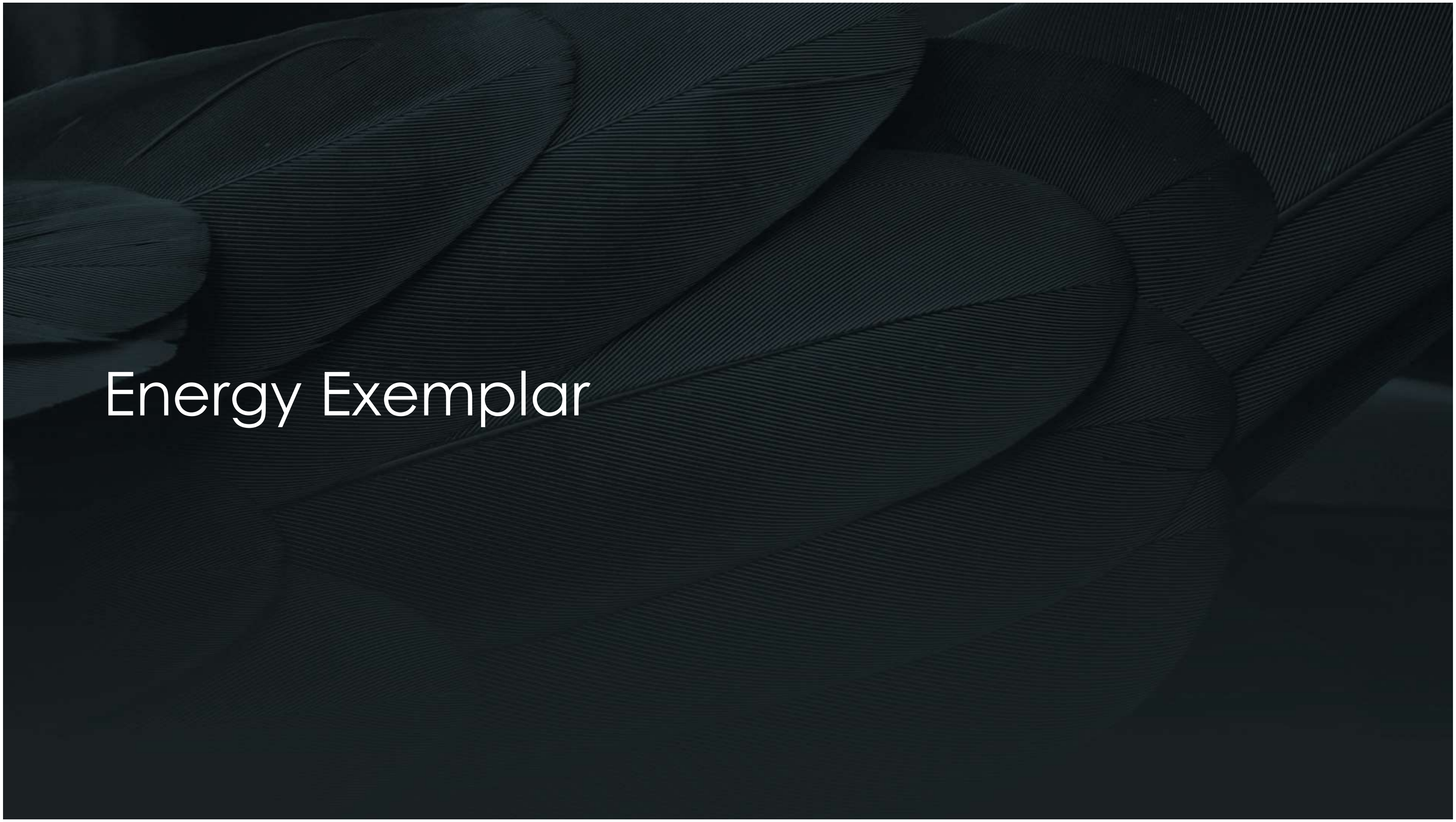
PLEXOS

BY ENERGY EXEMPLAR

Energy System Optimization Modelling through PLEXOS for SAARC member states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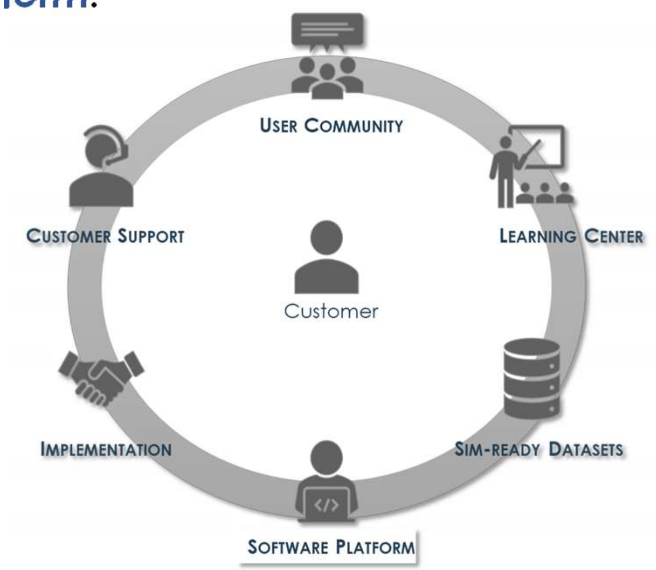
Why Energy Exemplar?

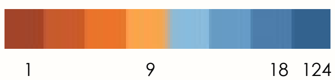
1. Market Leader since 1999. **350+ clients in 62+ countries**
2. No consulting. We're **focused on our platform**.
3. **24x6 support worldwide**
4. Strong **investment in development**
5. **Social gateway** to a global community
    1. Network at User Group Meetings
    2. Adopt Best Practices
    3. Enjoy the knowledge transfer



Energy Exemplar footprint

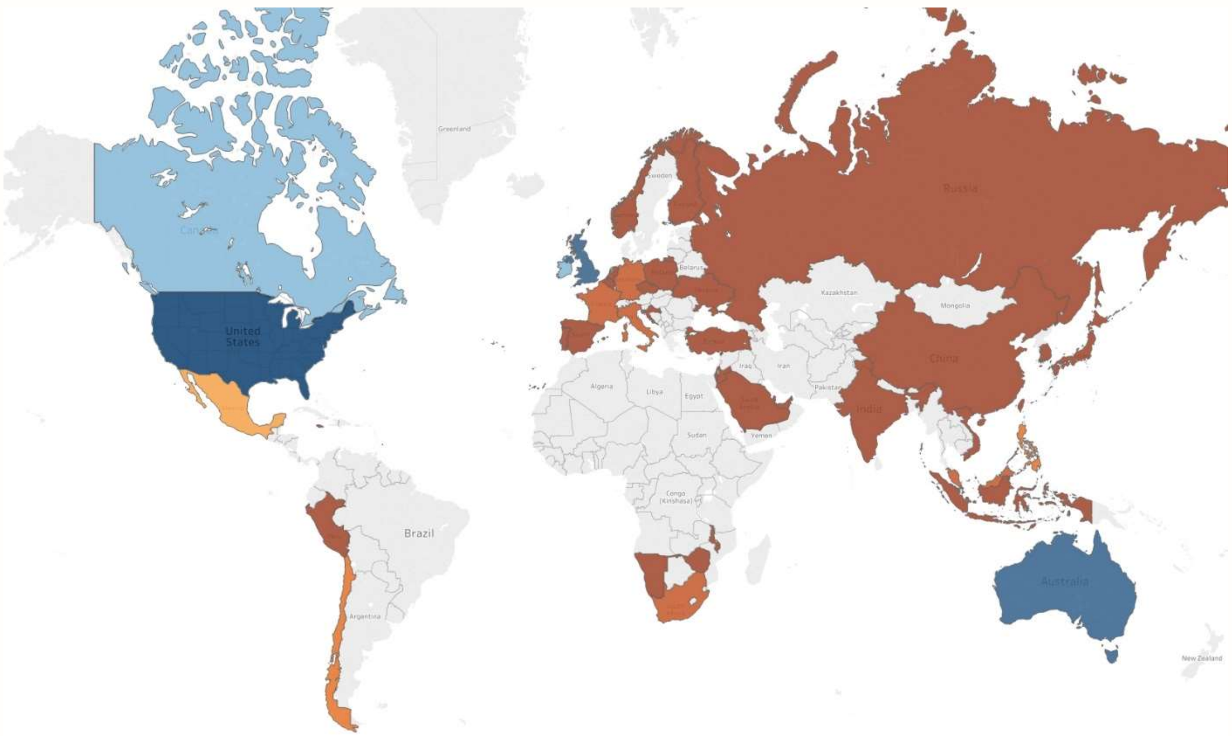
***1,700** users at over **350** companies in **62** countries*

Clients by Region:



Clients by Segment:

Utilities:	97
Consultants:	44
Power Producers:	39
Researchers:	28
Regulators:	21
TSOs:	14
ISOs:	13
Traders:	5
Energy Analysts:	4
International Institutes:	3



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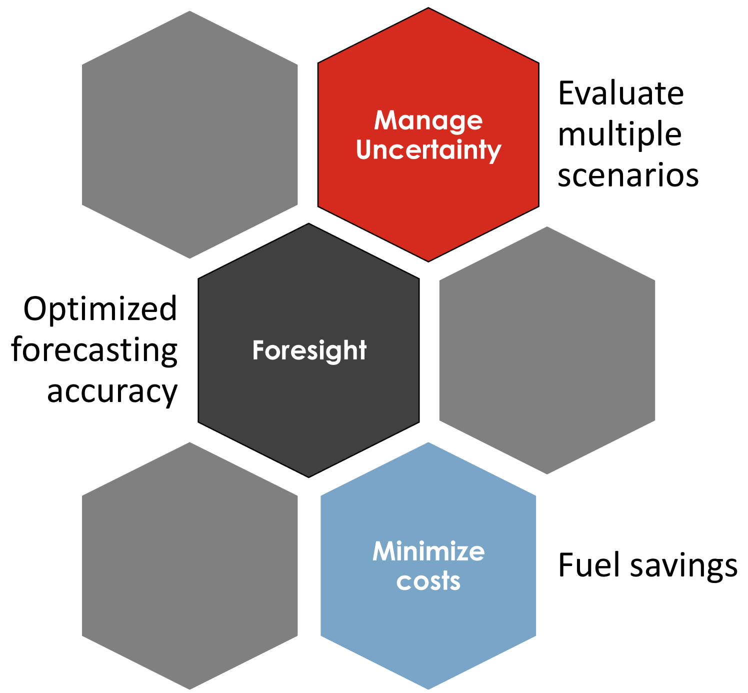
Asia Pacific Customers

Why optimization?



Is your existing approach optimal enough?

PLEXOS Integrated Platform

Why PLEXOS?

- **Best In Class**
  - Power
  - Gas
  - Water
- **Cutting-edge**
  - Mathematical Optimization
  - Deterministic & Stochastic Techniques
  - Robust
- **Multi-task**
  - Long
Medium
Short-term
  - Integrated Tools
- **Transparent**
  - Not a black box
  - Customizable

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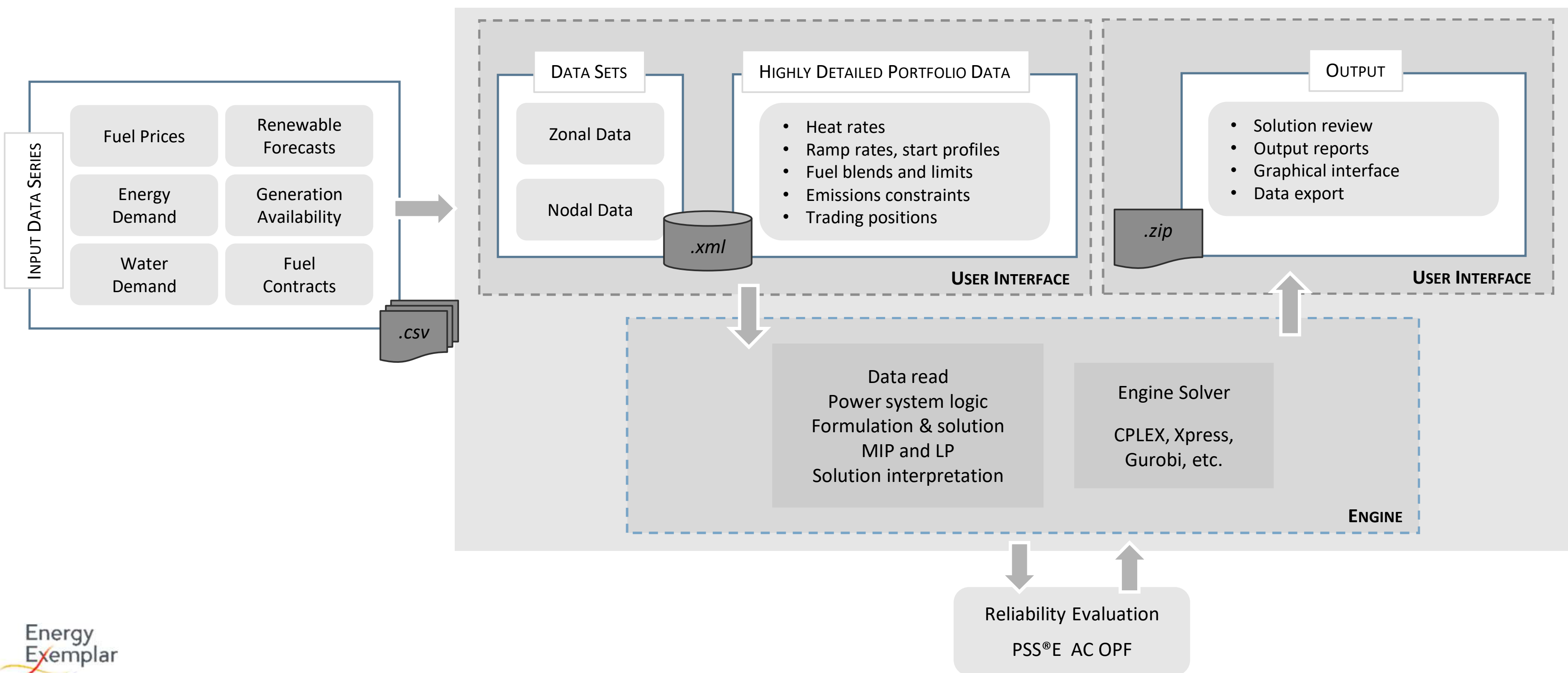
How PLEXOS works?



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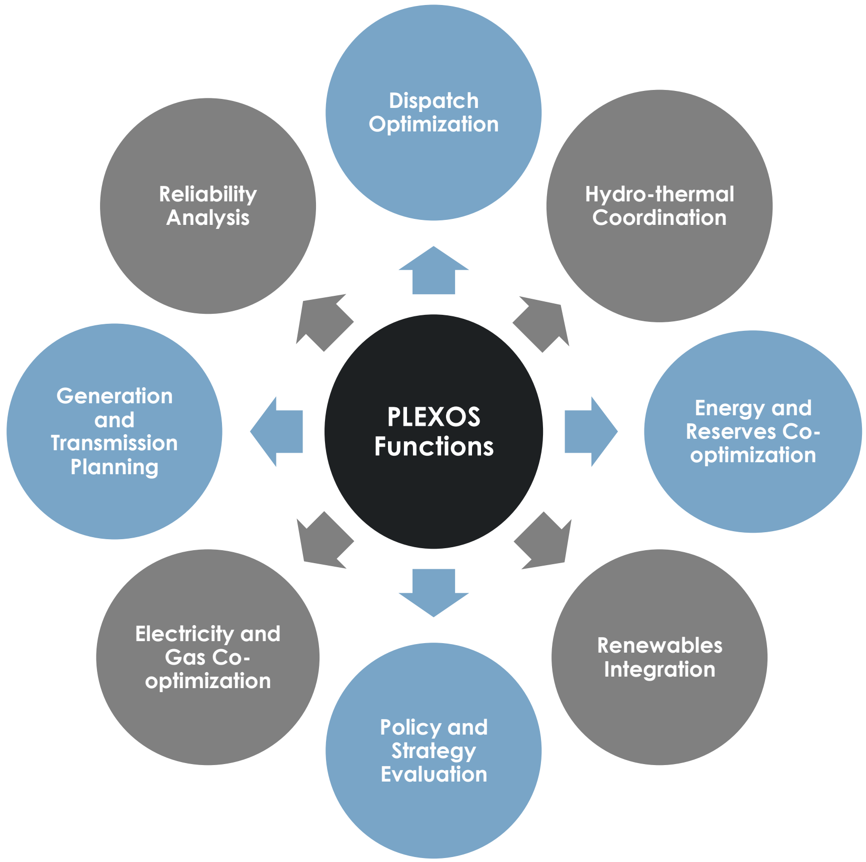
PLEXOS Main Applications



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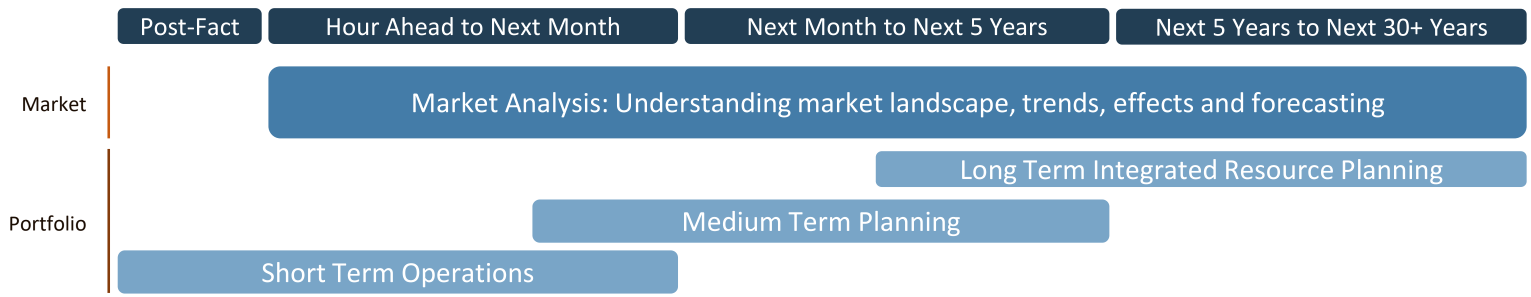
PLEXOS® Integrated Energy Model



Why single engine?

- Collaboration among institutions
- Co-optimize across use cases
- Performant for the most complex problems
- Role based UI

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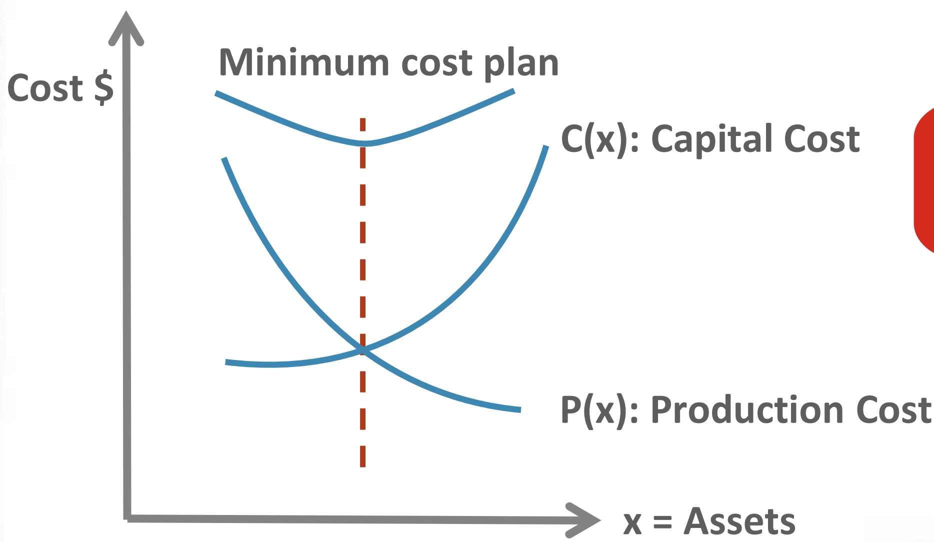
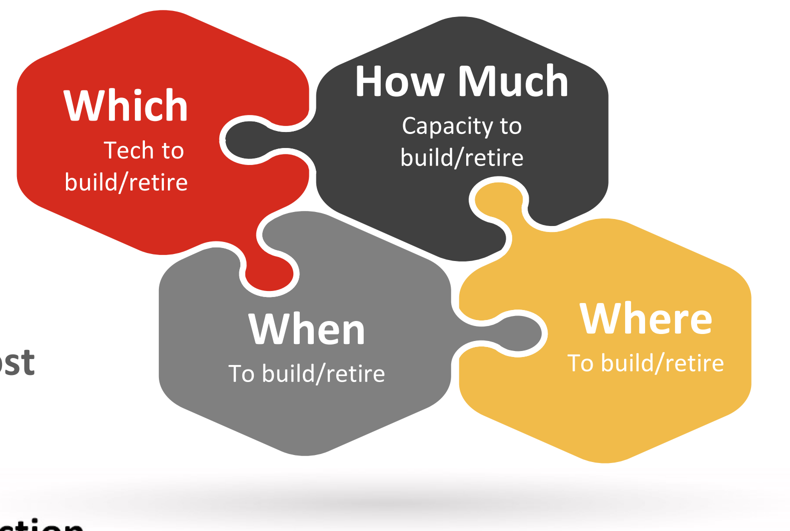
PLEXOS® Long-Term Planning





MIP Objective: Minimize NPV of capital & production

C(x) + P(x) = Total Cost

Indicative Generation Capacity Expansion Plan (IGCEP 2047)

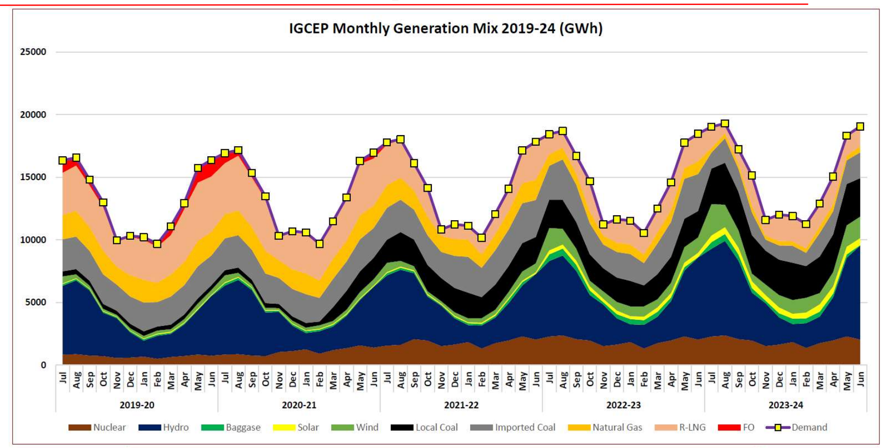
Objectives:

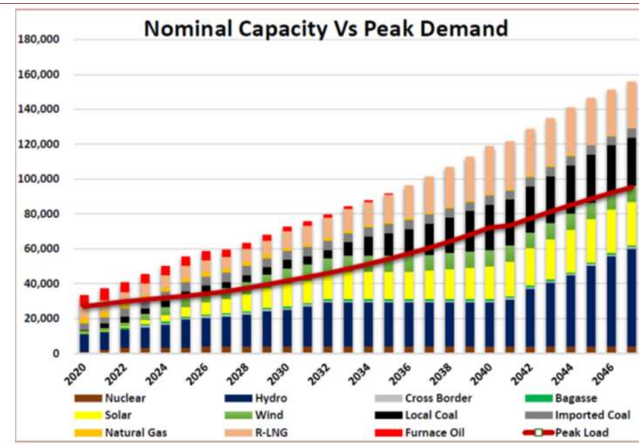
Identify new generation requirements by capacity, fuel technology and commissioning dates on year-by-year basis;

Satisfy the Loss of Load Probability (LOLP) not more than 1% year to year;

Cater for the long-term load growth forecast and reserve requirements; and

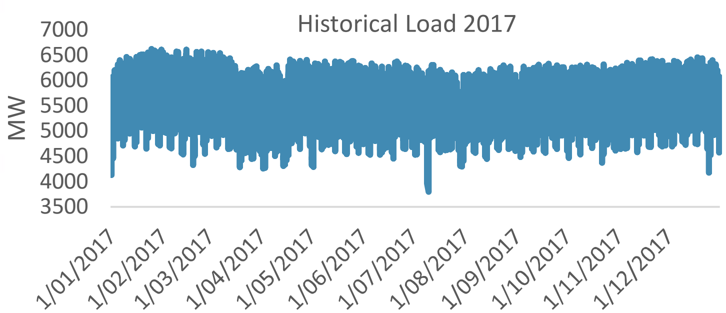
Provide a least cost optimal generation expansion plan for development of hydroelectric, thermal, nuclear and renewable energy resources to meet the expected load demand up to the year 2047



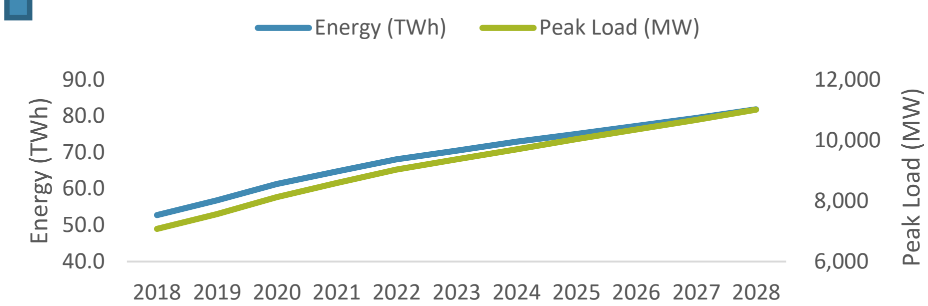


Load Forecasting

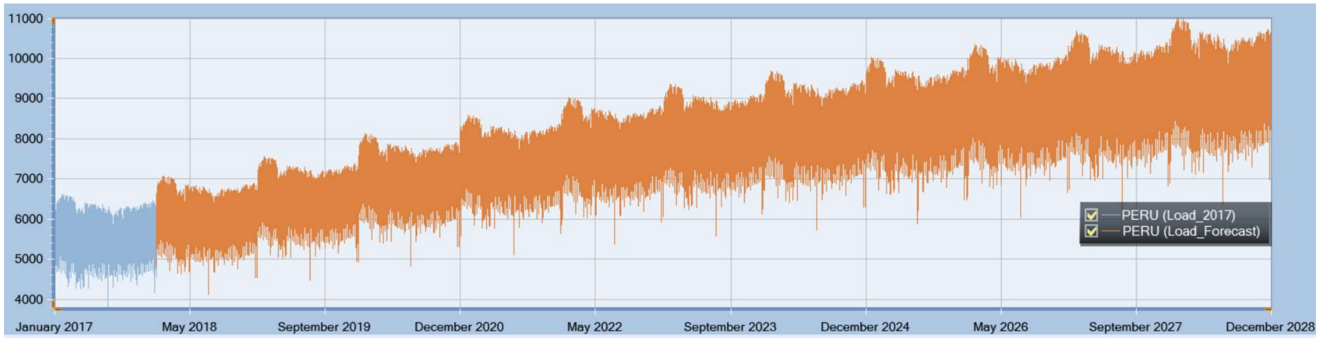
Base Load Profile



Peak and Energy Forecast



Forecasted Load Profile



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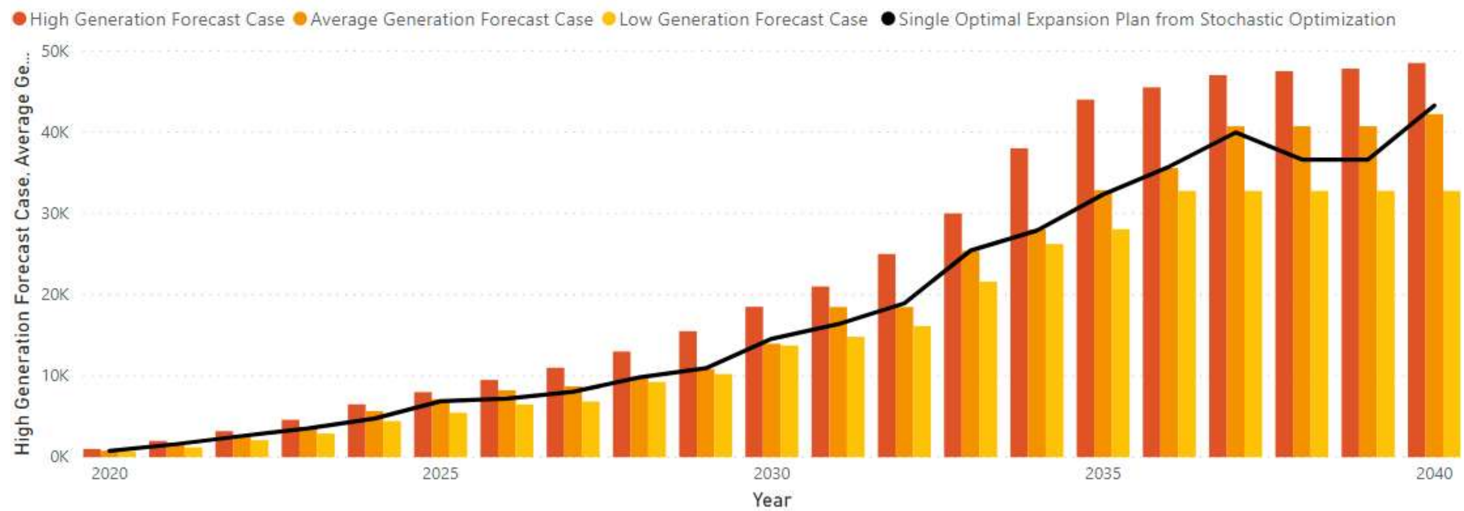
Renewable Energy Integration

PLEXOS® Stochastic Optimization considers **multiple renewable profiles** to deliver **a single optimal build decision**.



Uncertainty doesn't disappear
…it's just accounted for properly

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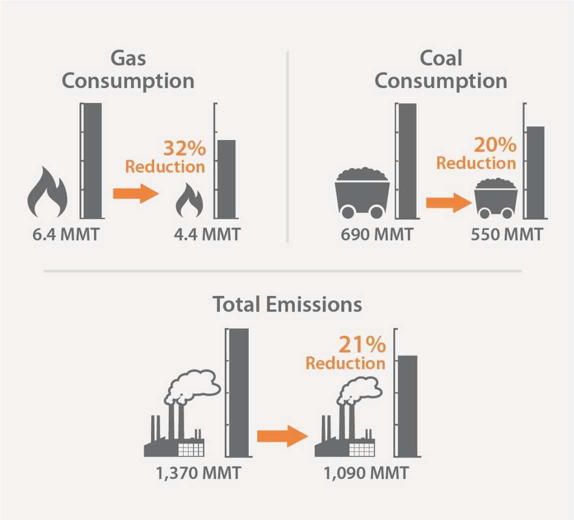
GREENING THE GRID: Pathways to Integrate 175 Gigawatts of Renewable Energy into India's Electric Grid

SCENARIO NAME	SOLAR (GW)	WIND (GW)	DESCRIPTION	PURPOSE
No New RE	5	23	Wind and solar capacities installed as of 2016	Establish a baseline to measure impact of adding new RE to the system
20S-50W	20	50	Total installed capacity as targeted in Green Energy Corridors & National Solar Mission	Evaluate changes to power system planning and operations to meet near-term targets
100S-60W	100	60	Current Government of India target for 2022	Evaluate changes to planning and operations to meet the official target of 175 GW RE
60S-100W	60	100	Solar and wind targets reversed in comparison to official target	Understand differential impacts of wind versus solar on need for system flexibility
150S-100W	150	100	Ambitious RE growth	Evaluate how needs for system flexibility would change under a higher wind and solar build-out

A 175-GW RE target by 2022 that places greater emphasis on wind over solar (60 GW wind, 100 GW solar), achieves higher RE capacity factors

Higher RE penetration levels brings benefits of reduced fuel consumption and lower CO^2 emissions.



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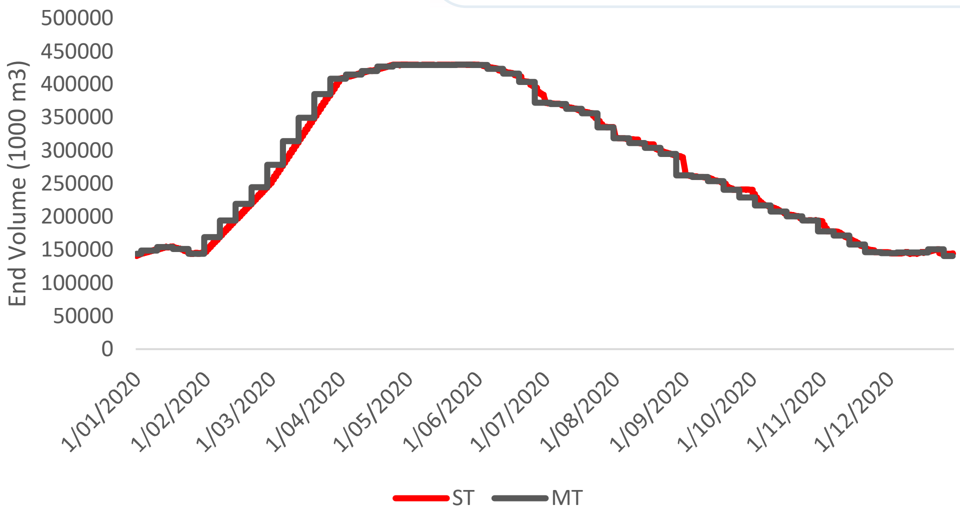
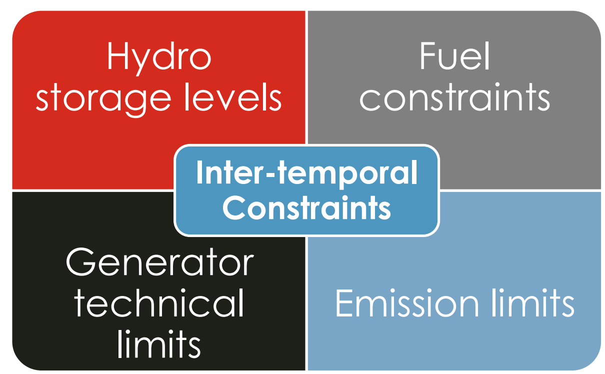
PLEXOS® Medium Term Planning

LT Plan → **MT Schedule** → ST Schedule

Decompose inter-temporal constraints that would otherwise be too long for ST Schedule





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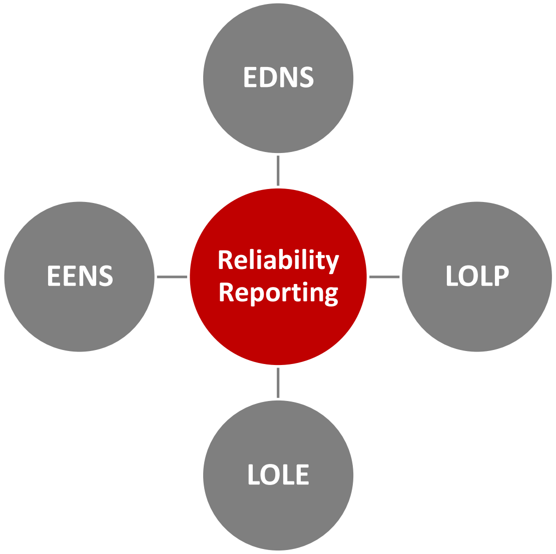
System Security and Maintenance Planning

Projected Assessment of System Adequacy (PASA) is a simulation phase that focuses on the balance of supply and demand in the medium term. The functions of the PASA simulation phase are:

- To schedule maintenance events of any asset (transmission lines, generators, gas pipelines).
- Allocate outages events
- Compute reliability statistics such as:



Hydro Optimization

Multiple phase simulation (Long – Medium – Short)	Ensures optimal use of storage down to chronological level
Cascading networks	Major and minor storages and junctions Natural inflows and spillways and canals
Constraints	Minimum releases for environment Operational constraints and hydro generation efficiency
Monte Carlo or Stochastic Optimisation	Multistage stochastic optimisation for better modelling of storage release policies under uncertainty

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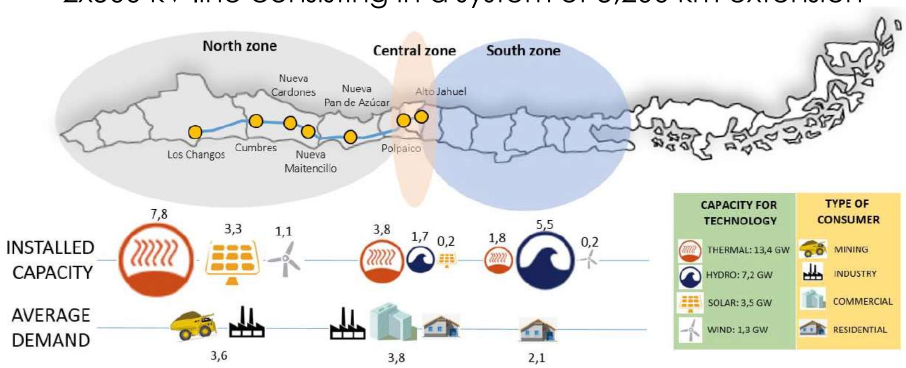
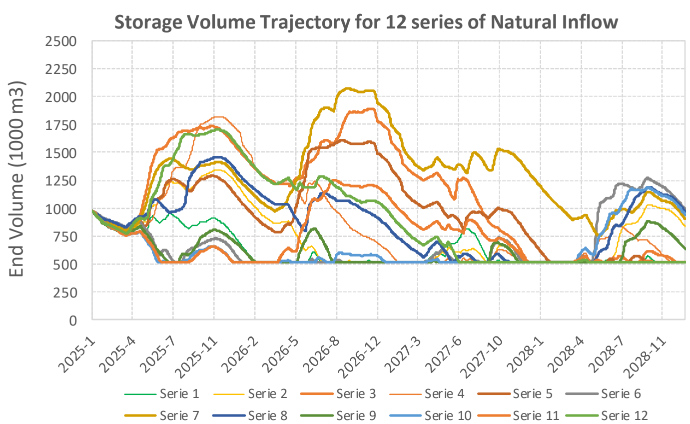
Hydro Operation and Planning

2 interconnected systems connected through a 1,700 MVA 2x500 kV line consisting in a system of 3,200 km extension





Challenges:

1) **Transmission**: High congestions in the transmission lines due to large supply of solar energy in the north to serve high demand in the central zone

2) **Cycling:** Increase in startups between 16 and 21 hours (Solar gen decrease) and shutdowns between 6 and 12 hours (Solar gen increase).

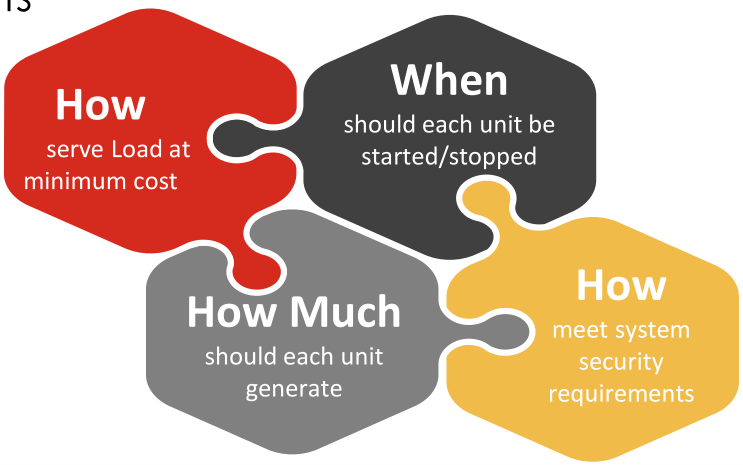
3) **Ramping**: High ramping requirements with solar generation increase/decrease.

4) **Hydro constraints:** Highly complex irrigation constraints.

PLEXOS® Short Term Formulation

Minimize: Operational Costs + Start–up/Shutdown Costs
(Maximization of societal benefits)

Subject to:
Energy balance
Technical limits
System security requirements



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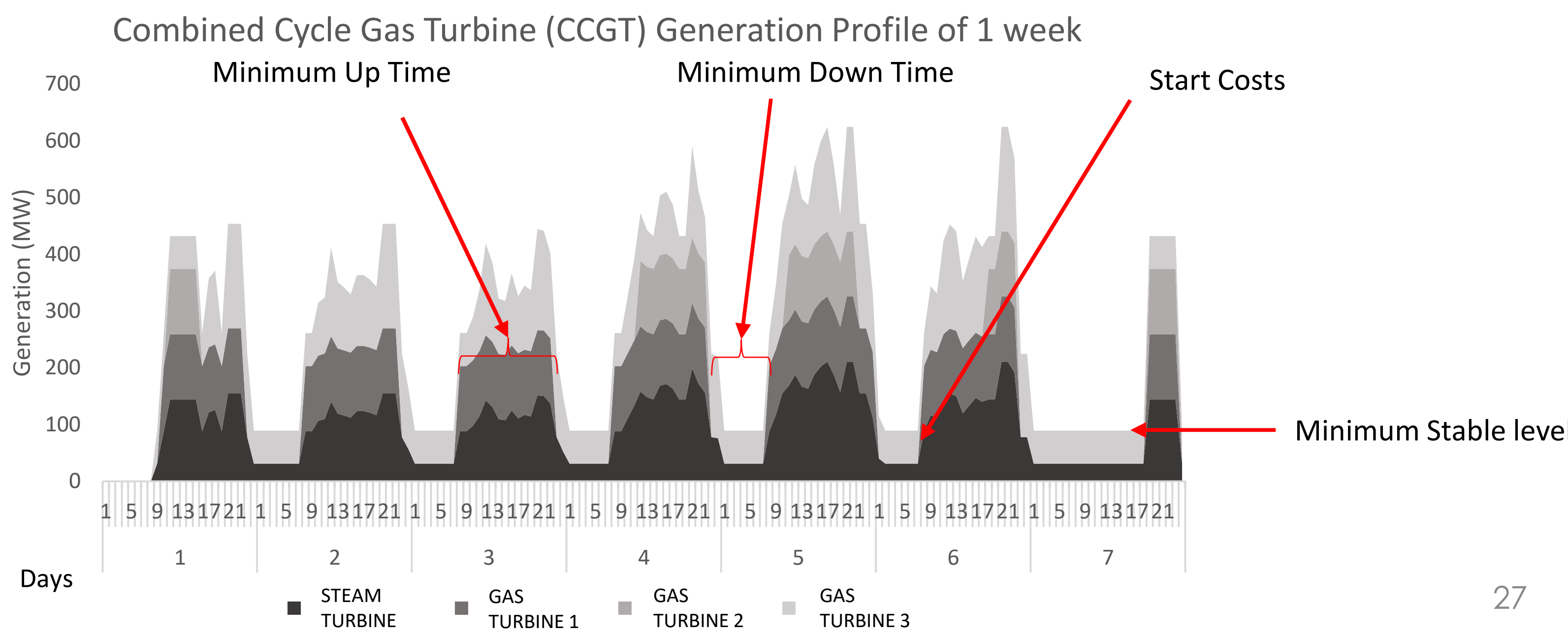
Dispatch Optimization

Mixed Integer Programing

Over 300+ Unit Commitment properties

Constraints modelling

Resolution down to 1-second



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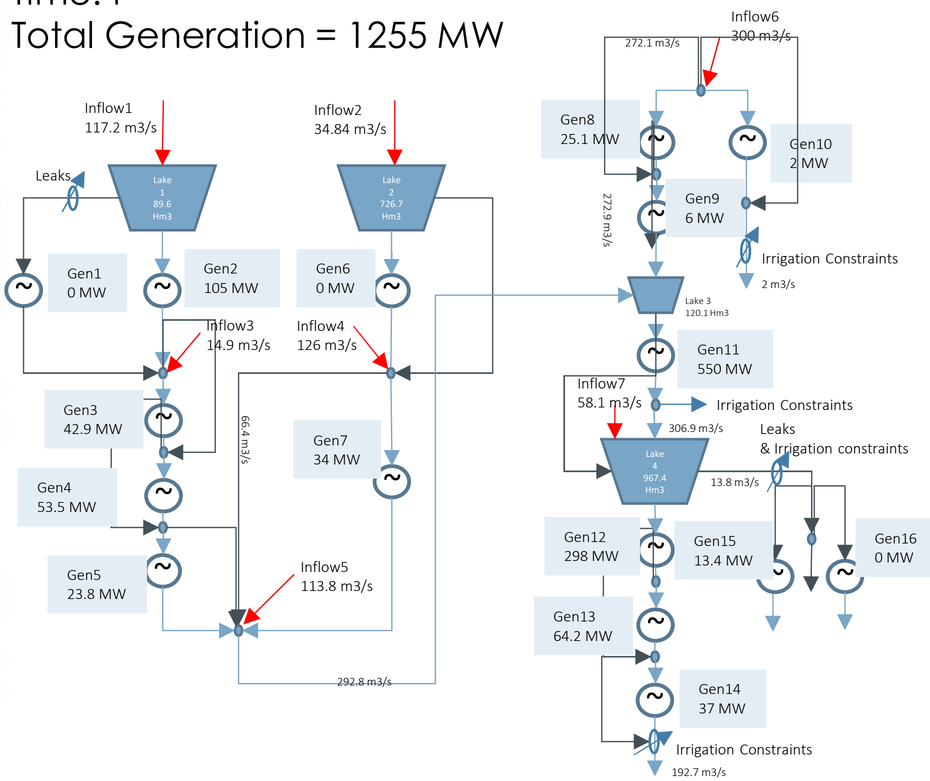
Reduce Fuel Costs

1. PLEXOS unit commitment algorithms work to minimize costs subject to constraints
2. CLP has many fuel constraints
   1. Coal port and different mix ratios for coal plant in Hong Kong
   2. Nuclear imports from China
   3. Gas supply contracts with max daily quantity, take or pay etc.
3. CLP has different technologies like steam turbines, CCGTs and GTs
   1. Over 300 UC properties in PLEXOS emulate life like dispatch
4. CLP has an emissions constraint for Hong Kong
   1. The PLEXOS constraint class allows almost any constraint to be applied
   2. The PLEXOS conditional class is like setting up “if” statements in excel
   3. The PLEXOS variable class allows relationships to be assigned
5. These features together with Mixed Integer Programming emulate the real world.
6. Very significant savings are achieved

Cascading System Optimization

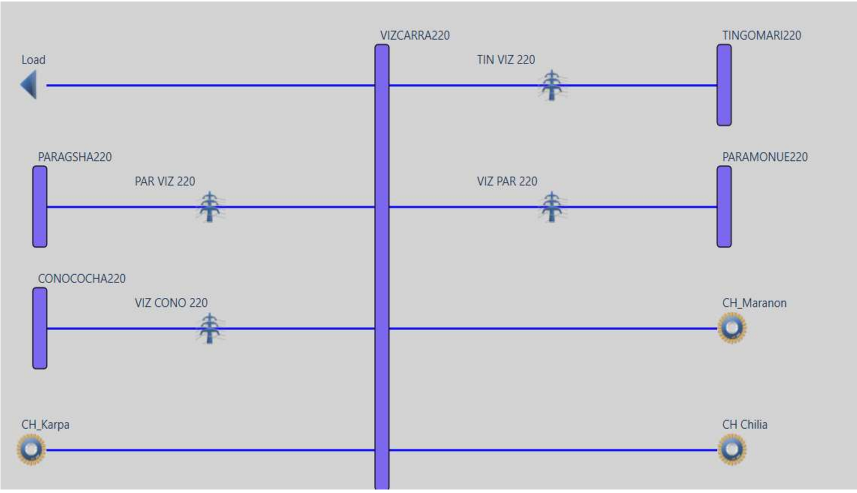
Time: t
Total Generation = 1255 MW



- Generators flow water from their Head Storage to their Tail Storage or ‘to the sea’.
- A Waterway flows water from one Storage to another
- As the water runs downstream in a cascade system, there is also a loss of potential energy during the trajectory which can be handle with PLEXOS

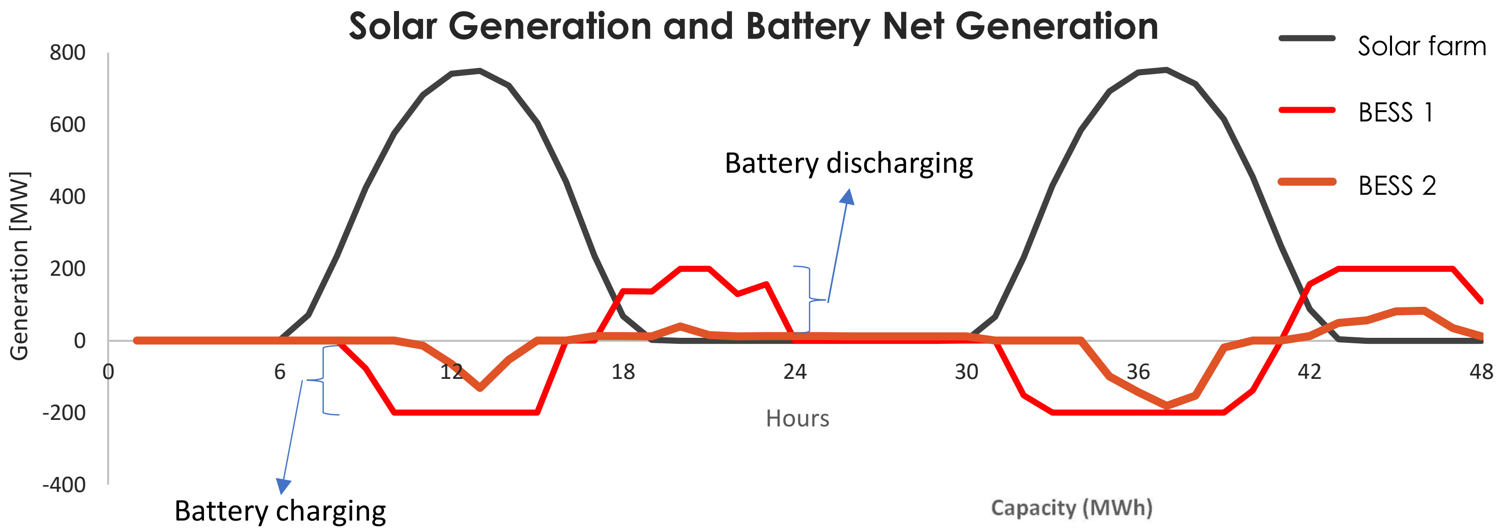
Transmission Modelling

- Transmission operation
- Transmission Expansion Planning
- Security Constrained Economic Dispatch (SCED)
- 'N-x' Contingency Analysis
- Congestion Costs
- Transmission aggregation and Network reduction
- PSSE Power Flow Raw Data file Importer



Single Line Diagram (SLD) allow users to review nodal connection

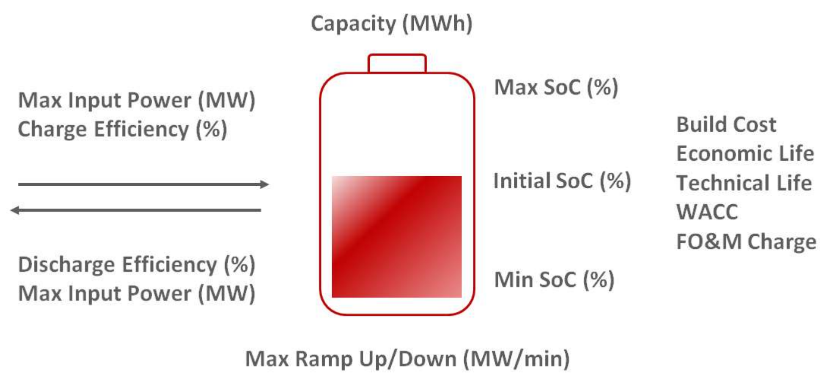
Battery Energy Storage System



Built in best in class battery models

BESS technical and economic representation

Represent all types of energy storage technologies



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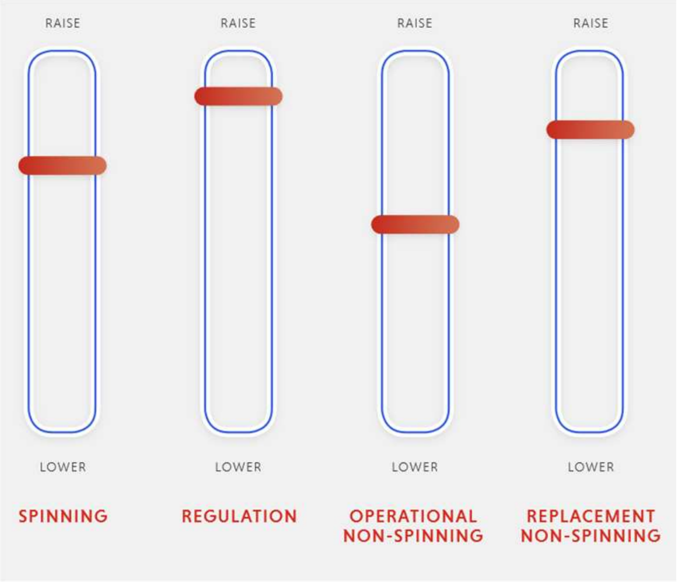
Ancillary Services Modelling

Model any class of ancillary service

Static and/or Dynamic requirement for the service

Define generators to provide reserve

- What price and hence cost was imposed by reserve?
- Which generators and / or interruptible load provide reserves?
- How reserve costs were allocated to generators?



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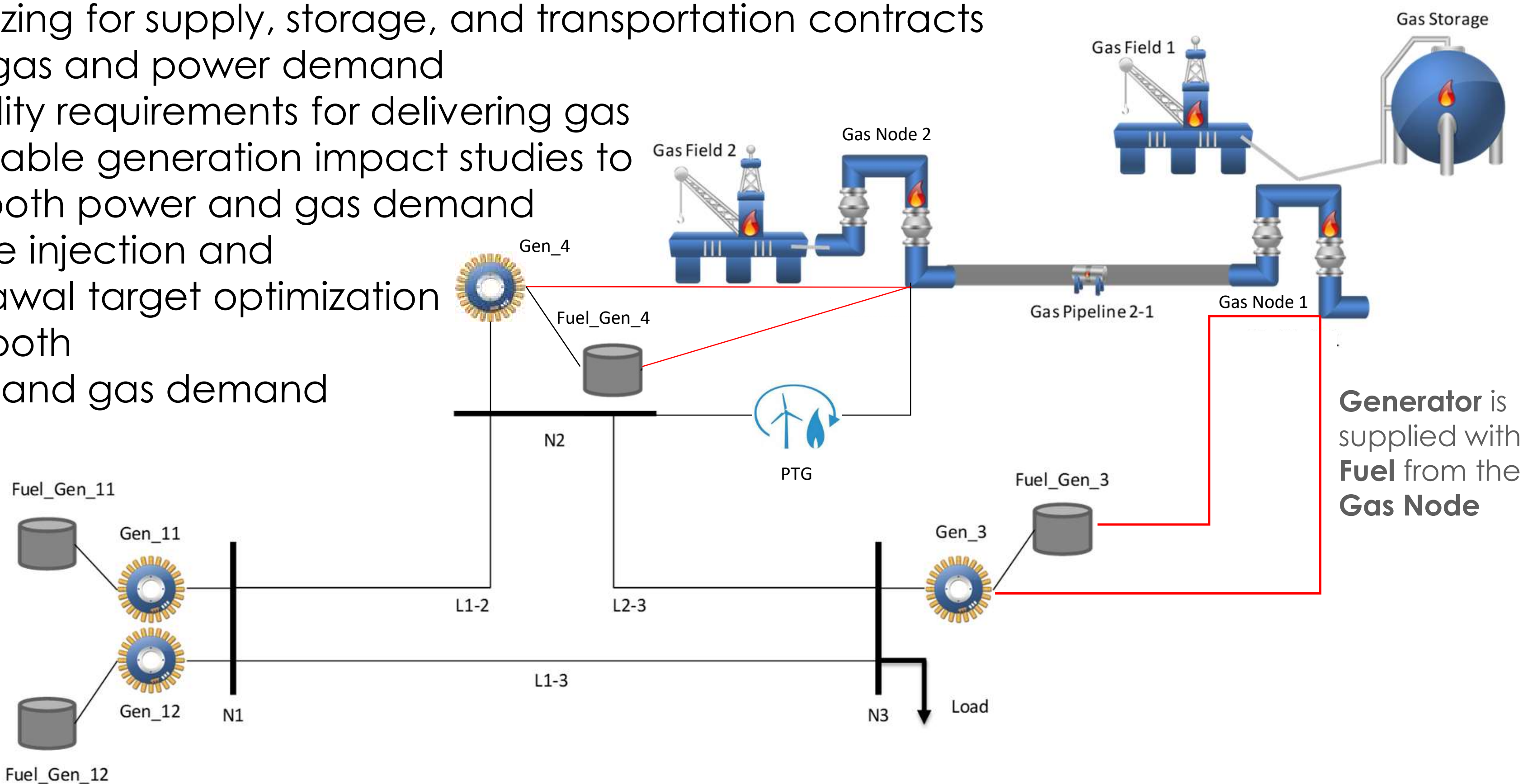
Electricity and Gas Co-optimization

- Right-sizing for supply, storage, and transportation contracts given gas and power demand
- Reliability requirements for delivering gas
- Renewable generation impact studies to serve both power and gas demand
- Storage injection and withdrawal target optimization given both power and gas demand



Generator is supplied with **Fuel** from the **Gas Node**

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Integrated Strategic Optimization

- High & low renewable penetration scenarios impact on gas demand
- Impacts of nuclear & coal retirements to the gas demand
- Increasing carbon price impact on merit order between gas and coal
- Modelling the injection of Biomethane or Hydrogen into the gas system
- Power (excess wind power)to Gas Production (Hydrogen) Scenarios
- Scenario Analysis- Electricity & Gas

Concluding Remarks

- Better knowledge
- Accurate foresight
- A confident direction
- Optimal operation

Thank you for your kind attention

Do not hesitate to contact us if you have any question or want to know more about our solutions.

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