The **GridPath** Electricity Modeling Platform

Advanced Software for Power-System Planning

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November 23, 2020

Blue Marble Team

Dr. Ana Mileva is the founder of Blue Marble Analytics and the primary architect of the GridPath platform. Previously a consultant at E3, Ana was the lead developer of the RESOLVE model, now used widely for resource planning. She has wide-ranging experience consulting for utilities, government agencies, NGOs, and developers.

Dr. Ranjit Deshmukh is an Assistant Professor in the Environmental Studies department at UCSB and a faculty scientist at LBNL. Ranjit's research interests lie at the intersection of energy, environment, and economics, specifically in low-carbon energy systems, electricity markets, and clean energy access.

Gerrit De Moor is an expert in integrated resource planning, renewable integration, and system reliability modeling. In his previous role at (E3), he was one of the main contributors to the development of E3's production simulation, capacity expansion planning, and resource adequacy tools.

Power System Modeling Approaches

Types of System Models

years

seconds

Capacity expansion model
Generation and transmission investments

Production cost model
And Resource adequacy model
System operational costs and impacts

Power/load flow model
Transmission planning and reliability

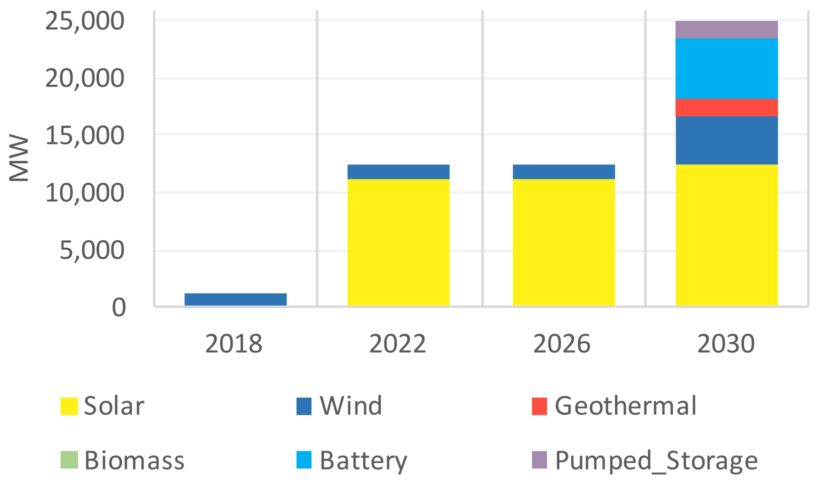
Transient stability model
Reliability and transient analysis

Capacity expansion model

Objective: Identify generation, storage, DR, and transmission investments and retirements

Method:

- Simultaneously minimize capacity and operations costs across several years
- Minimize system costs subject to technical, environmental, and policy constraints.



Limitations:

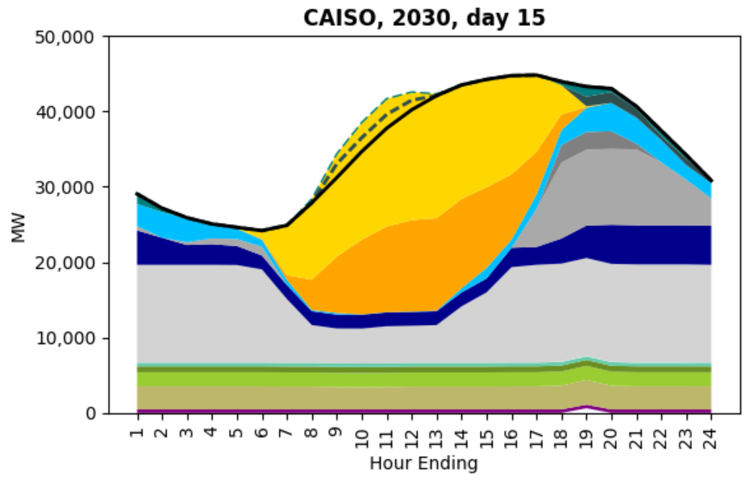
- To limit the size of the problem, inputs limited to only representative timepoints.
- Generators/storage may be simplified into fleets.
- Transmission flows represented by transport or DC power flow (not AC).

Production cost model

Objective: Estimate operating costs of the system and assess impacts of investments or strategies on system operation

Method:

- Unit commitment and economic dispatch model solved over 1 day or 1 year at 5, 15 min or hourly temporal resolution.
- Minimize operational costs subject to technical, environmental, and policy constraints.



Limitations:

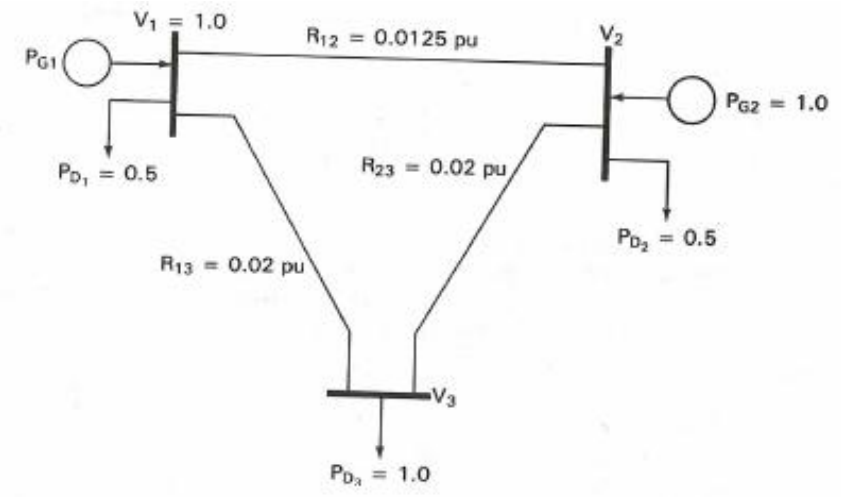
- Generators, storage, DR, and transmission are exogenously specified.
- Transmission flows represented by transport or DC power flow (not AC).

Power/load flow model

Objective: Estimate voltages, currents, and power flows in a power system

Method:

- Steady state analysis of AC or DC power flows
- Optimal power flow also minimizes costs



Limitations:

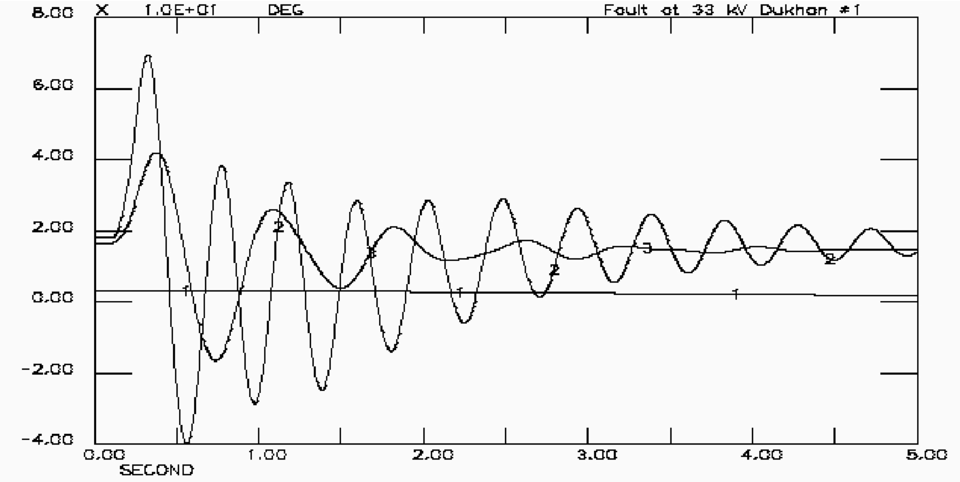
- Generators, storage, DR, and transmission are exogenously specified.
- Only a snapshot of the power system is analyzed. Need to identify times and generation/load conditions of interest.

Transient stability model

Objective: Estimate voltages, currents, and power flows in a power system

Method:

- Introduce contingency (loss of large generator or transmission line) and simulate power system response.



Limitations:

- Generators, storage, DR, and transmission are exogenously specified.

Which Power System Model to Choose?

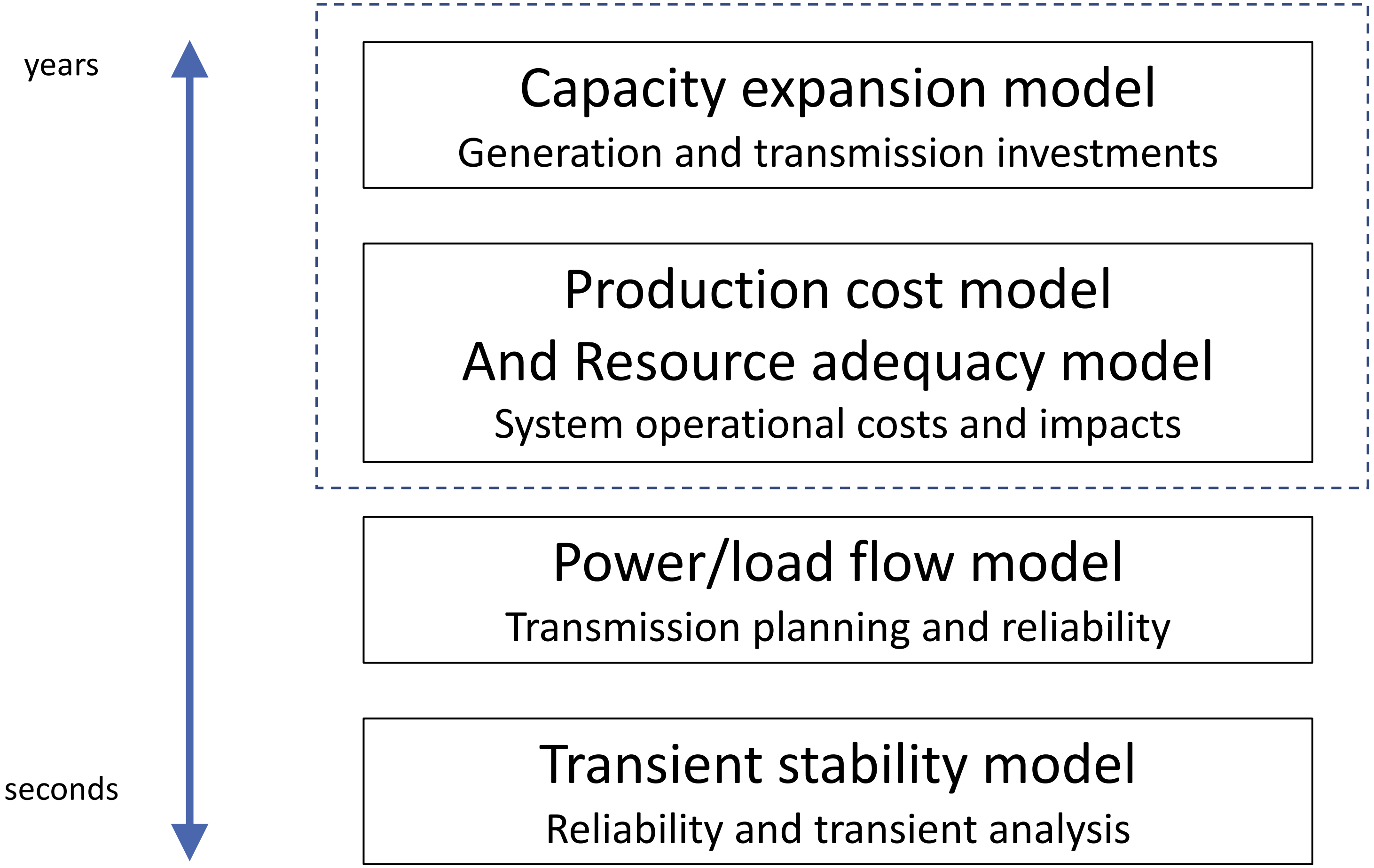
Select the model depending on the question.

- How much additional coal or gas generation do we need given a certain capacity of renewable energy and its variability?
- Which hours of the year is my system likely experience transmission and generation constraints?
- In those constrained hours, how will my system react to a contingency event?

Combination of models are essential to answer questions, especially in future low carbon grids.

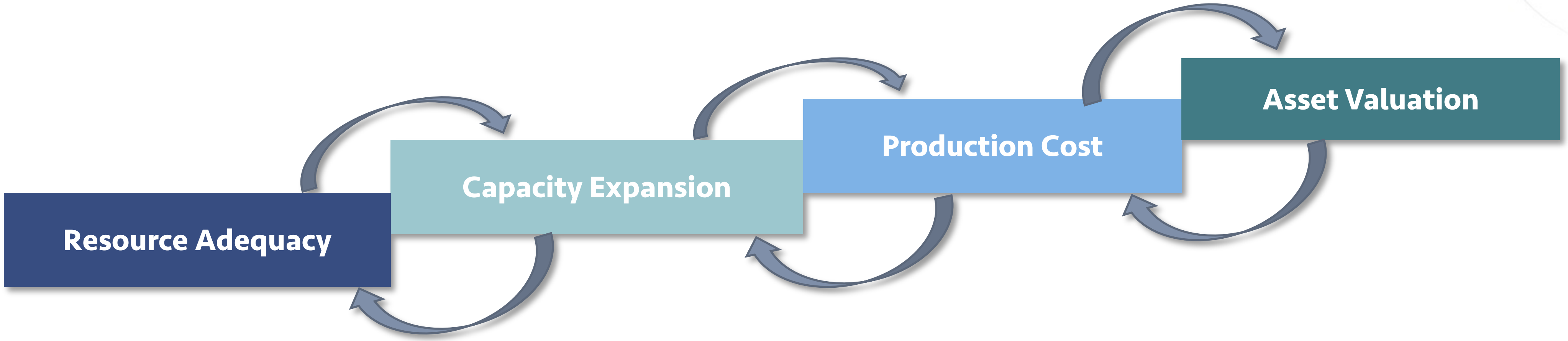
All models are wrong, but some are useful – George Box

GridPath Modeling Platform Scope



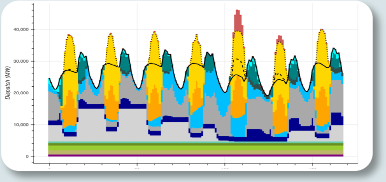
Intro to GridPath

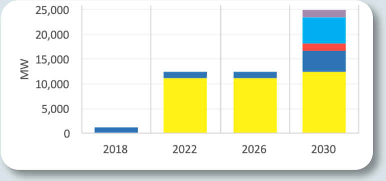
GridPath is an open-source modeling ecosystem that enables faster and more technically sophisticated planning for the clean energy transition.

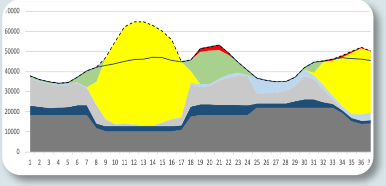


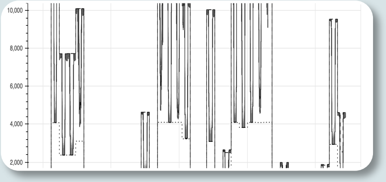
GridPath's modular architecture enables:		
A seamless interface between different modeling approaches Reduces the labor-intensive data-translation requirements across applications	**Varying levels of complexity** User has flexibility to include or exclude features easily User-defined granularity levels for modeling	**Extensibility and adaptability** Novel functionality can be added quickly and seamlessly to tackle new questions about an evolving, decarbonizing grid

GridPath Functionality









Production Cost

Detailed operations of a specified power system over a short period

Multi-stage unit commitment and dispatch at subhourly temporal resolution

High-fidelity operations (e.g. heat-rate curves, minimum up and down times, startup trajectories for generators; DC power flow for transmission)

Capacity Expansion

Investment in new infrastructure over a long period

Simplified modeling of system operations

Lower temporal resolution

Simplified and/or aggregated representation of generation and transmission

Resource Adequacy

Loss of load probability and capacity needs

Monte Carlo simulation of low-resolution system dispatch over many conditions

Simplified and/or aggregated representation of generation and transmission

Asset Valuation

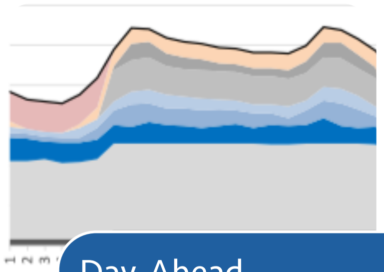
Market performance of set of assets

Detailed operations of an asset or a set of assets

Price-taker with exogenous energy and/or A/S price streams

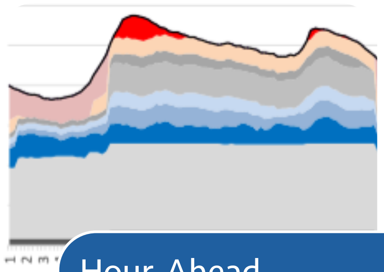
Production-Cost Simulation with GridPath

Multi-stage unit-commitment and dispatch with flexible temporal span and resolution



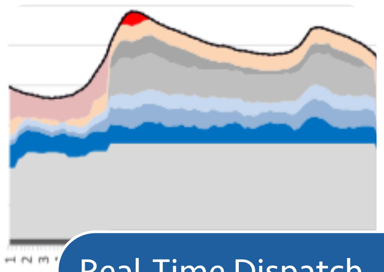
Day-Ahead Commitment

- Generator commitment schedules based on day-ahead load and renewable forecasts (e.g. hourly)
- Contingency, load-following, and regulation reserves



Hour-Ahead Commitment

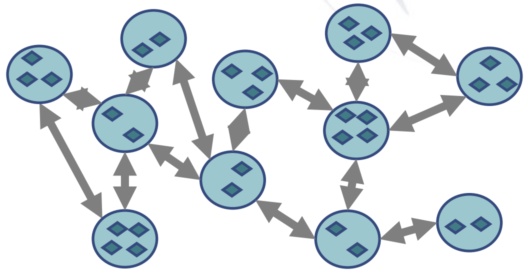
- Residual generator commitment schedules based on hour-ahead load and renewable forecasts (e.g. 15-minute)
- Contingency, load-following, and regulation reserves

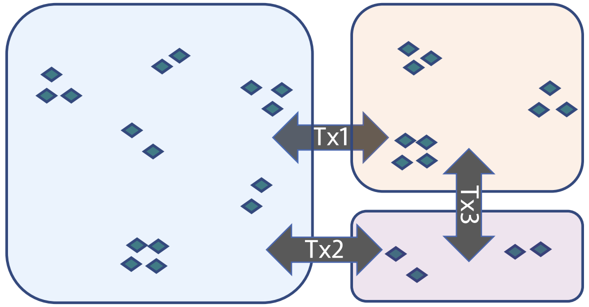


Real-Time Dispatch

- Actual load and renewable output (e.g. 5-minute)
- Contingency and regulation reserves
- Load-following reserves allowed to dispatch to compensate for net load forecast error

Zonal or nodal topographies possible





Generators modeled with a high level of operational fidelity

- Heat rate curves
- Minimum up and down times
- Ramp rates
- Start costs by cooling state
- Startup and shutdown trajectories

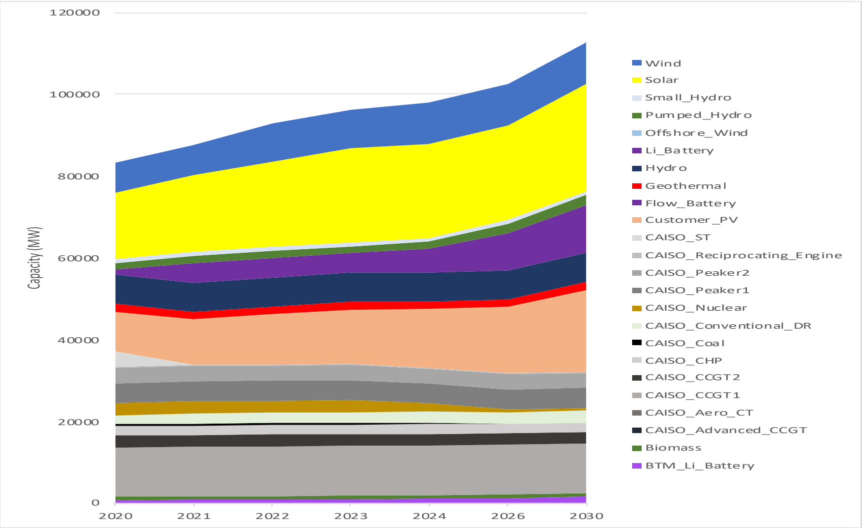
Transmission lines can be represented via

- Transport model
- DC power flow

Capacity Expansion with GridPath

Examine how the generation mix should evolve over the long-term

Decide whether to **build or retire generation, storage, transmission**

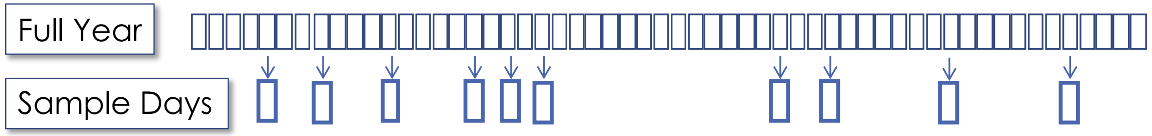


Consider the impact of:

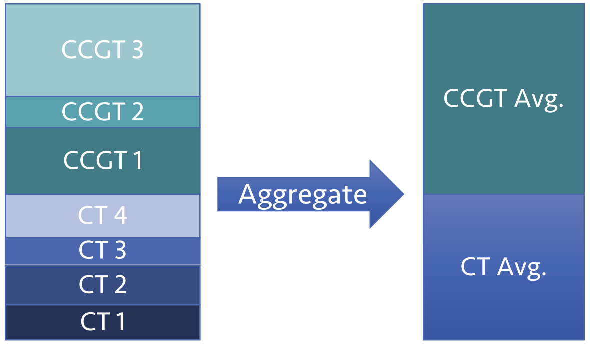
- ✓ Load growth and profile changes
- ✓ Power system policies
  - ✓ Renewables Portfolio Standard (RPS)
  - ✓ Carbon cap
- ✓ Reliability requirements

Computational feasibility generally requires that aspects of the system be modeled in a simplified manner

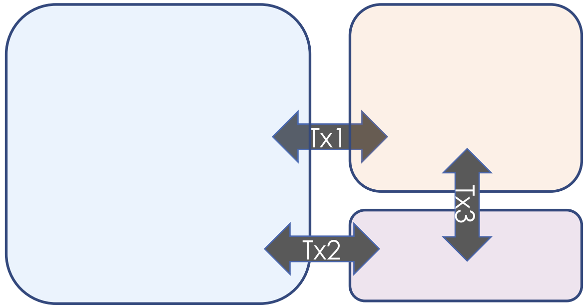
✓ Sample days instead full year of dispatch



✓ Aggregation of plants



✓ Simplified transmission representation



Capacity Expansion with GridPath

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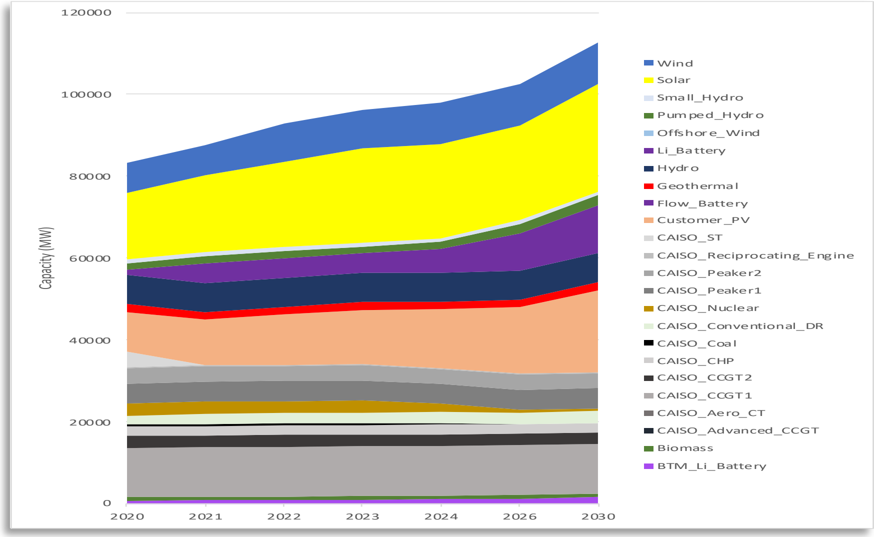

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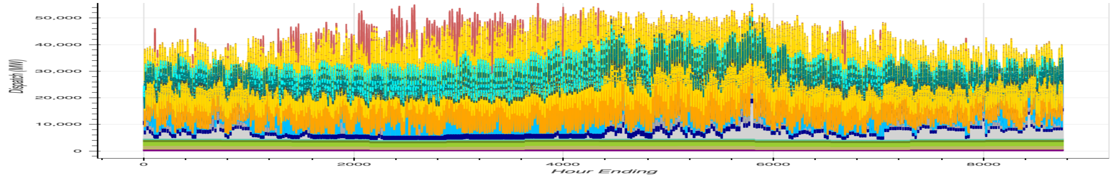
- ✓ Reliability requirements

Computational feasibility generally requires that aspects of the system be modeled in a simplified manner

- ✓ 8760 dispatch



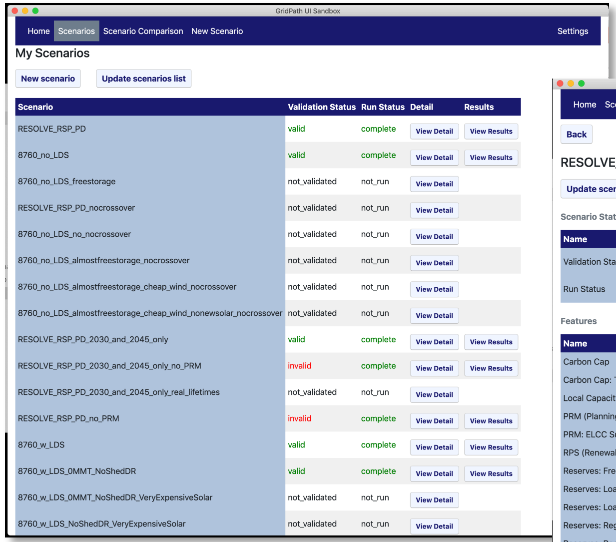
- ✓ Plant-level detail

Unlike other capacity-expansion models, GridPath does not decide what to simplify ahead of time

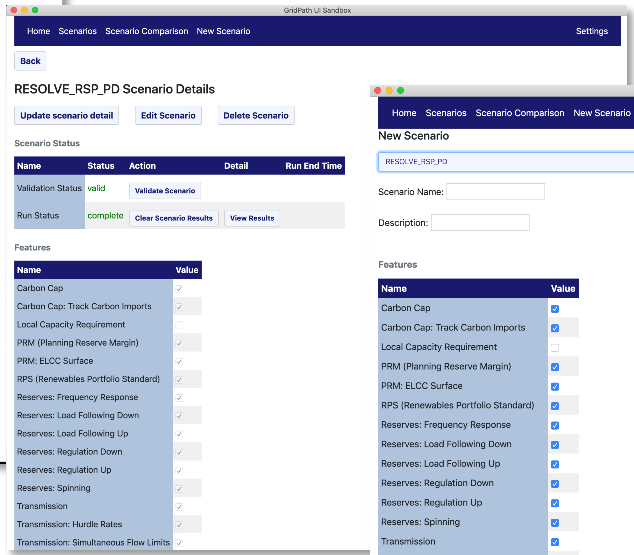
User can add detail usually reserved for production cost simulation in capacity expansion model (while potentially removing detail elsewhere to keep problem feasible)

User Interface

GridPath's user interface can enable a wider range of users to interact with the platform

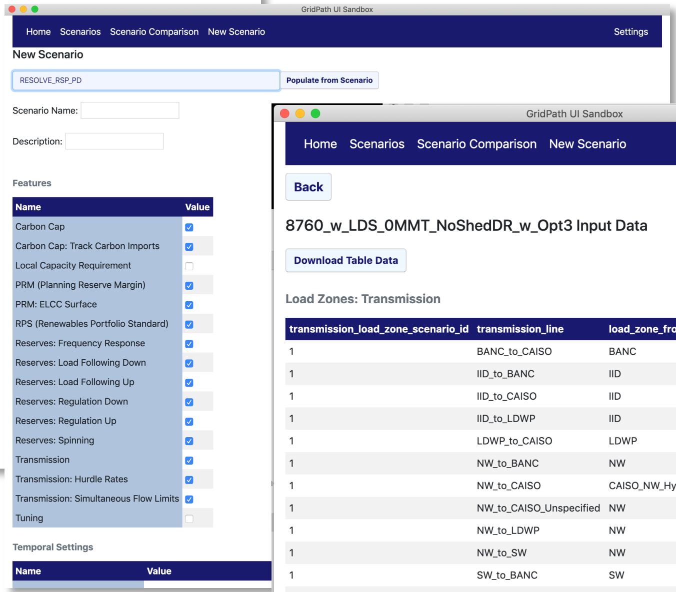


The main screen shows the list of scenarios with their validation and run status



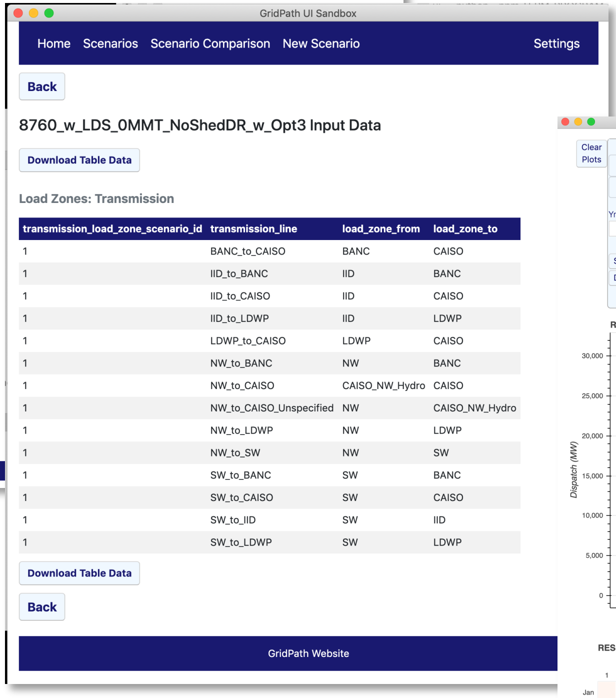
User can view detail for each scenario including status, input data, and results

User can also run, validate, edit, and delete the scenario

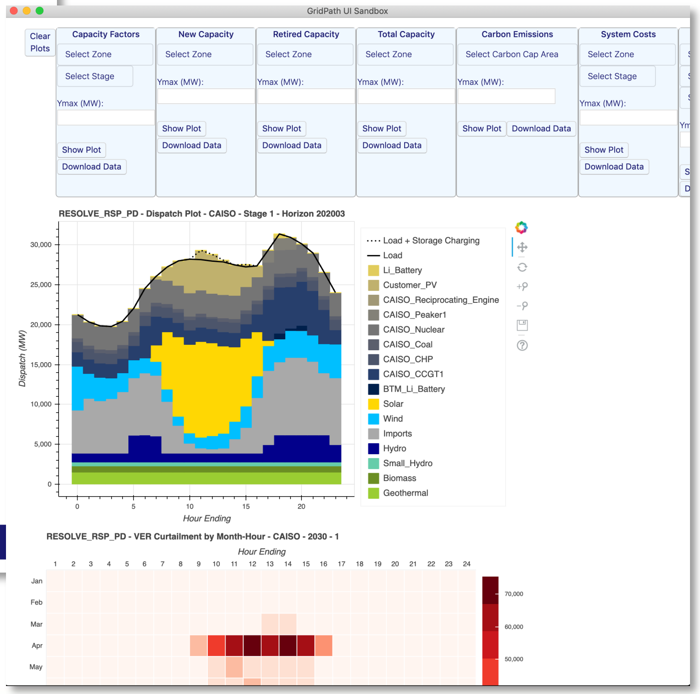


New scenarios can be created and run from within the user interface

All input and results data can be viewed and downloaded from the UI



The UI also includes a range of interactive results visualizations



Main UI Features

- Access scenario/runs table
- Give information about each scenario
- Create new scenarios
- Run scenario
- View scenario results
- Compare scenario results

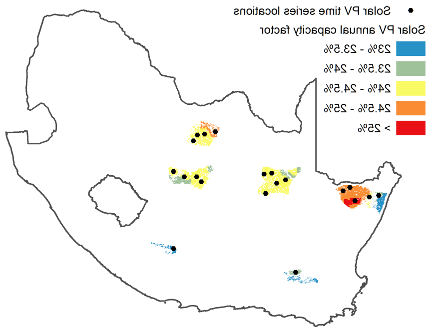
GridPath Studies

GridPath Studies: Least cost scenarios for South Africa

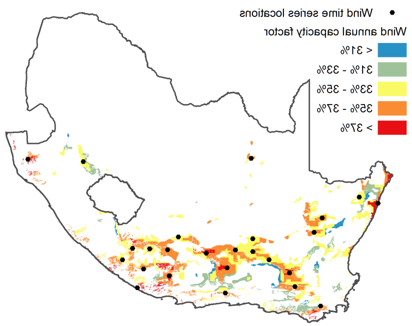
Zonal Setup

- Model South Africa's electricity system as a single node (no transmission)
- Spatial diversity in wind and solar resources

SOLAR PV



WIND

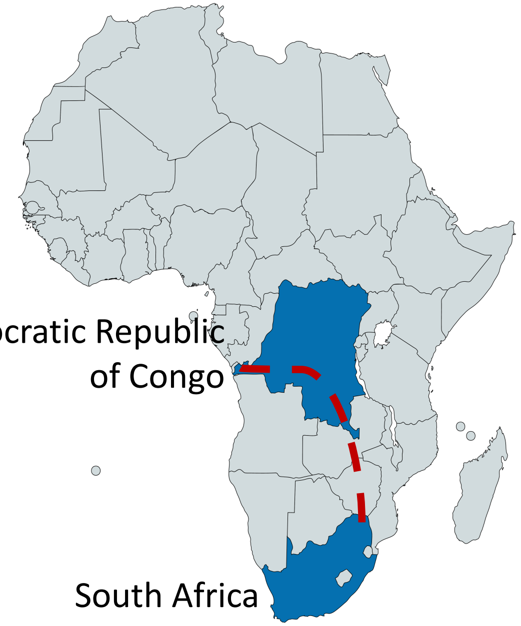


Temporal Setup

- 4 investment periods each representing several years between 2020 and 2035
  - Select dozens of wind and solar sites, conventional coal, combined cycle and combustion gas turbines, battery storage
- 12 sample days of 24 hours each per investment period, weighted appropriately to represent a year

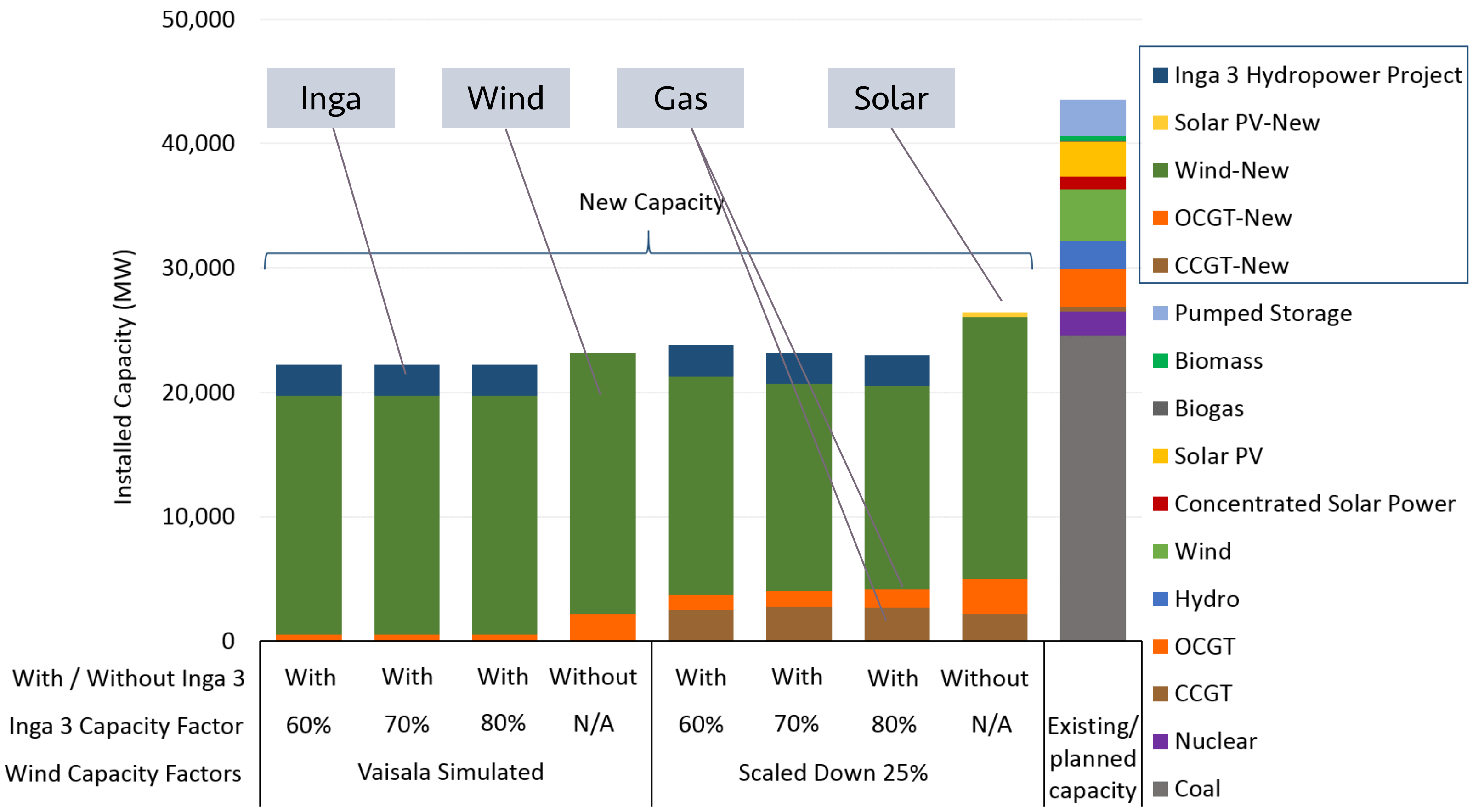
Policy

- Build the system either WITH or WITHOUT the 4.8 GW Inga 3 dam
- Least cost investments without any renewable targets or carbon caps.



GridPath Studies: Least cost scenarios for South Africa

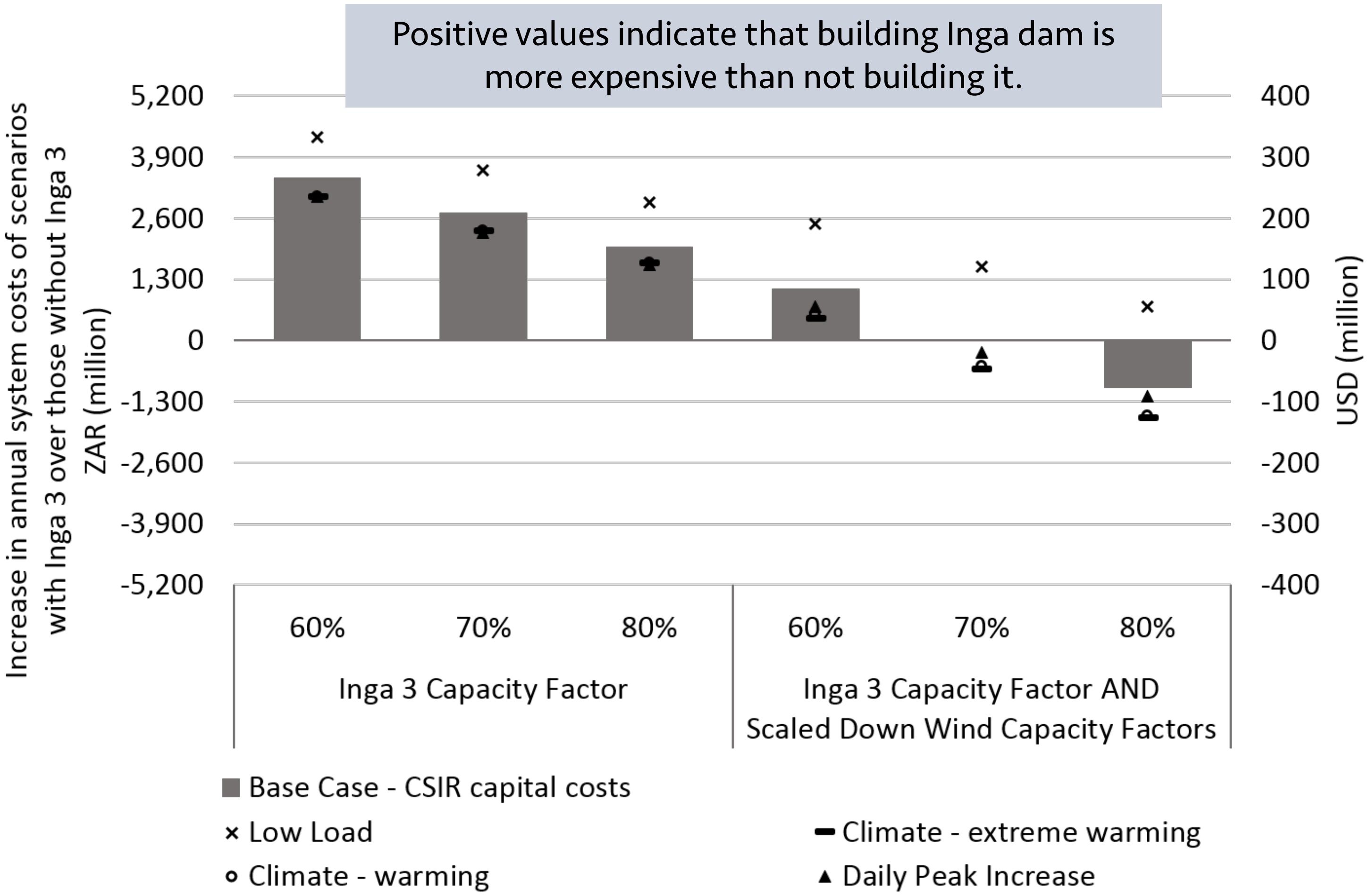
GridPath analysis main goal: identify **the least cost generation investments to meet future demand**



- South Africa's future load (in 2035) can be mostly met by investments in wind, natural gas, and solar.

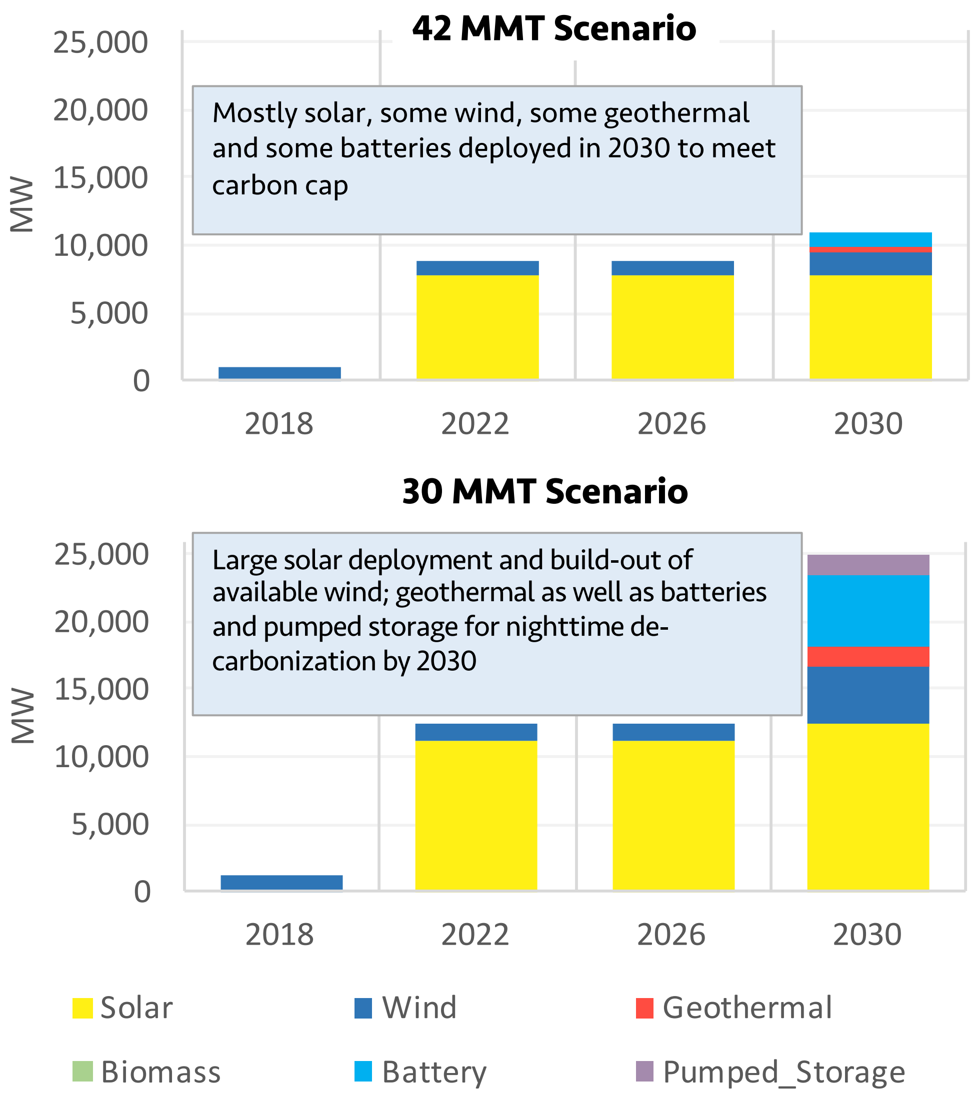
GridPath Studies: Least cost scenarios for South Africa

GridPath analysis main goal: understand **the benefits and costs of one major generation project**



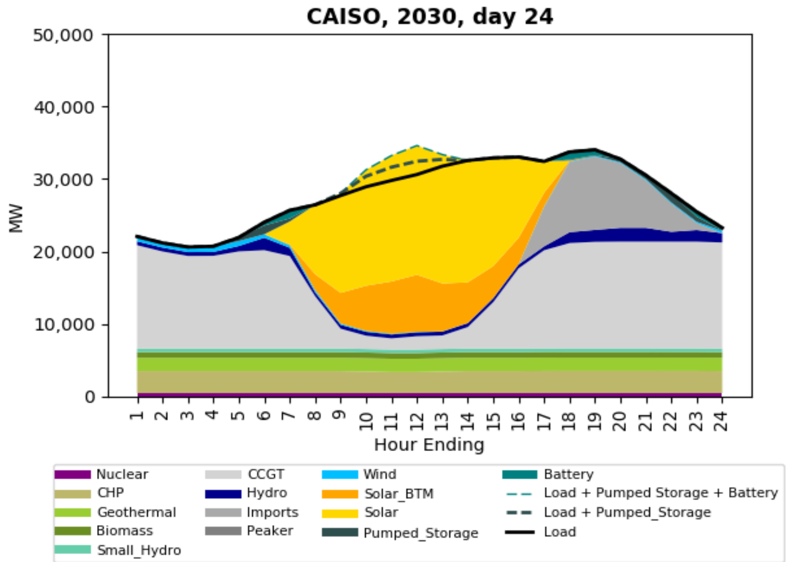
- In almost all scenarios, South Africa's system costs with Inga3 were higher than without Inga 3 dam.

GridPath Studies: California Resource Planning



The goal of California Integrated Resource Plan (IRP) proceeding is to develop an optimal portfolio of resources for use in long-term electricity planning, known as the Reference System Portfolio.

We have benchmarked GridPath to the 2017-2018 and 2019-2020 IRP results.



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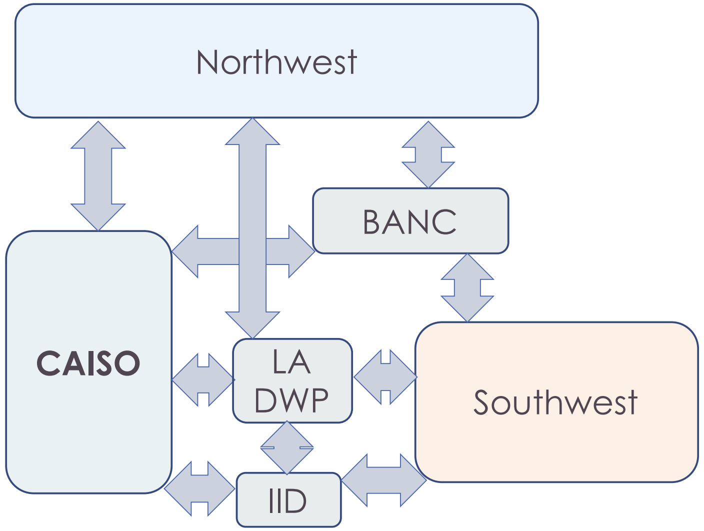
GridPath Studies: California Resource Planning

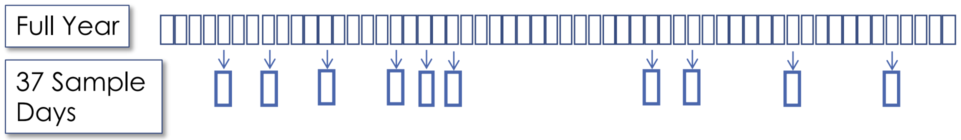
Zonal Setup

- Model CAISO and 5 more load zones (LADWP, BANC, IID in California; Northwest; Southwest)



Temporal Setup

- 4 to 7 investment periods each representing several years between present day and 2030 or 2045
  - Choose among dozens of wind and solar sites in and outside California, different types of storage and gas
- 37 sample days of 24 hours each per investment period, weighted appropriately to represent a year



Policy

- 50-60% renewable portfolio standard (RPS) in 2030 (generators in and outside CAISO can contribute)
- Carbon cap (in-CAISO generation + imports x intensity)

Reliability

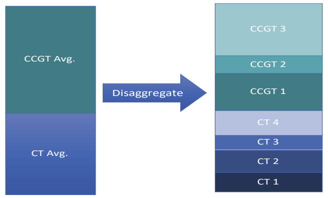
- Operating reserve requirements in CAISO (spinning reserves, regulation up and down, load following up and down, frequency response)
- 15% planning reserve margin (PRM) with endogenous wind and solar capacity credit

GridPath Studies: California Resource Planning

GridPath analysis main goal: understand **value streams** and **economic retirement of gas generators**

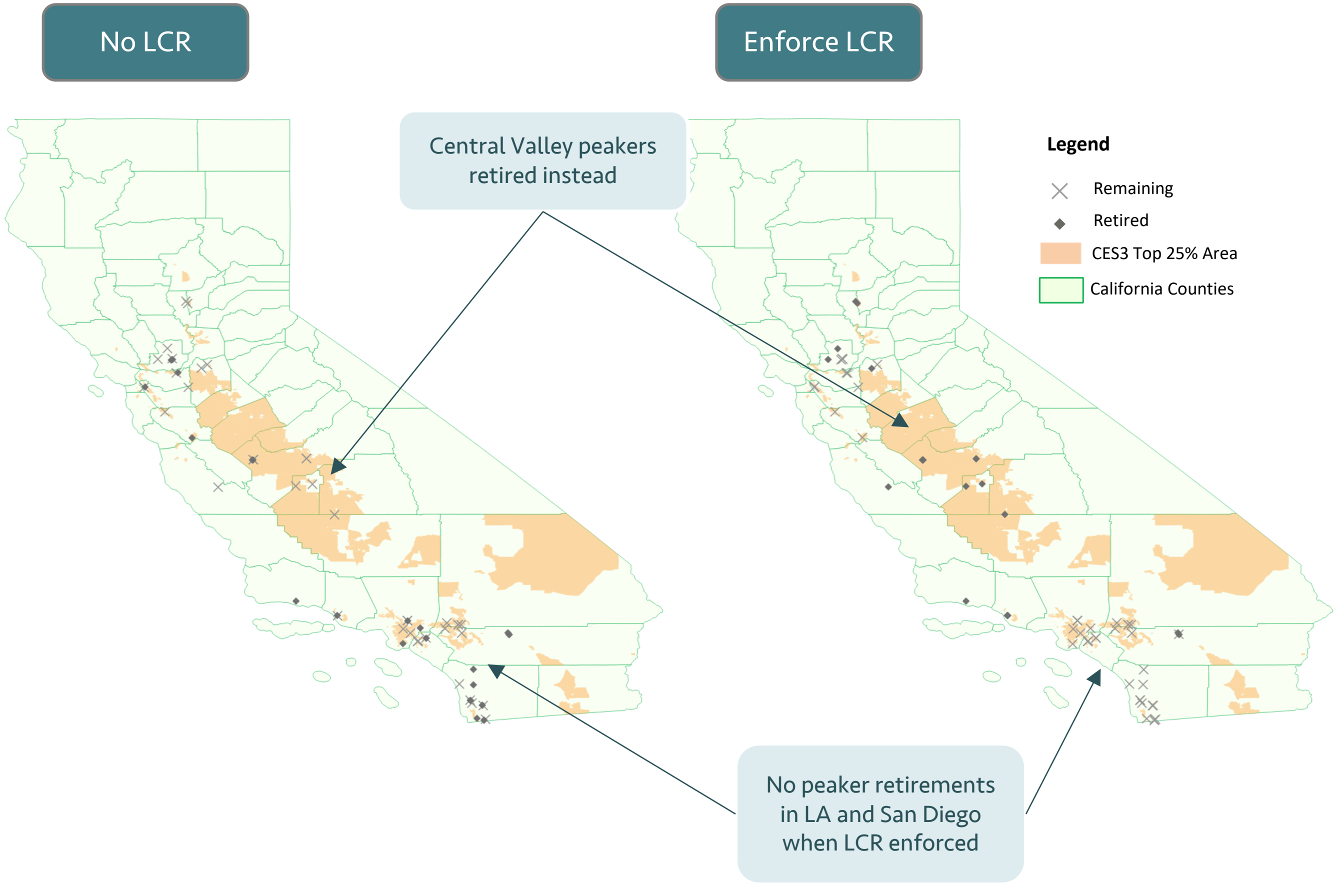
Additional functionality added:

- Disaggregate "peaker" and "CCGT" fleets to plant level and model individual plant operating characteristics



- Allow retirements of peakers and CCGTs, therefore avoiding the need to pay their annual fixed O&M cost

- Model local capacity requirements to ensure sufficient resources are available for local reliability in addition to system-level services

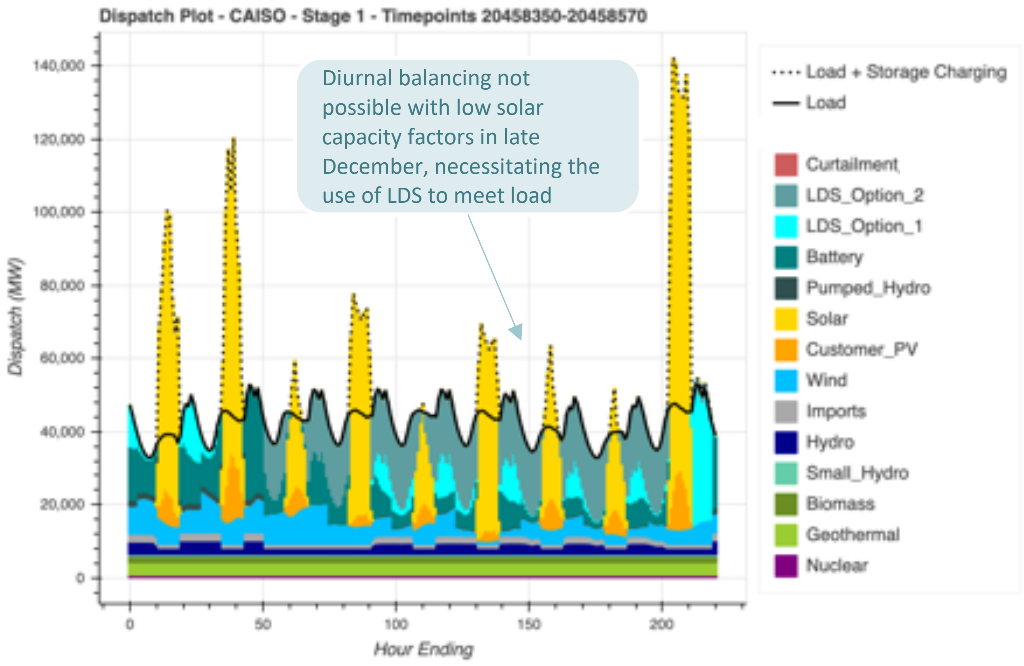


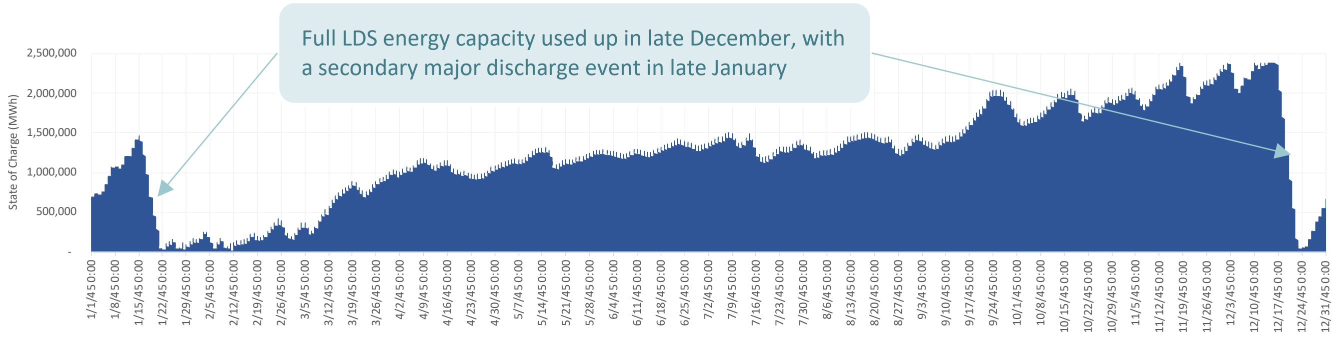
GridPath Studies: California Resource Planning

GridPath analysis main goal: understand value of **long-duration storage**

Additional functionality added:

- Instead of the 37 "sample" days, use 8760 sequential hours in order to capture energy shifts that happen over longer time scales than a single day
- Develop "extreme weather" load and renewable profiles

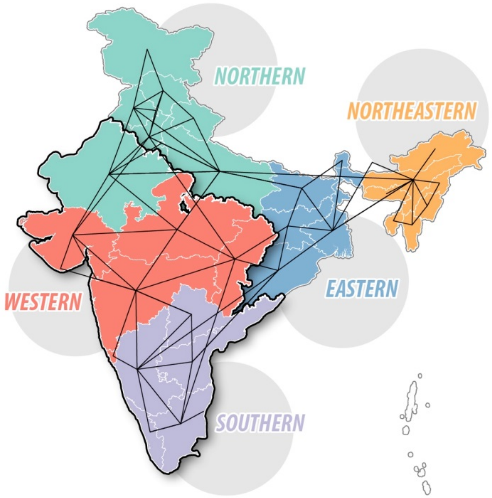




GridPath Studies: Optimal investments with RE targets in India

Zonal Setup

- Model India's electricity system as a single node (no transmission) and with 30+ load zones (with transmission)
- Spatial diversity in wind and solar resources



Temporal Setup

- 4 investment periods each representing several years between 2018 and 2030
  - Select dozens of wind and solar sites, conventional coal, combined cycle and combustion gas turbines, battery storage
- 12 sample days of 24 hours each per investment period, weighted appropriately to represent a year

Policy

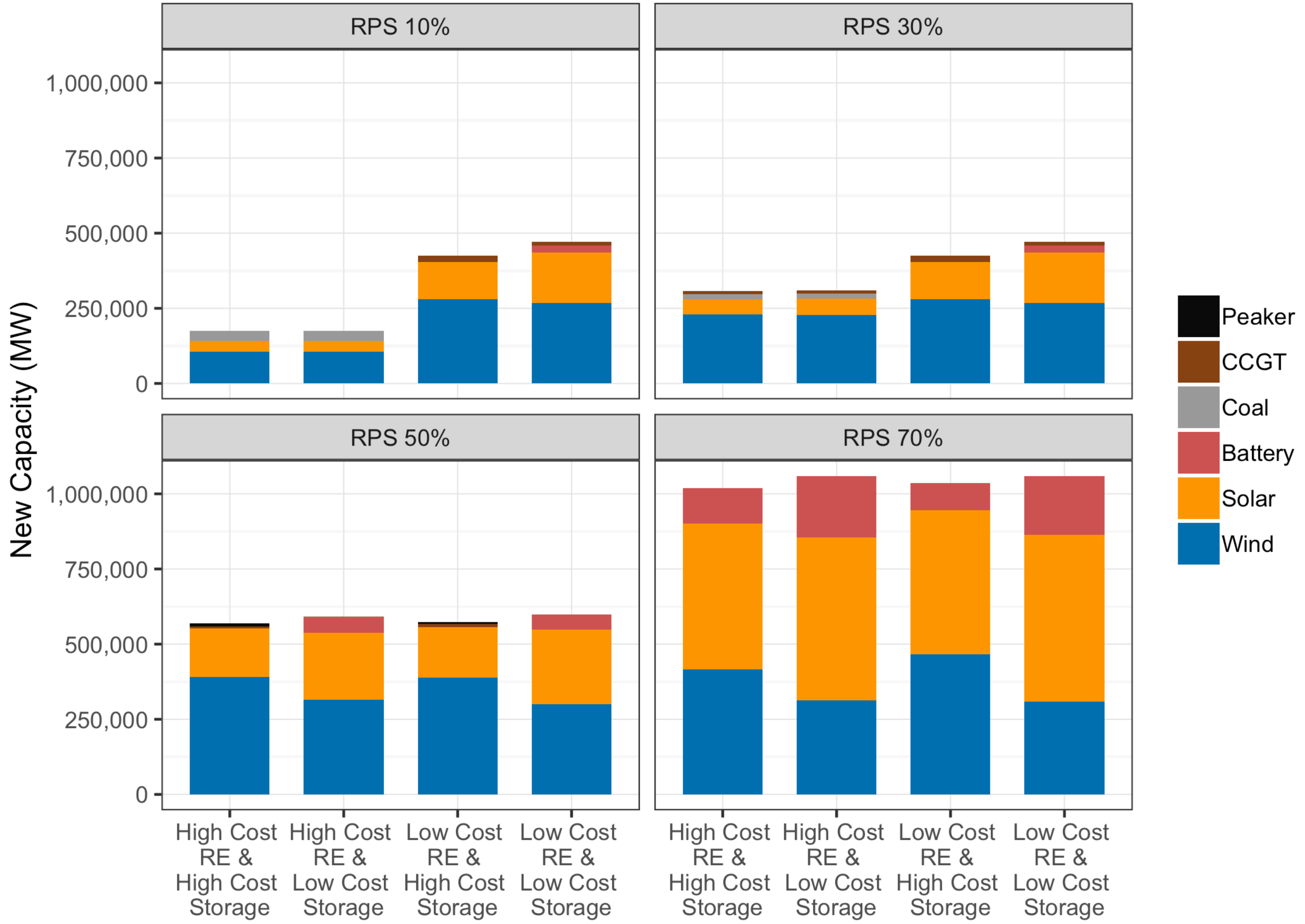
- Renewable Portfolio Obligation targets of 10%, 30%, 50%, and 70% (only wind and solar
- Multiple cost trajectories for wind, solar, and battery storage

Reliability

- Operating reserve requirements at the regional and state level (ongoing study)
- Planning reserve margin (PRM)

GridPath Studies: Optimal investments with RE targets in India

GridPath analysis main goal: identify **the least cost generation investments to meet future demand and meet renewable energy goals**

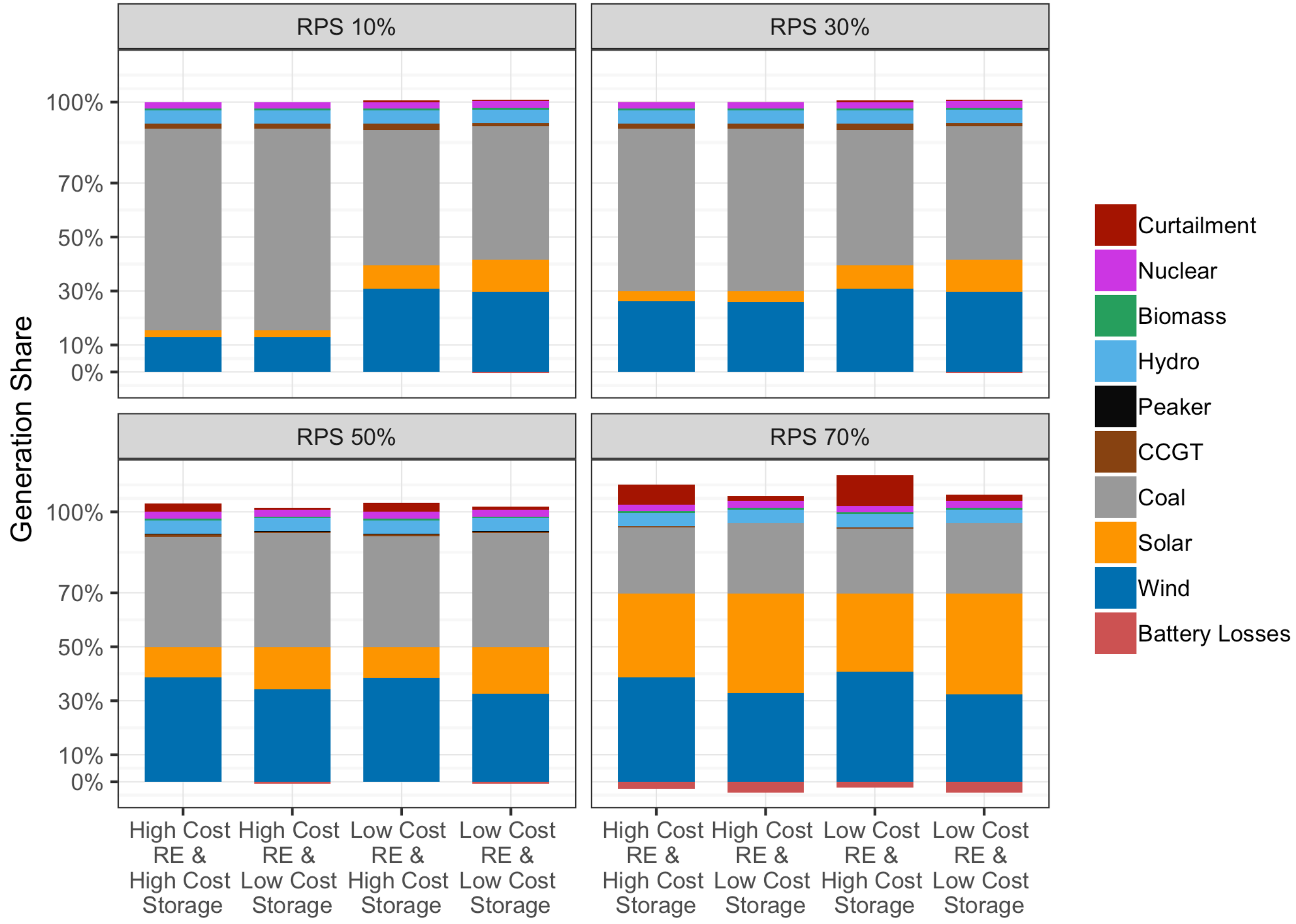


Preliminary results (single node model)

- When wind and solar costs are low, 400-440 GW of variable renewable energy (VRE) capacity can be built cost-effectively
- For low RPO targets, battery storage is optimal only when wind, solar, and battery costs are low
- But battery storage is selected for higher (50-70%) RPO targets
- Results will get more interesting with transmission

GridPath Studies: Optimal investments with RE targets in India

GridPath analysis main goal: estimate **generation, renewable energy curtailment, cost, and emissions** in future (and present) electricity system



Preliminary results (single node model)

- Low cost wind and solar could result in achieving 40% share in total generation cost-optimally.
- Renewable energy curtailment increases with high RPS targets
- Storage reduces renewable energy curtailment

GridPath Studies: Ongoing studies in other regions

- Southern Africa Power Pool (12 countries)
- Myanmar
- US (Western Electricity Coordinating Council)
- China

Thank You

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