NREL
NATIONAL RENEWABLE ENERGY LABORATORY





Picking the best from the all-resources menu:

Advanced Tools for Resource Planning

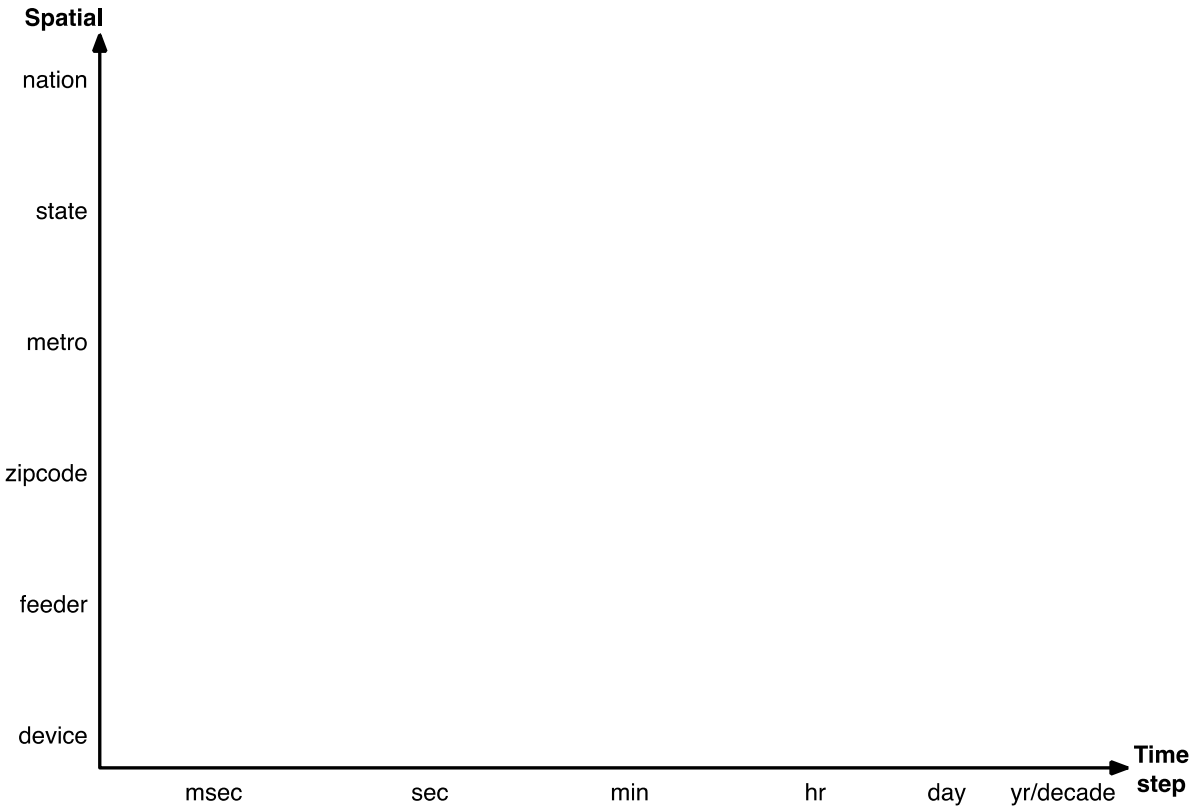
Bryan Palmintier, PhD
Senior Research Engineer, Power Systems Engineering Center
National Renewable Energy Laboratory (NREL)

GETTING THE MENU RIGHT: An All-Resources Approach to Planning for a More Dynamic, Low-Carbon Grid

McKnight Foundation, Minneapolis, MN
November 28, 2017

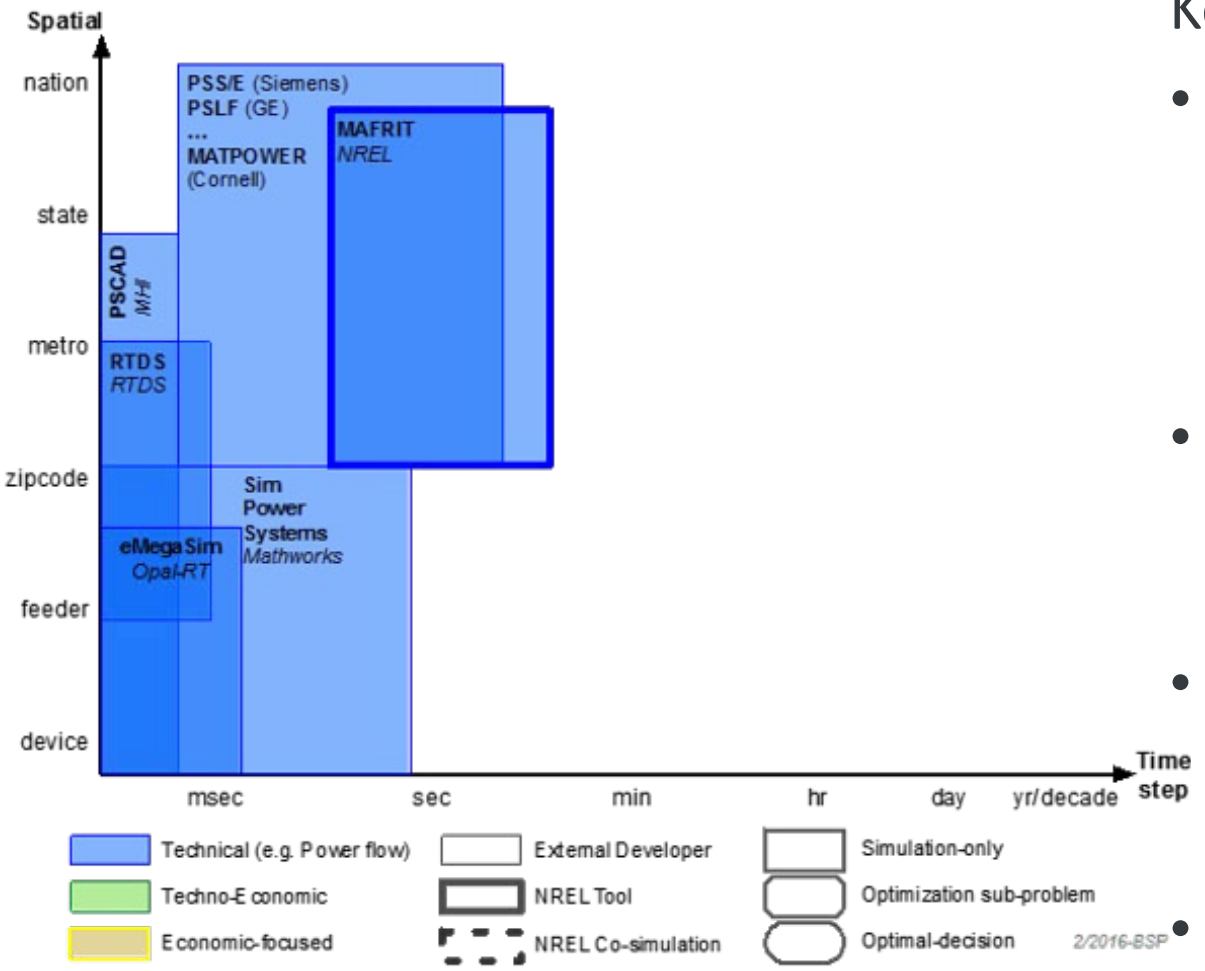
NREL/PR-5D00-70697

Tools: A wide range of space and time



2/2016-BSP

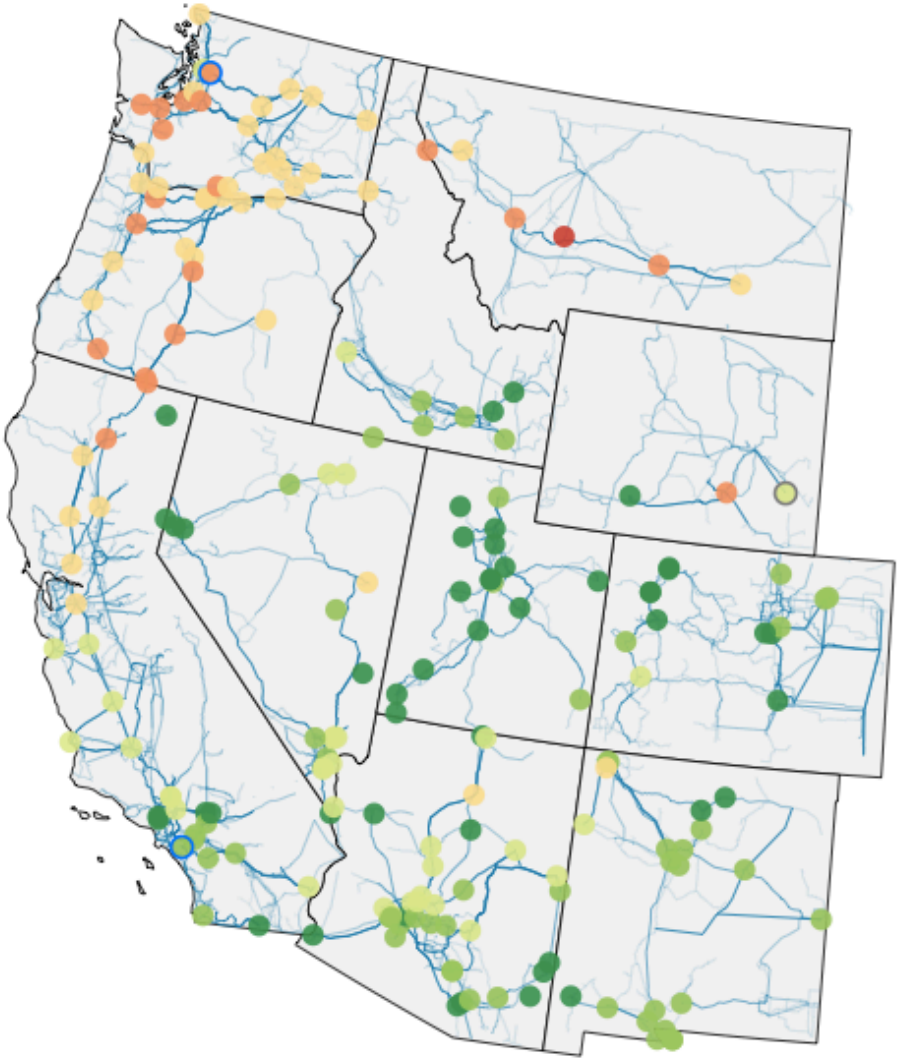
Tools: "Dynamics" Simulation



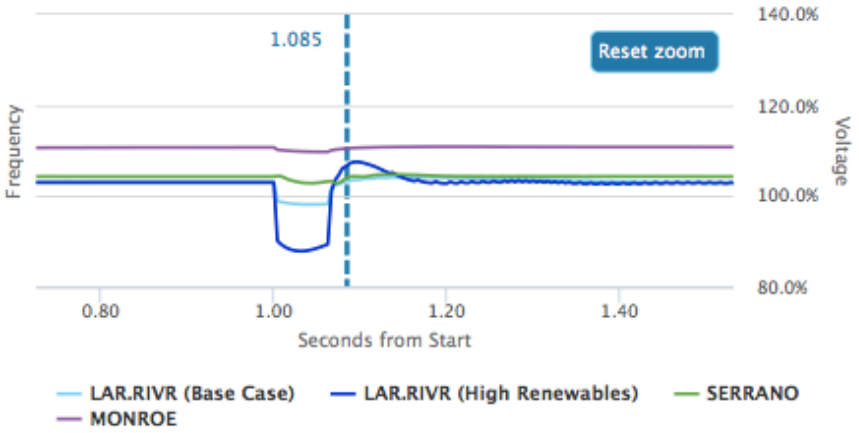
Key Questions:

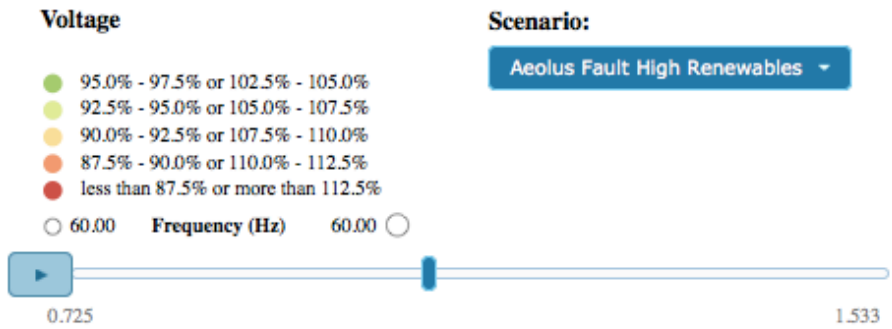
- How will system respond to a fault/outage?
  - Frequency
  - Voltage
- Can inverter-based technologies provide sufficient inertia?
- Will protection and control schemes provide reliability?
- What ride-through settings are required

Western Wind and Solar Integration Study

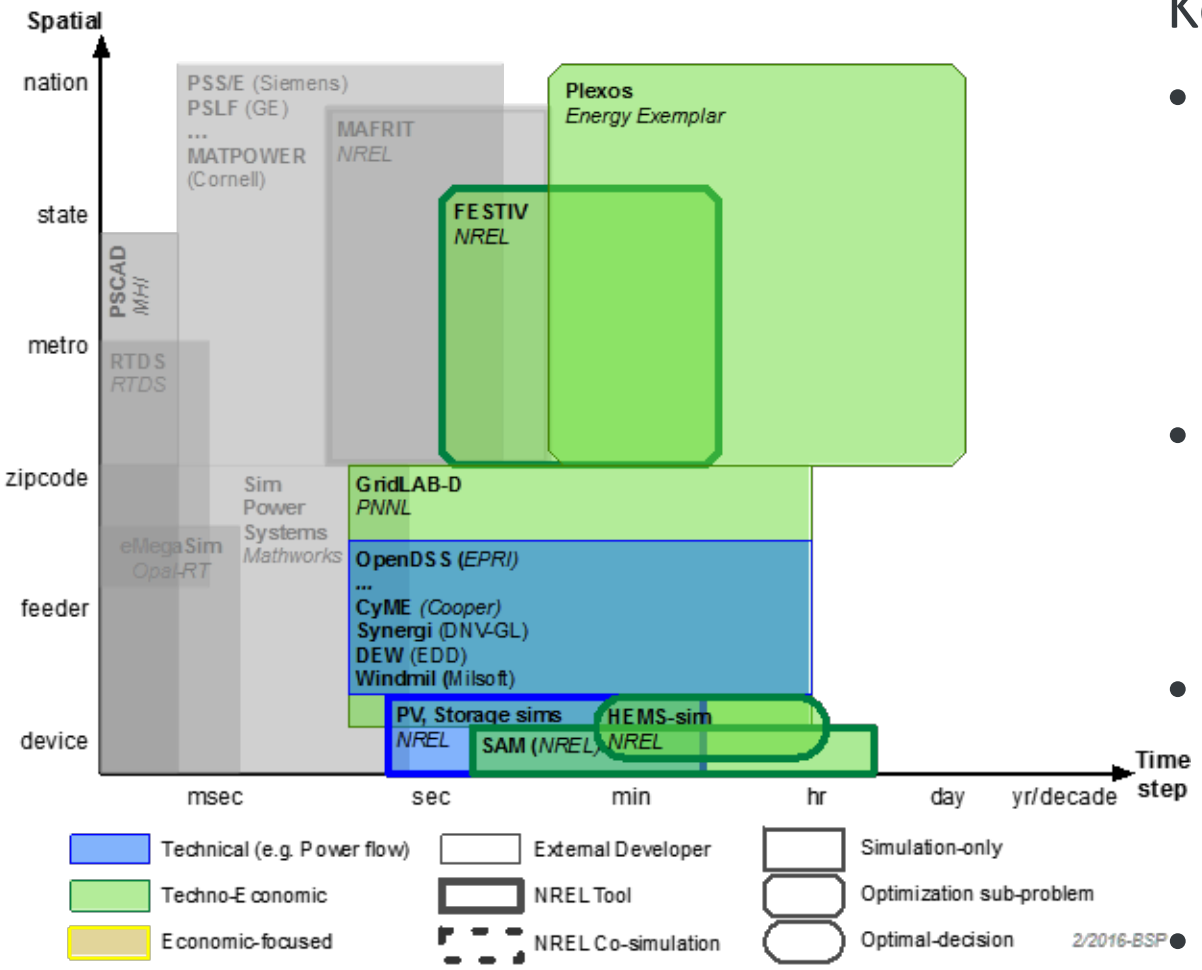


The primary objectives of Phase 3 of the Western Wind and Solar Integration Study (WWSIS-3) were to examine the large-scale transient stability and frequency response of the Western Interconnection with high wind and solar penetration. WWSIS-3 evaluated a variety of system conditions, disturbances, locations, and renewable penetration levels to help draw broader conclusions. Key finding was that ***with good system planning, sound engineering practices, and commercially available technologies, the Western Interconnection can withstand the crucial first minute after grid disturbances with high penetrations of wind and solar.***





Tools: Operations Simulation (Production Cost / QSTS)

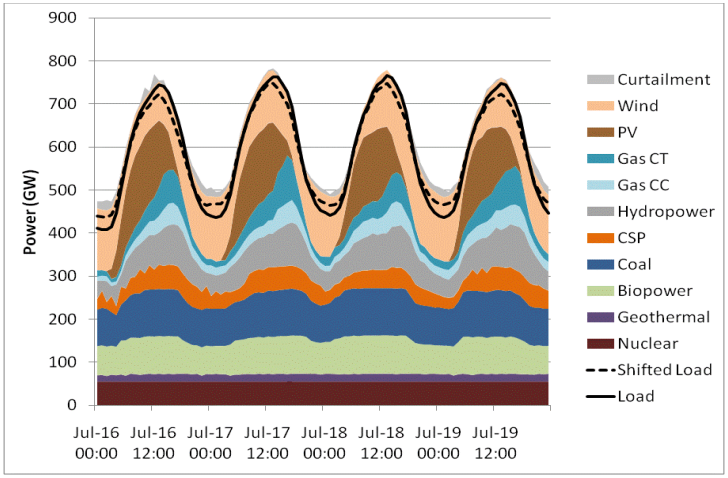


Key Questions:

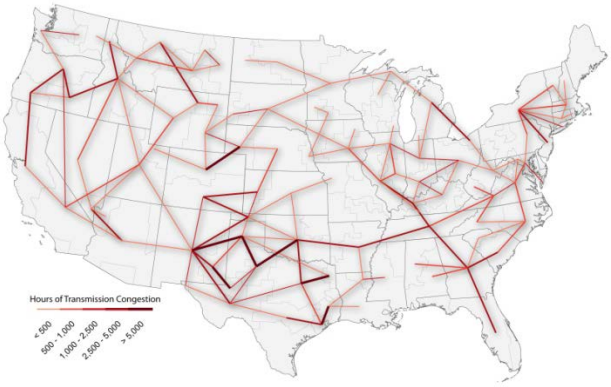
- Can supply meet demand at all times?
  - Curtailment?
  - Congestion?
- Market Design/Operations:
  - Locational prices
- Can Distribution operate effectively?
  - Voltage?
- Value of forecasts?
- Viable cash-flow?

Typical Operations Simulation Outputs

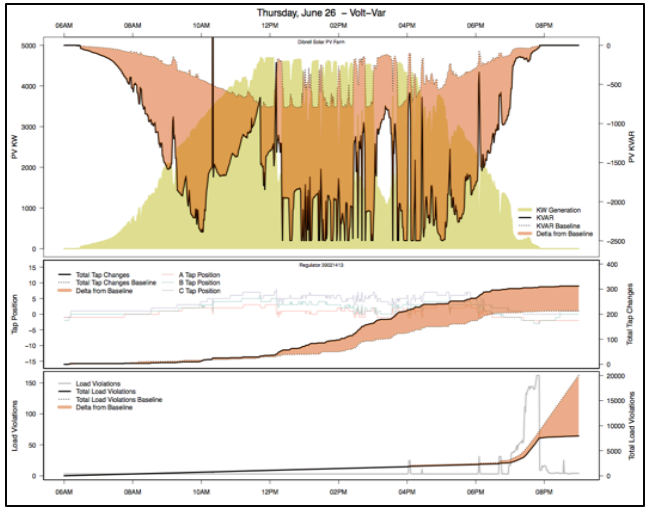
Prices and total production cost



Dispatch information (ramping, cycling, fuel usage by type)

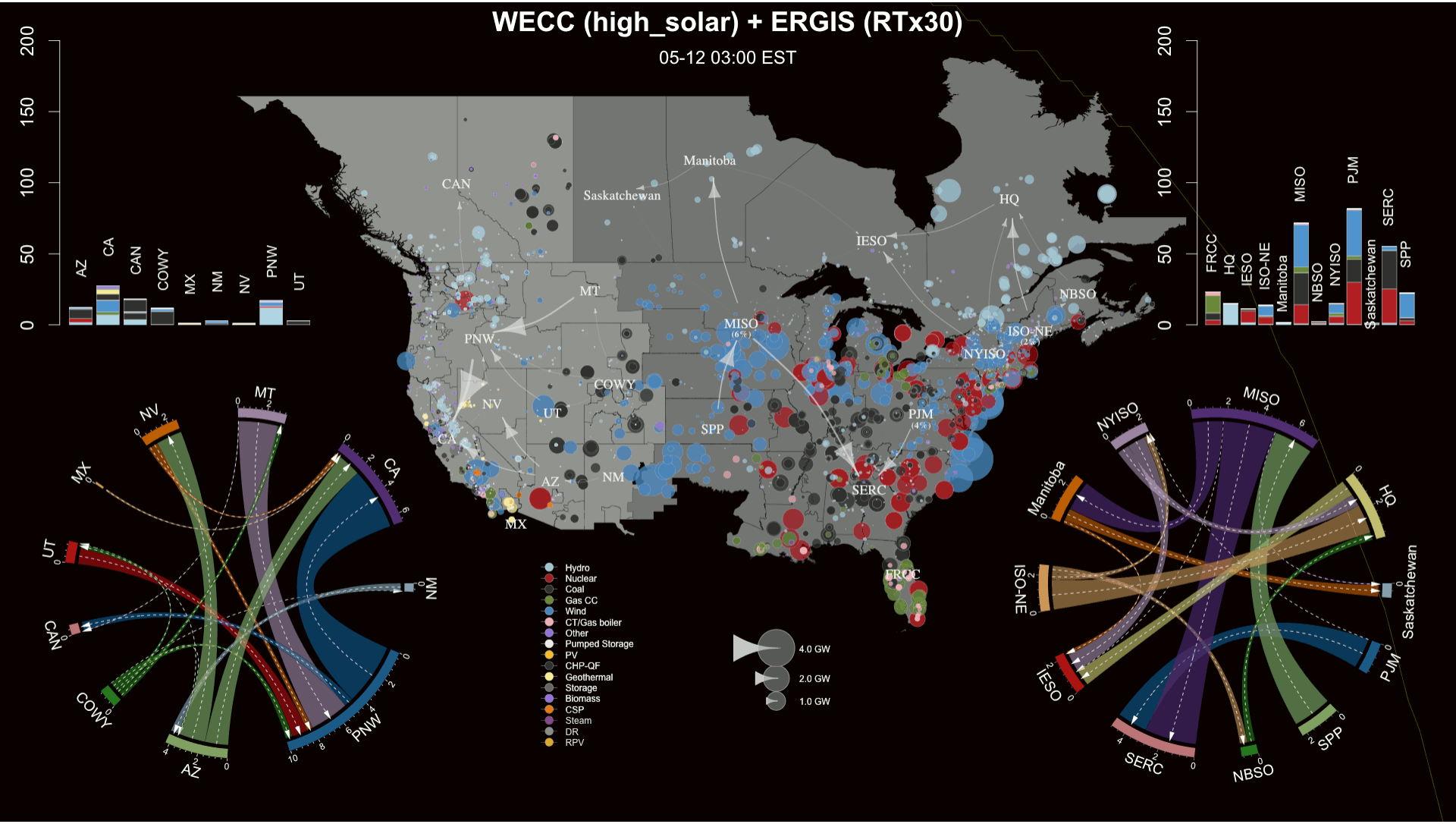


Transmission congestion

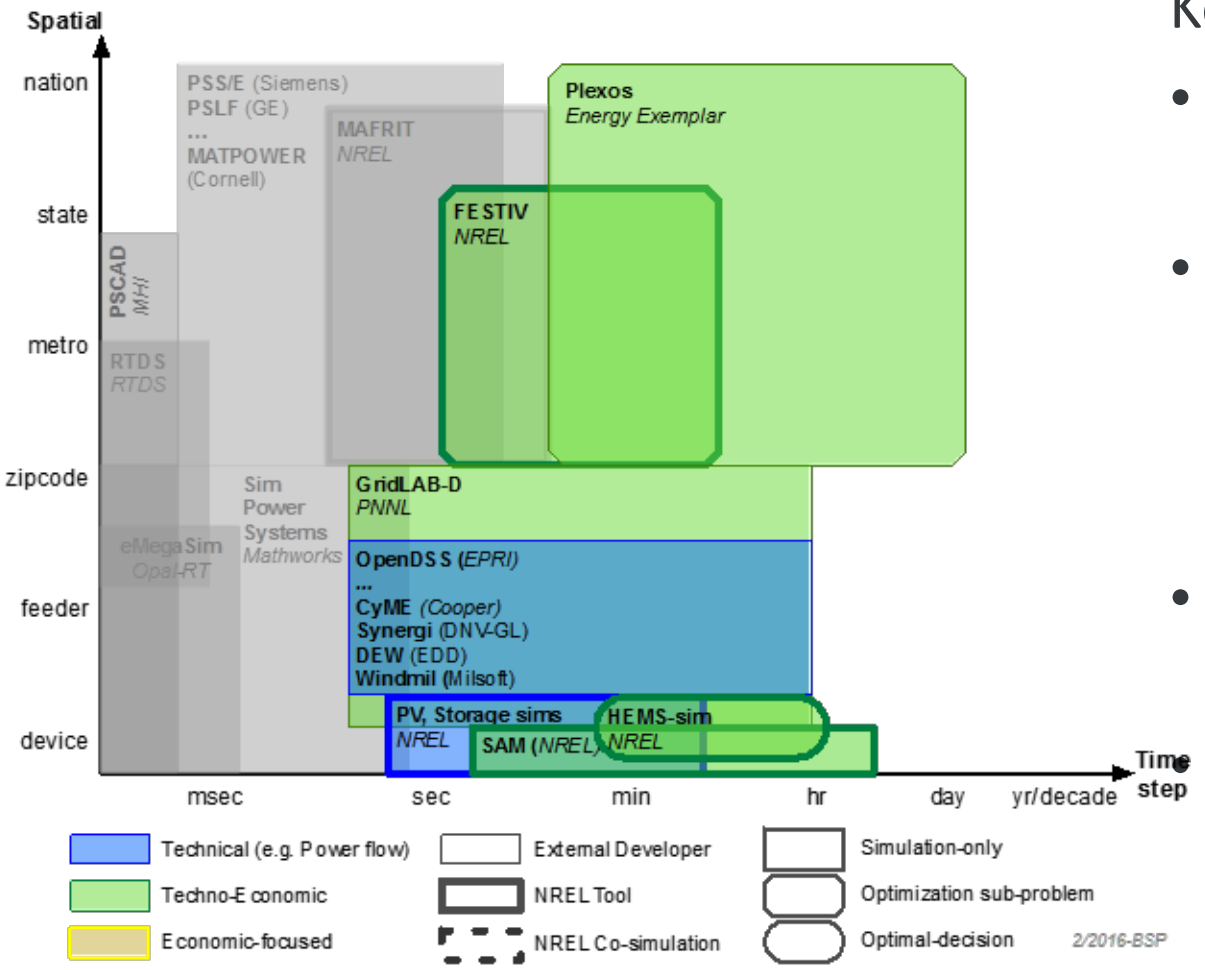


Detailed Distribution voltage and equipment operation

Large-scale Production Costing in Context: The big picture



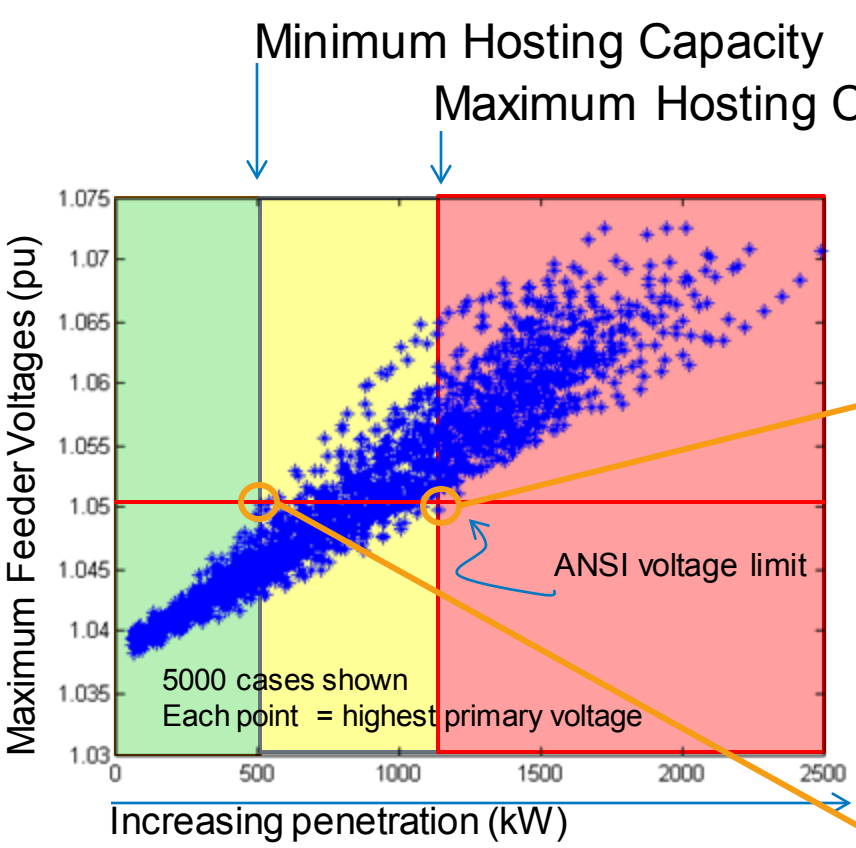
Tools: Metric Assessment

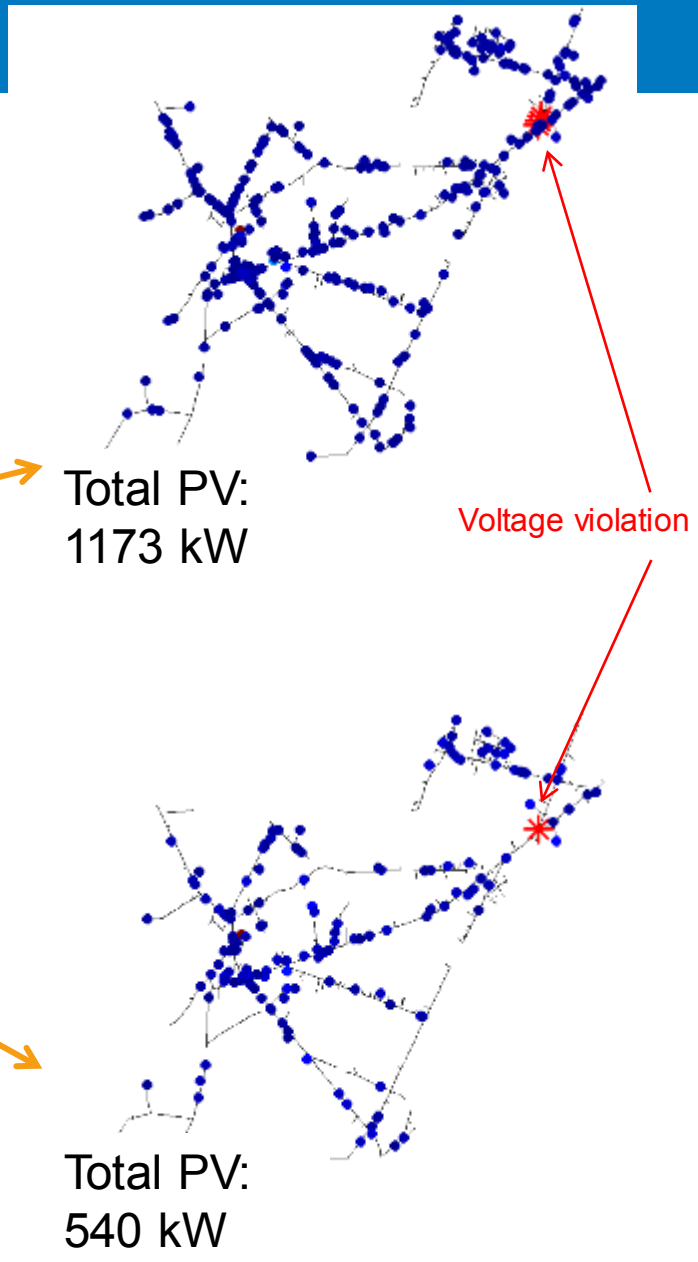


Key Questions:

- What is the system capacity margin?
- What type and quantity of reserves and "ancillary" services?
  - Which resources?
- What is the DER hosting capacity?
- Cost-benefit analysis

Hosting Capacity Background



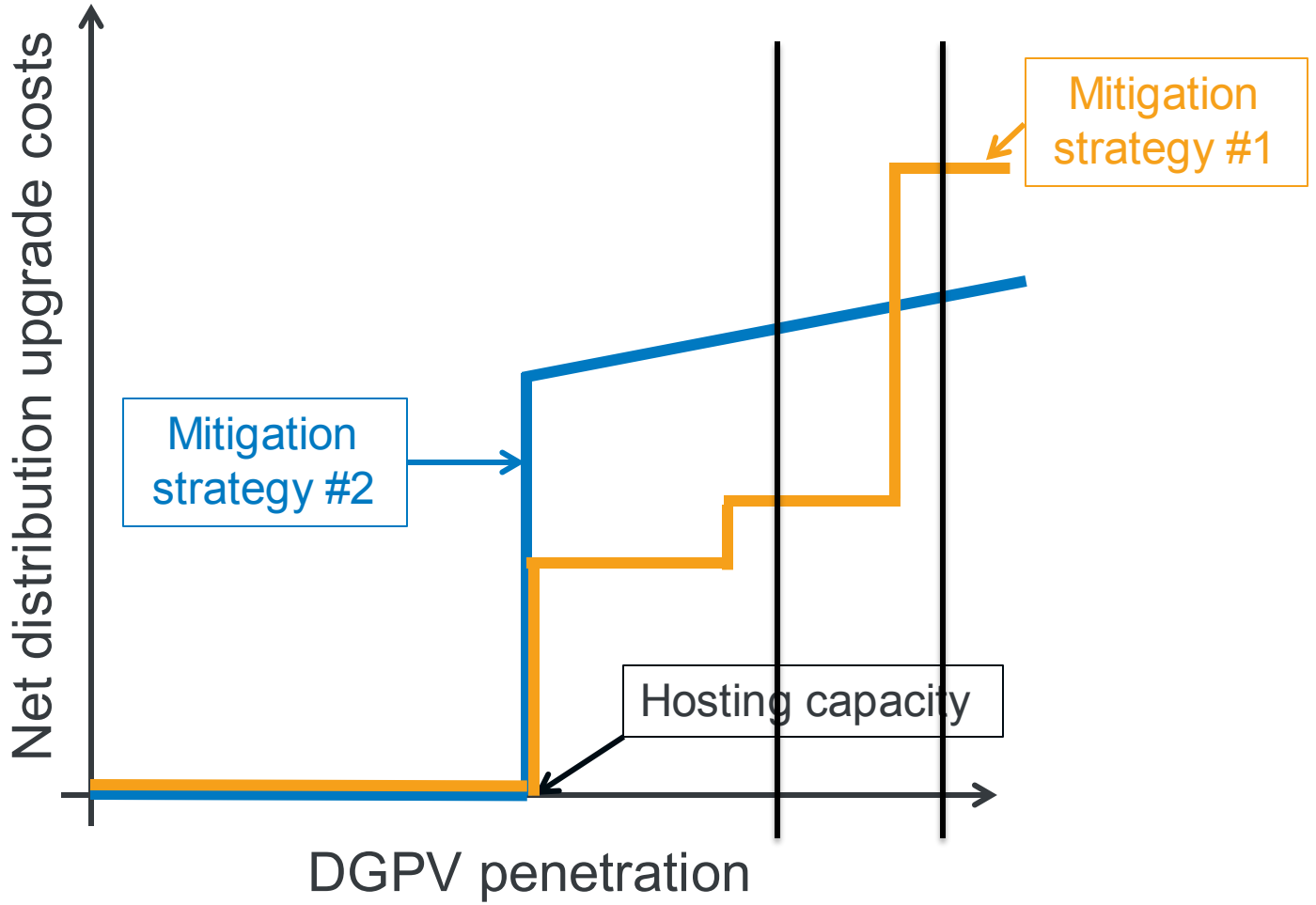


No observable violations regardless of size/location
Possible violations based upon size/location
Observable violations occur regardless of size/location

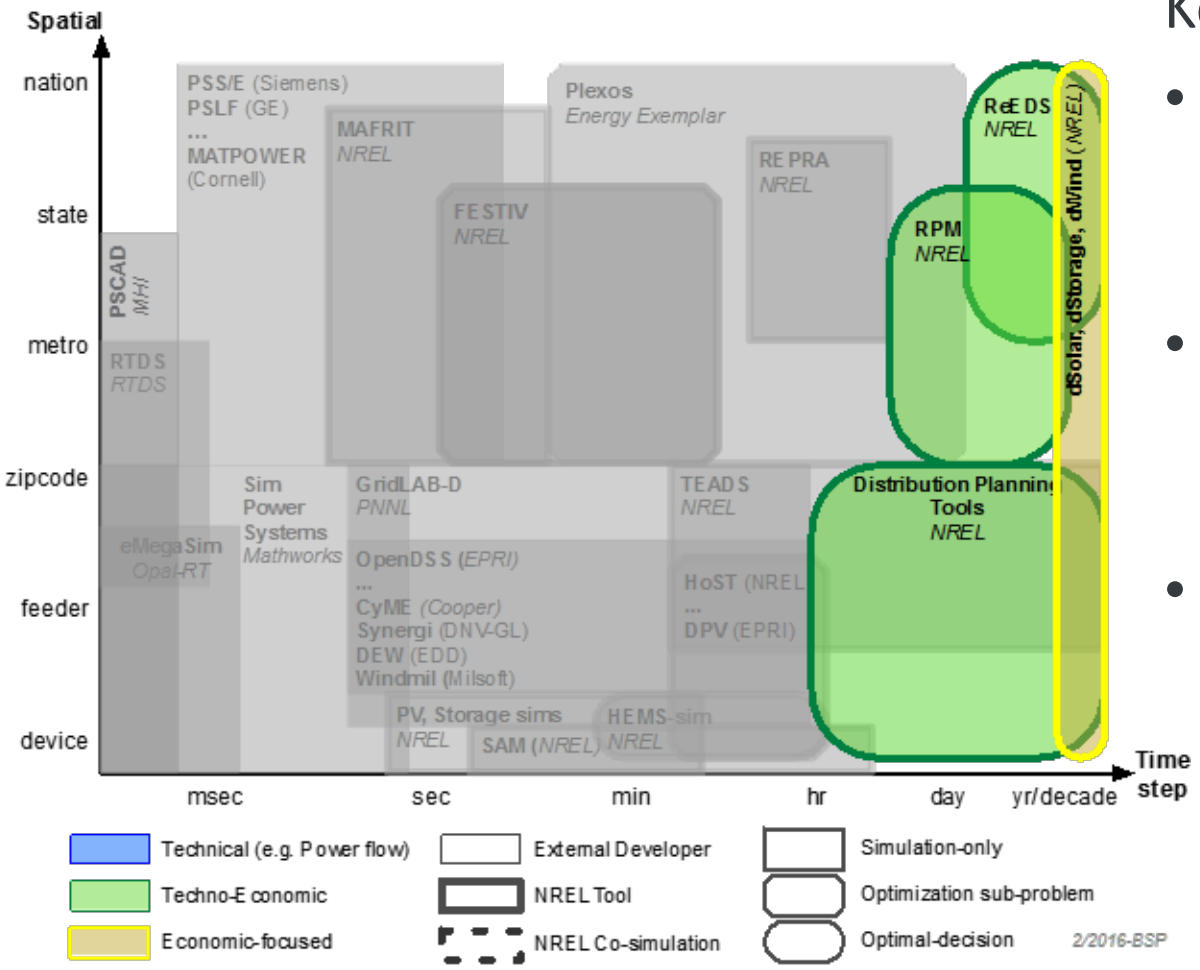
Source: Jeff Smith, EPRI, "Alternative Screening Methods PV Hosting Capacity in Distribution Systems", Presented at HiPen Solar Forum 2013, Feb 13-14, San Diego, CA.

Beyond Hosting Capacity

Costs on a specific feeder or distribution system



Tools: Planning & Trends



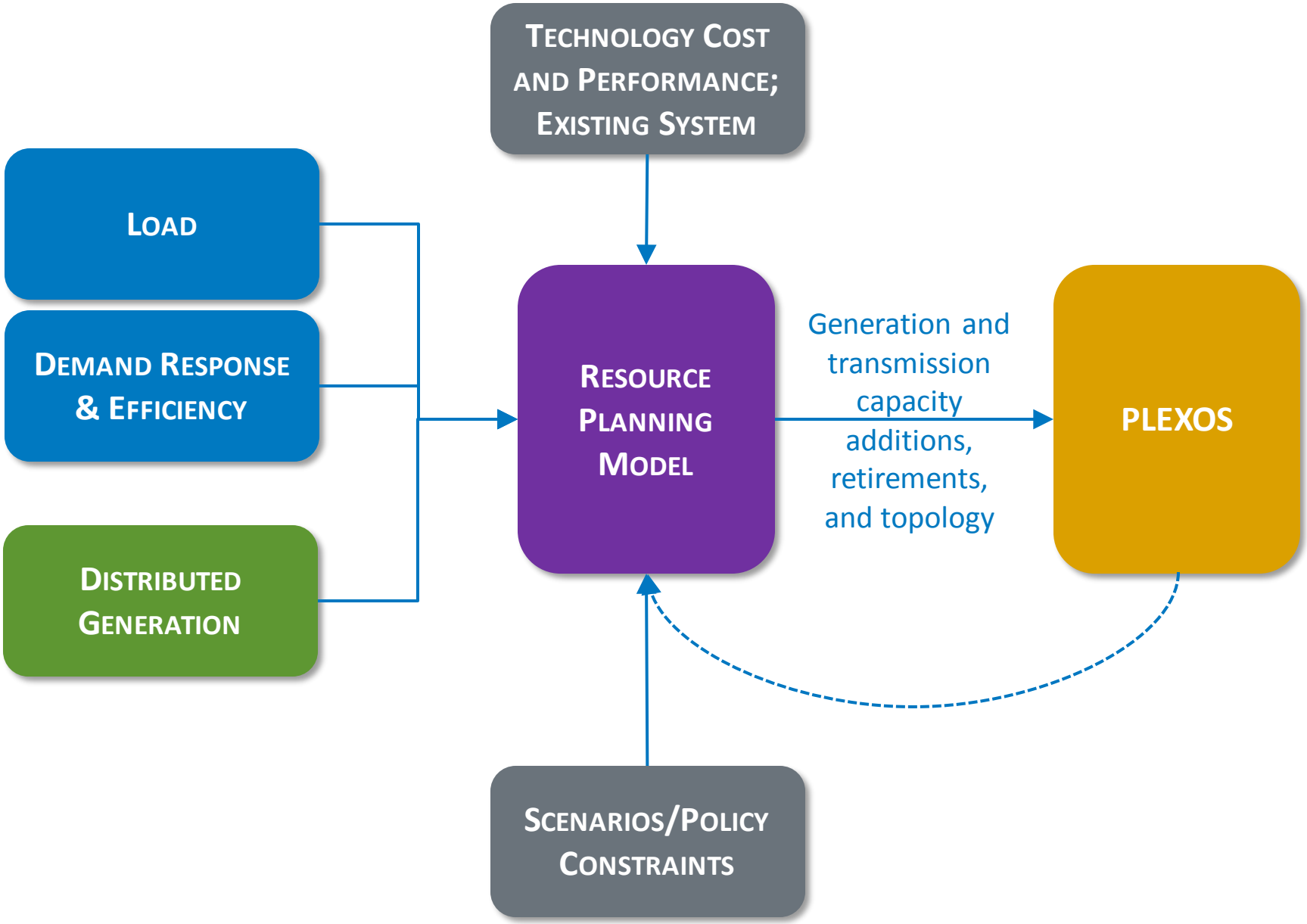
Key Questions:

- What is least cost mix of generation and transmission?
- How might tariffs/prices/incentives impact DER adoption?
- What are costs and options to expand hosting capacity?

The Resource Planning Model (RPM): detailed capacity expansion and dispatch for a region, utility service territory, or state

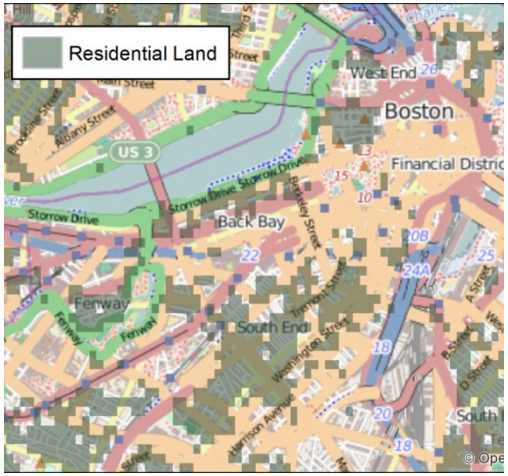
- Highly detailed capacity expansion and dispatch (2010-2035/*2050*)
  - **unit-level plant and transmission representation** within the region of interest
- Flexible structure for a dynamic regional focus
- **Hourly chronological dispatch** for representative sets of days (or weeks) to characterize dispatch for a given year
- Key outputs: detailed generation and transmission capacity builds, emissions, fuel consumption, system costs; wholesale electricity prices, credit prices, and allowance prices

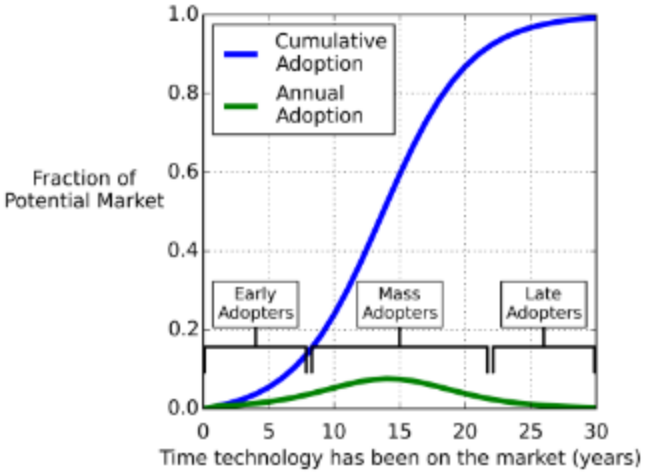
Data/Modeling Flow

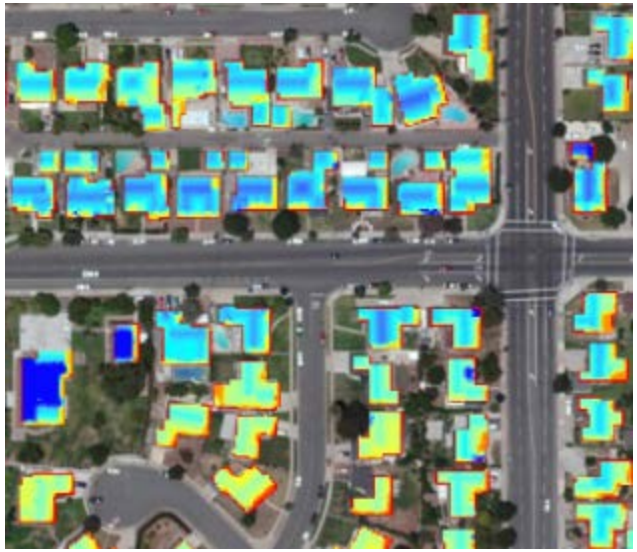


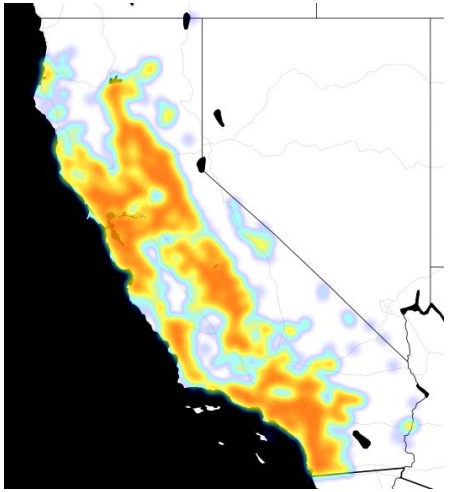
Distributed Gen. Market Demand Model (dGen)

- Forecast customer adoption of distributed generation technologies (solar, storage, wind, geothermal)
  - electricity costs,
  - technology cost and performance,
  - policy and regulation, and
  - customer behavior



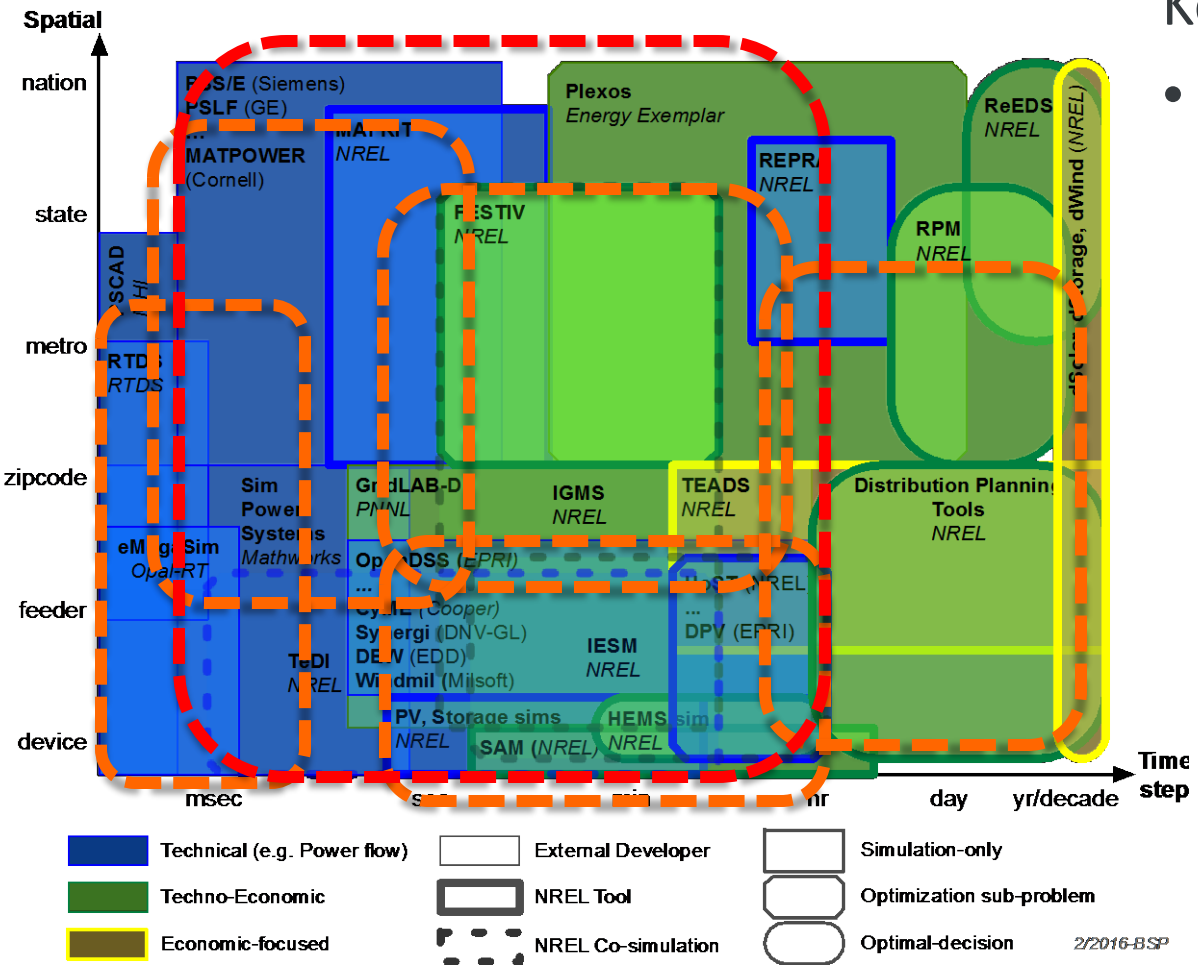






Source: http://www.nrel.gov/docs/fy16osti/65298.pdf

Tools: Integrated Simulations



Key Questions:

- Closed-loop interactions between T+D+
  - Physical limits on DER
  - DERs as Price-makers
  - Reactive power/Voltage

Palmintier, et al. Modeling and Simulation Tools for Analyzing High Penetrations of Variable Renewables in Electric Power Systems. Forthcoming NREL Technical Report

Integrated T&D Grid Modeling System (IGMS)

Summary:

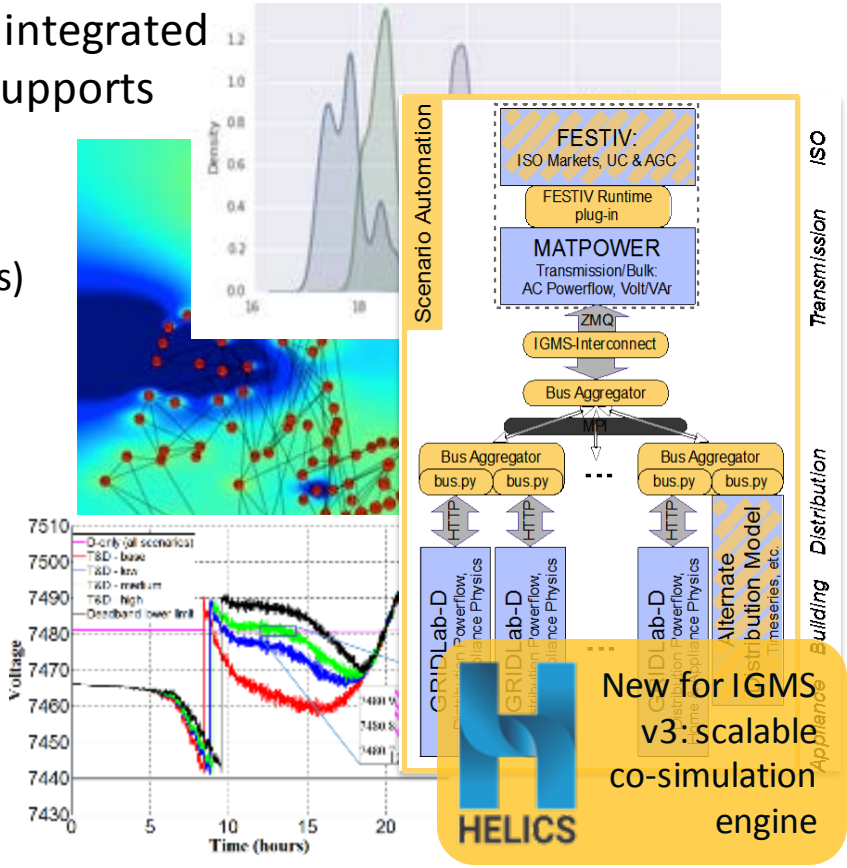
A next-generation analysis framework for full-scale integrated market+transmission+distribution simulation that supports millions of highly distributed energy resources.

End-to-End T&D Modeling Capability

- detailed multi-period wholesale markets (including LMPs)
- generator/reserve dispatch (AGC)
- AC Powerflow (bulk transmission)
- Full unbalanced 3-ph power flow for 100s-1000s of distribution feeders
- Physics based end-use models of buildings and DERs
- Semi-Automated import from PLEXOS, SynerGi, & CyME

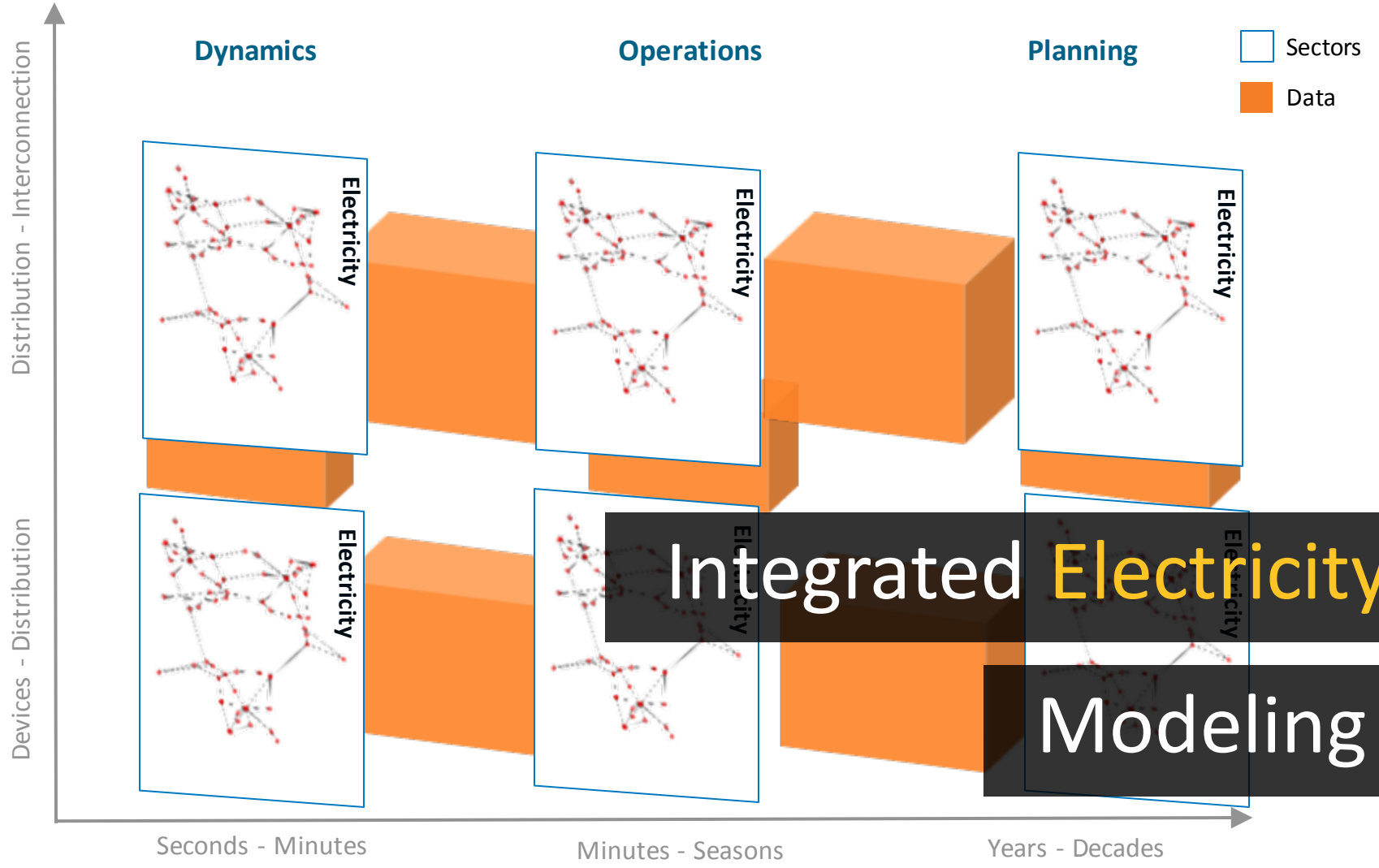
Example Applications

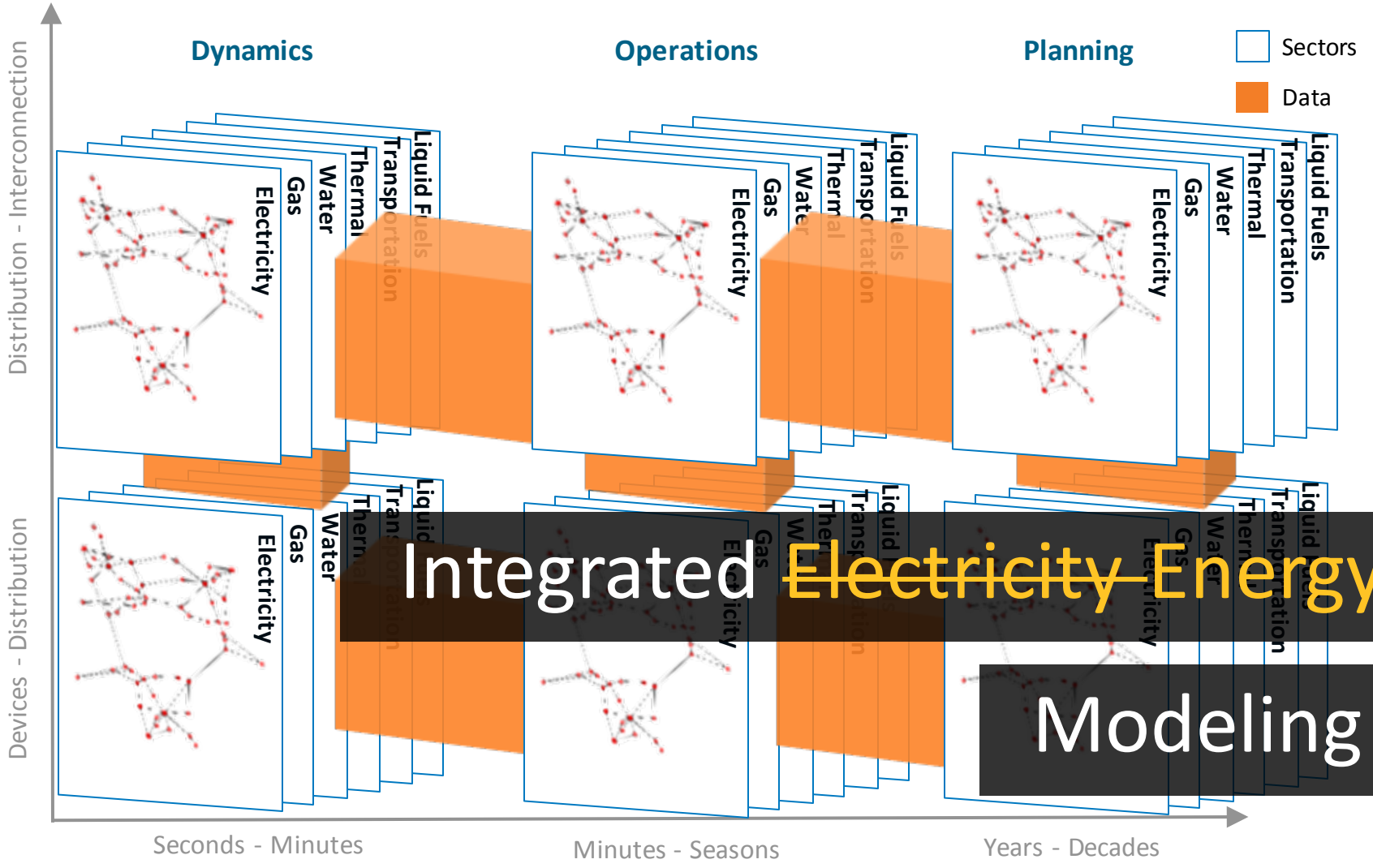
- **Past:** Analyze distributed PV support for grid operations
- **Full System:** All Transmission + all distrubition + all customers. e.g. >2.3M electrical nodes, >700k customers
- **Current Research:**
  - Wholesale price interaction of DERs
  - Distribution market, DER, and service designs
  - Communication/Control Architectures (w/ HECO)



NREL's Integrated Grid Modeling System (IGMS) provides a first-of-a-kind co-simulation with transmission-level markets, 1000s of distribution feeders, and 1Ms of DERs

http://www.nrel.gov/docs/fy16osti/65550.pdf


Dynamics
Operations
Planning
Sectors
Data
Distribution - Interconnection
Devices - Distribution
Electricity
Seconds - Minutes
Minutes - Seasons
Years - Decades
Integrated Electricity
Modeling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Seconds - Minutes
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Years - Decades
Liquid Fuels
Transportation
Thermal
Water
Gas
Electricity
Integrated ~~Electricity~~ Energy
Modeling

Pushing the Frontier

Interconnections Seam Study	North American Renewable Integration Study	Electrification Futures Study	Multi-scale Production Cost Modeling	Los Angeles 100%
What happens if the east joins the west?	What if North America works together?	What if the energy economy electrifies?	Can we make models more detailed and faster?	Can LA operate on 100% Renewable Energy
December 2017	October 2019	October 2019	October 2018	January 2020

Thank you!

Bryan.Palmintier@nrel.gov

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