycles)
CALENDAR LIFE (years)
WACC (% p.a.)
FO&M CHARGE ($/kW/year))
ETC.

LONG-TERM APPLICATIONS

- Can carry out cost-benefit analysis of transmission and distribution network deferrals
- Can assess potential benefits from reduced transmission congestion
- Can model grid stabilization and transmission loss reduction

SHORT-TERM APPLICATIONS

- Can solve chronological unit commitment using a sub-hourly resolution
- Can optimize bidding strategies for energy time shifting
- Can identify and evaluate revenue stream opportunities in the energy and reserve market
- Can model renewable energy smoothing, peak-shaving and load-leveling

Vehicle to Grid

For cost-benefit analysis of smart charging, bi-directional & uncontrolled charging. As EV penetration grows, the load swing will be significant and therefore require more realistic modeling.

In countries like Australia EVs will be

50%

50% of all cars

This is likely to account for

10%

10% of the energy
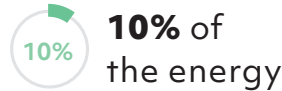
consumption but the swing in load (depending on the charging activity) could be very significant!

Investment Decision Analysis

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>
> – Mutlu Yildirim, ETRM, Turkey

Ancillary Services and Energy Co-Optimization

Utilities and system operators must be on high alert for unforeseen contingencies so as to address imbalances in electricity markets.

"Having complex models to be solved, **PLEXOS still computes the results in a fair period** of time. The graphical solution viewer enables us to quickly check our model's consistency."
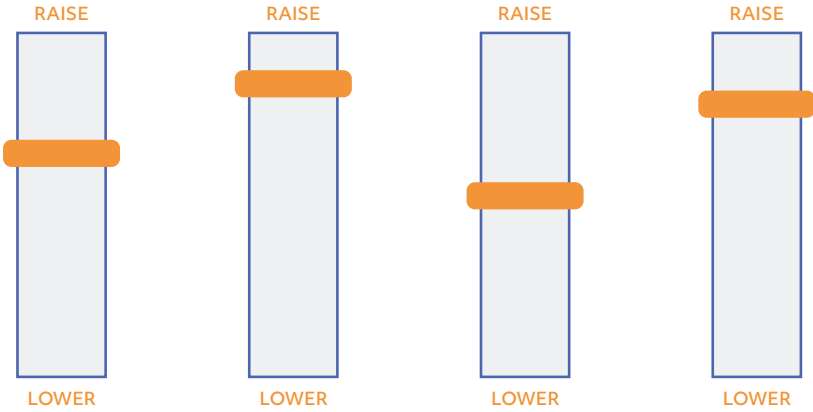
– Hendrik Heese, Borusan EnBW Enerji

PLEXOS Models Multiple Reserve Class
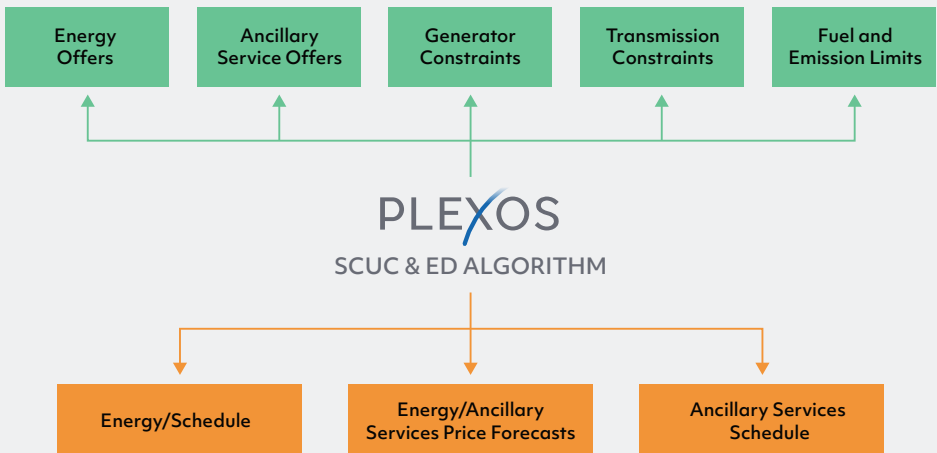
SPINNING	REGULATION	OPERATIONAL NON-SPINNING	REPLACEMENT NON-SPINNING
RAISE	RAISE	RAISE	RAISE
LOWER	LOWER	LOWER	LOWER

ERCOT is one of many entities who rely on PLEXOS to model reserve provisions co-optimized with generation dispatch and unit commitment to a sub-hourly level, with detailed treatment of start-up, shut-down, ramping and other constraint interaction minute by minute.

Entities across different countries commonly report back changes in a GT utilization vis-à-vis more efficient plant post detailed co-optimization of reserves and energy in PLEXOS.

Energy Offers	Ancillary Service Offers	Generator Constraints	Transmission Constraints	Fuel and Emission Limits

PLEXOS
SCUC & ED ALGORITHM

Energy/Schedule	Energy/Ancillary Services Price Forecasts	Ancillary Services Schedule

Demand Side Management

PLEXOS optimizes not only the supply, but also demand side management. At a high level, demand response is typically represented as one of the following:

FLEXIBLE DEMAND
- Non-conforming load that can be consumed at any point over a given period
- Examples include hydrogen and electric vehicles

PEAK SHAVING
- Interruptable load
- Usually for emergency conditions or alternative to turning on high cost generators
- Typically governed by commercial terms of a demand response program.

PEAK SHIFTING
- Movement of non-essential processes to a low cost period of the day
- Typically consumers receive a payment or incentive for participating in such a program

PLEXOS can optimize a portfolio of demand response contracts either independently against the market, or as a part of a wider portfolio.

POWER STATION

ON-PEAK

OFF-PEAK

10 AM   9 PM   10 AM
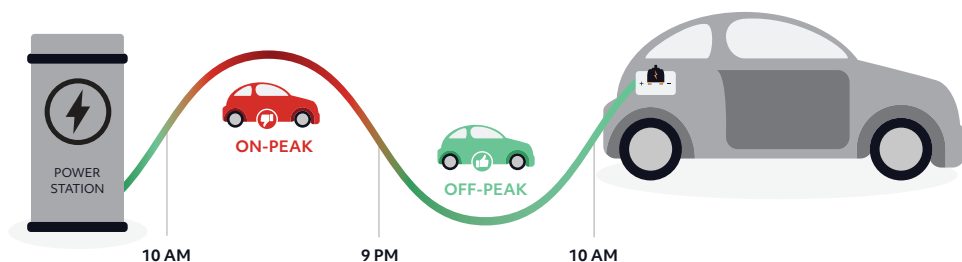
Typically, small consumers are aggregated into Virtual Power Plants before being passed to PLEXOS for optimization.

NREL SEAMS Project

Joining Eastern, Western and ERCOT Interconnections
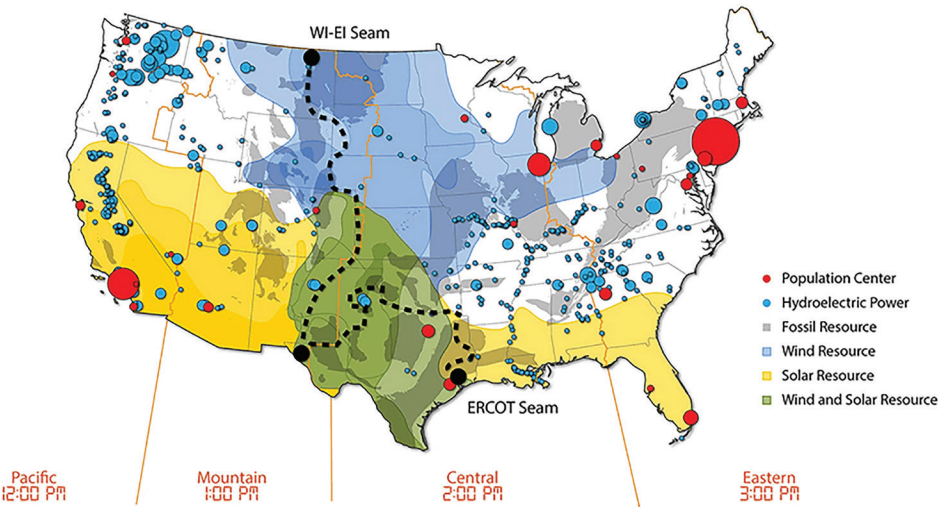
More Information Here

USD $1+ Billion

economic value delivered
by joining interconnections

Proper Modeling

and geographic diversity
increasesability to
integrate more renewables

90,000 Nodes

10,000 generators and
all main lines in
details with PLEXOS

Data

✓ **Integrated Datasets**
  • Zonal (Regional Transfers)   • Nodal (Extensive Transmission Net Work)

✓ **Dedicated Data Team**

✓ **Extensively Tested, Calibrated & Documented**

✓ **Easy To Overlap With Proprietary Updates**