Overview of Training and Connections to State Planning Efforts

Juliet Homer (PNNL) & Eran Schweitzer (PNNL)

October 14, 2025

BERKELEY LAB

NREL

Pacific Northwest NATIONAL LABORATORY

Funding Acknowledgement

The technical assistance activity that produced this resource was funded by the U.S. Department of Energy's: Office of Energy Efficiency and Renewable Energy (EERE) Energy Grid Integration; EERE Vehicle Technologies Office; EERE Building Technologies Office; EERE Solar Energy Technologies Office; Office of Cybersecurity, Energy Security, and Emergency Response; Office of Electricity; and Grid Deployment Office.

The authors are solely responsible for any omissions or errors contained herein.

Agenda

- Webinar series overview – Juliet Homer
- Power System Planning: The Big Picture – Juliet Homer
- Diggin Deeper Into Models & Data – Eran Schweitzer
- Q&A, Discussion – All

Seven Webinars - 1

1. Overview of Webinar Series and Connections to State Planning Efforts
    - October 14, 2:30-3:30 p.m. Eastern
    - Juliet Homer & Eran Schweitzer (PNNL)
2. Developing Forecasts - General Overview
    - October 23, 4-5 p.m. Eastern
    - Brittany Tarufelli & Allison Campbell (PNNL) and J.P. Carvallo (LBNL)
3. Developing Forecasts – Load Expansion
    - October 29, 4-5 p.m. Eastern
    - Sean Murphy & J.P. Carvallo (LBNL) and Christine Holland (PNNL)
4. Developing Forecasts – Distributed Energy Resources
    - November 6, 2-3 p.m. Eastern
    - Sean Murphy & Margaret Pigman (LBNL) and Shibani Ghosh (NREL)

Seven Webinars - 2

5. Resource Adequacy Analysis – Basics
   - November 10, 3-4 p.m. Eastern
   - Jose Lara, Sebastuan Machado, & Rafael Monge (NREL) and Allison Campbell & Eran Schweitzer (PNNL)
6. Transmission and Distribution System Planning – Basics
   - November 13, 3-4 p.m. Eastern
   - Jose Lara & Vincent Westfallen (NREL)
7. The Evolution of Resource Accreditation
   - December 2, 3-4 p.m. Eastern
   - Travis Douville (PNNL)

Focus of the Webinar Series: Load Forecasting and Resource Adequacy

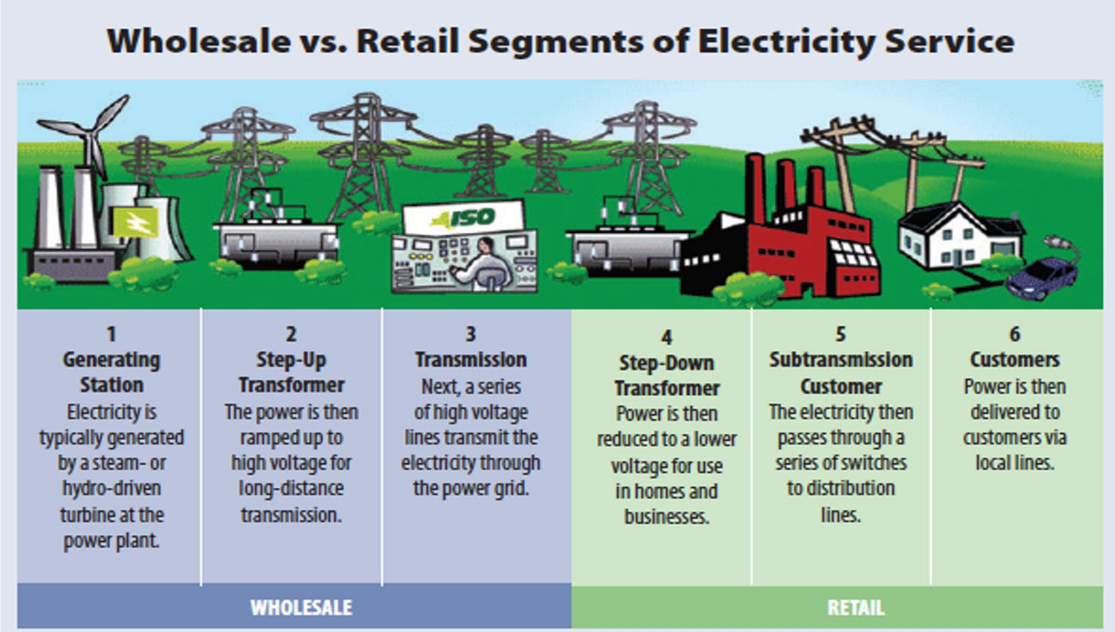
- Empower state agency professionals with **fundamental and essential information on forecasting and resource adequacy (RA)**, crucial for participating in or overseeing electricity planning.

- Share **key concepts, methods, techniques, and examples** that webinar series participants can use in their work in the electricity sector.

Walk away able to ask good questions and understand the answers!

Focus of today's webinar is to provide a foundation connecting forecasting and RA to grid planning

- Utilities conduct a variety of different grid planning activities and states entities engage in grid planning activities in different ways.
- Forecasting is the foundation of grid planning
  - Load, generation, costs and performance
- Resource adequacy (RA) is having the capacity to serve load.
  - Generating resources are supply.
  - Load is the demand the utility must serve.
  - The transmission and distribution systems bring supply to load.



Source: NY ISO

- RA is traditionally considered in terms of resource development and procurement, but misses important details on the deliverability of those resources to the loads.
- Utilities may assume a "copper plate" or otherwise assume there is little to no problem getting resources to load, which is increasingly not the case.
- Understanding how different utility planning activities interact with each other is important.

Power System Planning – The Big Picture

Context Matters - planning processes in states vary based on different factors

Factors	Why it matters?	Examples
Vertically integrated versus restructured	In vertically integrated utilities, load-serving entities are responsible for generation and transmission, not just distribution	**Restructured:** TX, IL, OH, PA, MD, DE, NJ, CT, NY, RI, MA, NH, ME **Partially deregulated:** CA, OR, MI **Vertically integrated:** all others
Within an RTO/ISO versus not	In RTO/ISO regions, the RTO/ISO is responsible for resource adequacy through market constructs	West (outside CA) and Southeast are not part of RTO/ISOs Texas, New York, and California are single-state ISO
Market construct	Market constructs impact how utilities and RTO/ISOs plan and secure energy	**Centralized capacity market**: PJM, ISO-NE, NYISO **Voluntary capacity market:** MISO **Energy-only market**: SPP, ERCOT **Resource adequacy program:** CAISO **Bilateral market:** West and Southeast
State Integrated Resource Planning (IRP) requirements	Utilities in states with IRP requirements conduct long-term generation (and transmission) planning processes based on state guidelines	**States *without* formal IRP requirements***: AL, DE, FL, IA, IL, MA, ME, MD, NH, NJ, NY, OH, PA, RI, TN, TX, WI

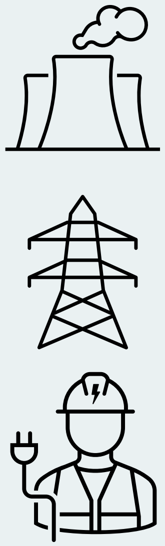
*Source: LBNL 2025: Best practices in Integrated Resource Planning

At the highest level – Types of electric system planning

- **Generation or resource planning** – Identifies the types and locations of power plants and contracted generation needed to meet future electricity demand
- **Transmission planning** – Identifies how electricity is transported from where it's generated to distribution areas
- **Distribution planning** – Identifies how electricity is delivered from the transmission system to end-use customers

Resource Adequacy Analysis - The process of ensuring that an electric system has enough electricity generation to meet customer demand and enough transmission capacity to deliver it at every hour of the year.

- Includes both future generation and transmission assumptions
- Considers a wide range of normal and extreme conditions
- Is measured by the probability of an outage due to insufficient capacity.
    - Example: An RA standard may be less than 1 day of generation-related outages every 10 years.



Types of plans that may be required by public utility commissions

Integrated resource plans, or IRPs, are plans to meet the utility's future electricity demands by selecting the portfolio of resources with the best combination of expected costs (investment and production costs) and risks for the utility's customers.

- IRPs often include both generation and, to a lesser extent, transmission planning
- Ensuring resource adequacy is a critical objective that IRPs seek to achieve through a comprehensive planning approach.
- Planning Reserve Margins are outputs of Resource Adequacy analysis and inputs to resource expansion models.

Distribution system plans or integrated distribution system plans that lay out distribution system needs and plans for addressing those needs.

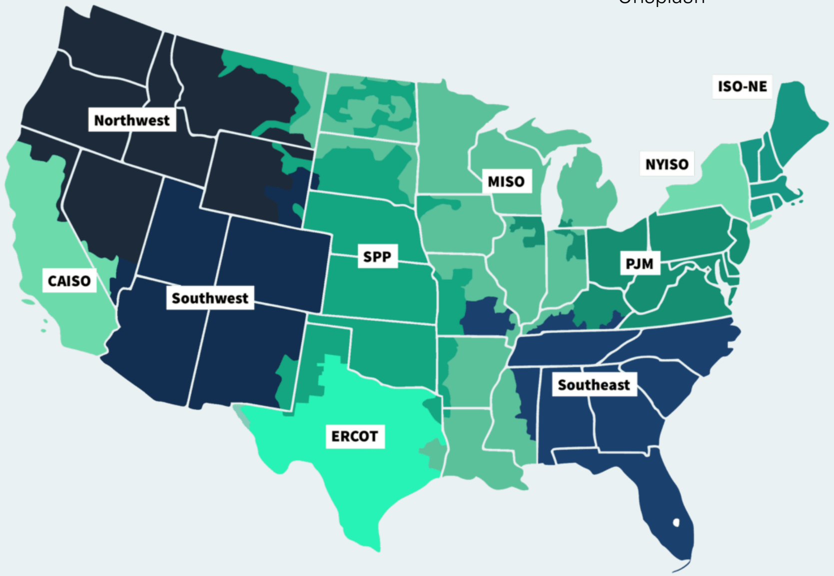
Integrated grid plans that include generation, transmission, and distribution system needs and investments

Topic-specific plans, such as resilience plans, wildfire protection plans, storm protection plans, and clean energy implementation plans, are required in some states

States play a critical and varied role in electric transmission planning

- Transmission-owning utilities and RTOs/ISOs conduct transmission planning as part of **local system reliability studies** to meet NERC (North American Electric Reliability Corporation) reliability standards
    - They also plan for **economic and policy-driven upgrades**
- **FERC Order 1920** requires transmission planning organizations to conduct **recurring regional long-term (20-year) transmission planning**
- In vertically integrated utility states, utilities include **transmission in integrated resource plans**,
- **States roles**:
    - Participate in and influence RTO/ISO planning processes
    - For regional transmission planning (FERC Order 1920), provide input on scenarios and cost allocation
    - Acknowledge or approve transmission in integrated resource plans
    - In some cases, approve transmission costs for cost recovery in rate cases
- FERC approves interstate transmission rates and planning, but **siting and permitting are almost always a state-level responsibility**

Unsplash



From FERC website

Basic Model Types Used in Electricity Planning

Model type	What they do	Examples	Used in what planning types? (G, T, & D)
Load models	Represent consumption of electricity in space and time; inputs to capacity expansion models	Utility-developed load forecast profiles	All
Network topology models	Map and visualize how power grid components are connected; used to analyze electricity flow, identify bottlenecks, and plan expansions. Used by other models, such as powerflow and production cost models	Utility-developed GIS maps of utility systems.	All
Capacity expansion models	Determine the least-cost mix of power generation, storage, and transmission necessary to meet future electricity demand and policy goals	PLEXOS, Resource Planning Model (PRM), Strategist, Aurora, ReEDS	G and some T
Production cost models	Simulate the operation of a specific power system over a relatively short period of time to determine the least cost dispatch of resources to meet load at every hour, every where.	PLEXOS, PROMOD, GridView	G & T
Power flow models	Detailed simulation of the transmission network, including dynamic events that can occur in seconds or less	Positive Sequence Load Flow (PSLF), Power System Simulator for Engineering (PSSE)	T
Distribution system analysis models	Simulate and analyze electric distribution systems, from substation to customer; may include load flow, fault analysis, and evaluating impacts of distributed generation and storage	CYME, SYNERGI, GridLAB-D	D
Probabilistic models	Use probabilities to analyze uncertainties in key variables; models result in a distribution of possible results with associated probabilities	SERVM, GE-MARS	G (D&T)

G = Generation; T = Transmission; D = Distribution

Basic Model Types Used in Electricity Planning

Model type	What they do	Examples	Used in what planning types? (G, T, & D)
Load models	Represent consumption of electricity in space and time; inputs to capacity expansion models	Utility-developed load forecast profiles	All
Network topology models	Map and visualize how power grid components are connected; used to analyze electricity flow, identify bottlenecks, and plan expansions. Used by other models, such as powerflow and production cost models	Utility-developed GIS maps of utility systems.	All
Capacity expansion models	Determine the least-cost mix of power generation, storage, and transmission necessary to meet future electricity demand and policy goals	PLEXOS, Resource Planning Model (PRM), Strategist, Aurora, ReEDS	G and some T
Production cost models	Simulate the operation of a specific power system over a relatively short period of time to determine the least cost dispatch of resources to meet load at every hour, every where.	PLEXOS, PROMOD, GridView	G & T
Power flow models	Detailed simulation of the transmission network, including dynamic events that can occur in seconds or less	Positive Sequence Load Flow (PSLF), Power System Simulator for Engineering (PSSE)	T
Distribution system analysis models	Simulate and analyze electric distribution systems, from substation to customer; may include load flow, fault analysis, and evaluating impacts of distributed generation and storage	CYME, SYNERGI, GridLAB-D	D
Probabilistic models	Use probabilities to analyze uncertainties in key variables; models result in a distribution of possible results with associated probabilities	SERVM, GE-MARS	G (D&T)

G = Generation; T = Transmission; D = Distribution

Basic Model Types Used in Electricity Planning

Model type	What they do	Examples	Used in what planning types? (G, T, & D)
Load models	Represent consumption of electricity in space and time; inputs to capacity expansion models	Utility-developed load forecast profiles	All
Network topology models	Map and visualize how power grid components are connected; used to analyze electricity flow, identify bottlenecks, and plan expansions. Used by other models, such as powerflow and production cost models	Utility-developed GIS maps of utility systems.	All
Capacity expansion models	Determine the least-cost mix of power generation, storage, and transmission necessary to meet future electricity demand and policy goals	PLEXOS, Resource Planning Model (PRM), Strategist, Aurora, ReEDS	G and some T
Production cost models	Simulate the operation of a specific power system over a relatively short period of time to determine the least cost dispatch of resources to meet load at every hour, every where.	PLEXOS, PROMOD, GridView	G & T
Power flow models	Detailed simulation of the transmission network, including dynamic events that can occur in seconds or less	Positive Sequence Load Flow (PSLF), Power System Simulator for Engineering (PSSE)	T
Distribution system analysis models	Simulate and analyze electric distribution systems, from substation to customer; may include load flow, fault analysis, and evaluating impacts of distributed generation and storage	CYME, SYNERGI, GridLAB-D	D
Probabilistic models	Use probabilities to analyze uncertainties in key variables; models result in a distribution of possible results with associated probabilities	SERVM, GE-MARS	G (D&T)

G = Generation; T = Transmission; D = Distribution

Basic Model Types Used in Electricity Planning

Model type	What they do	Examples	Used in what planning types? (G, T, & D)
Load models	Represent consumption of electricity in space and time; inputs to capacity expansion models	Utility-developed load forecast profiles	All
Network topology models	Map and visualize how power grid components are connected; used to analyze electricity flow, identify bottlenecks, and plan expansions. Used by other models, such as powerflow and production cost models	Utility-developed GIS maps of utility systems.	All
Capacity expansion models	Determine the least-cost mix of power generation, storage, and transmission necessary to meet future electricity demand and policy goals	PLEXOS, Resource Planning Model (PRM), Strategist, Aurora, ReEDS	G and some T
Production cost models	Simulate the operation of a specific power system over a relatively short period of time to determine the least cost dispatch of resources to meet load at every hour, every where.	PLEXOS, PROMOD, GridView	G & T
Power flow models	Detailed simulation of the transmission network, including dynamic events that can occur in seconds or less	Positive Sequence Load Flow (PSLF), Power System Simulator for Engineering (PSSE)	T
Distribution system analysis models	Simulate and analyze electric distribution systems, from substation to customer; may include load flow, fault analysis, and evaluating impacts of distributed generation and storage	CYME, SYNERGI, GridLAB-D	D
Probabilistic models	Use probabilities to analyze uncertainties in key variables; models result in a distribution of possible results with associated probabilities	SERVM, GE-MARS	G (D&T)

G = Generation; T = Transmission; D = Distribution

Basic Model Types Used in Electricity Planning

Model type	What they do	Examples	Used in what planning types? (G, T, & D)
Load models	Represent consumption of electricity in space and time; inputs to capacity expansion models	Utility-developed load forecast profiles	All
Network topology models	Map and visualize how power grid components are connected; used to analyze electricity flow, identify bottlenecks, and plan expansions. Used by other models, such as powerflow and production cost models	Utility-developed GIS maps of utility systems.	All
Capacity expansion models	Determine the least-cost mix of power generation, storage, and transmission necessary to meet future electricity demand and policy goals	PLEXOS, Resource Planning Model (PRM), Strategist, Aurora, ReEDS	G and some T
Production cost models	Simulate the operation of a specific power system over a relatively short period of time to determine the least cost dispatch of resources to meet load at every hour, every where.	PLEXOS, PROMOD, GridView	G & T
Power flow models	Detailed simulation of the transmission network, including dynamic events that can occur in seconds or less	Positive Sequence Load Flow (PSLF), Power System Simulator for Engineering (PSSE)	T
Distribution system analysis models	Simulate and analyze electric distribution systems, from substation to customer; may include load flow, fault analysis, and evaluating impacts of distributed generation and storage	CYME, SYNERGI, GridLAB-D	D
Probabilistic models	Use probabilities to analyze uncertainties in key variables; models result in a distribution of possible results with associated probabilities	SERVM, GE-MARS	G (D&T)

G = Generation; T = Transmission; D = Distribution

Basic Model Types Used in Electricity Planning

Model type	What they do	Examples	Used in what planning types? (G, T, & D)
Load models	Represent consumption of electricity in space and time; inputs to capacity expansion models	Utility-developed load forecast profiles	All
Network topology models	Map and visualize how power grid components are connected; used to analyze electricity flow, identify bottlenecks, and plan expansions. Used by other models, such as powerflow and production cost models	Utility-developed GIS maps of utility systems.	All
Capacity expansion models	Determine the least-cost mix of power generation, storage, and transmission necessary to meet future electricity demand and policy goals	PLEXOS, Resource Planning Model (PRM), Strategist, Aurora, ReEDS	G and some T
Production cost models	Simulate the operation of a specific power system over a relatively short period of time to determine the least cost dispatch of resources to meet load at every hour, every where.	PLEXOS, PROMOD, GridView	G & T
Power flow models	Detailed simulation of the transmission network, including dynamic events that can occur in seconds or less	Positive Sequence Load Flow (PSLF), Power System Simulator for Engineering (PSSE)	T
Distribution system analysis models	Simulate and analyze electric distribution systems, from substation to customer; may include load flow, fault analysis, and evaluating impacts of distributed generation and storage	CYME, SYNERGI, GridLAB-D	D
Probabilistic models	Use probabilities to analyze uncertainties in key variables; models result in a distribution of possible results with associated probabilities	SERVM, GE-MARS	G (D&T)

G = Generation; T = Transmission; D = Distribution

Basic Model Types Used in Electricity Planning

Model type	What they do	Examples	Used in what planning types? (G, T, & D)
Load models	Represent consumption of electricity in space and time; inputs to capacity expansion models	Utility-developed load forecast profiles	All
Network topology models	Map and visualize how power grid components are connected; used to analyze electricity flow, identify bottlenecks, and plan expansions. Used by other models, such as powerflow and production cost models	Utility-developed GIS maps of utility systems.	All
Capacity expansion models	Determine the least-cost mix of power generation, storage, and transmission necessary to meet future electricity demand and policy goals	PLEXOS, Resource Planning Model (PRM), Strategist, Aurora, ReEDS	G and some T
Production cost models	Simulate the operation of a specific power system over a relatively short period of time to determine the least cost dispatch of resources to meet load at every hour, every where.	PLEXOS, PROMOD, GridView	G & T
Power flow models	Detailed simulation of the transmission network, including dynamic events that can occur in seconds or less	Positive Sequence Load Flow (PSLF), Power System Simulator for Engineering (PSSE)	T
Distribution system analysis models	Simulate and analyze electric distribution systems, from substation to customer; may include load flow, fault analysis, and evaluating impacts of distributed generation and storage	CYME, SYNERGI, GridLAB-D	D
Probabilistic models	Use probabilities to analyze uncertainties in key variables; models result in a distribution of possible results with associated probabilities	SERVM, GE-MARS	G (D&T)

G = Generation; T = Transmission; D = Distribution

Basic Model Types Used in Electricity Planning

Model type	What they do	Examples	Used in what planning types? (G, T, & D)
Load models	Represent consumption of electricity in space and time; inputs to capacity expansion models	Utility-developed load forecast profiles	All
Network topology models	Map and visualize how power grid components are connected; used to analyze electricity flow, identify bottlenecks, and plan expansions. Used by other models, such as powerflow and production cost models	Utility-developed GIS maps of utility systems.	All
Capacity expansion models	Determine the least-cost mix of power generation, storage, and transmission necessary to meet future electricity demand and policy goals	PLEXOS, Resource Planning Model (PRM), Strategist, Aurora, ReEDS	G and some T
Production cost models	Simulate the operation of a specific power system over a relatively short period of time to determine the least cost dispatch of resources to meet load at every hour, every where.	PLEXOS, PROMOD, GridView	G & T
Power flow models	Detailed simulation of the transmission network, including dynamic events that can occur in seconds or less	Positive Sequence Load Flow (PSLF), Power System Simulator for Engineering (PSSE)	T
Distribution system analysis models	Simulate and analyze electric distribution systems, from substation to customer; may include load flow, fault analysis, and evaluating impacts of distributed generation and storage	CYME, SYNERGI, GridLAB-D	D
Probabilistic models	Use probabilities to analyze uncertainties in key variables; models result in a distribution of possible results with associated probabilities	SERVM, GE-MARS	G (D&T)

G = Generation; T = Transmission; D = Distribution

Data and Information Critical to Power System Planning

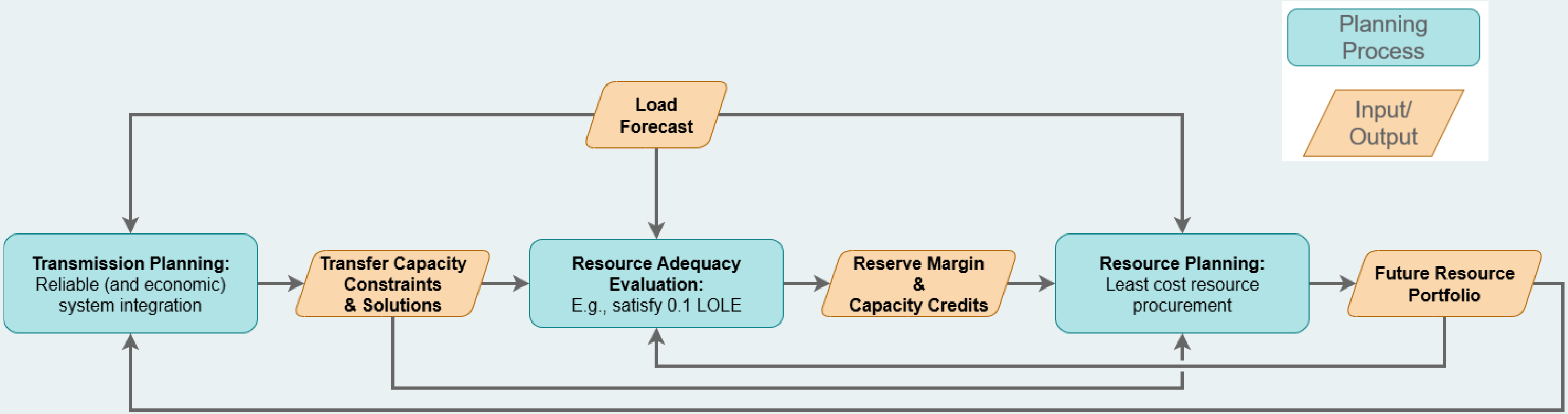
- Historical
  - End-use demand
  - Generator capacity, outage, performance, and fuel & O&M costs
  - Weather and resource availability
  - Asset age and condition
- Policy and RA objectives
- Forecasts
  - End-use demand (aka load)
  - Generator capacity, retirements, outage, performance, and cost
  - Fuel prices
  - Weather and resource availability
  - New generation cost, capacity/performance, and siting options
- Infrastructure options
  - Supply chain & availability
  - Costs of building and operating assets
  - Capabilities

→ Total revenue requirement, customer rate impacts, and risk profile

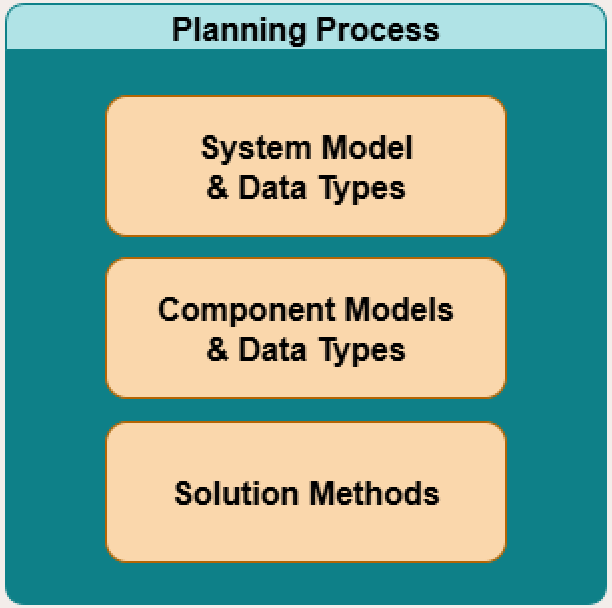
Digging Deeper into Models and Data

Planning processes inform one another

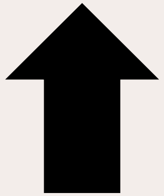
- The outputs from each process feed into the other processes
- All processes happen on a cyclical timeline, so the starting point is somewhat arbitrary



Components of a planning processes



Require **different models and data** types to execute on the methodology



Each process adopts a **different solution methods** to achieve its aims

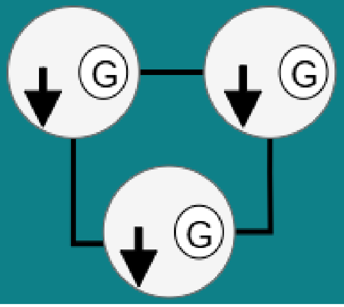
System Models & Data Types

Model Domains

Policy Models | Engineering Models

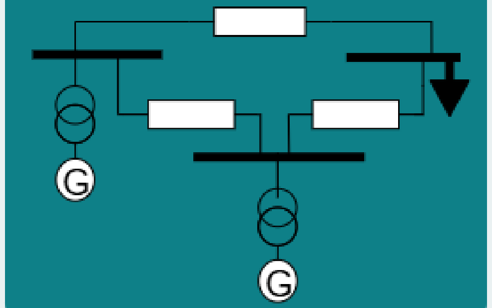
Pipe & Bubble

- load and generation aggregated in bubbles/zones
- transmission modeled as pipes
- ↓ little to no representation of physics



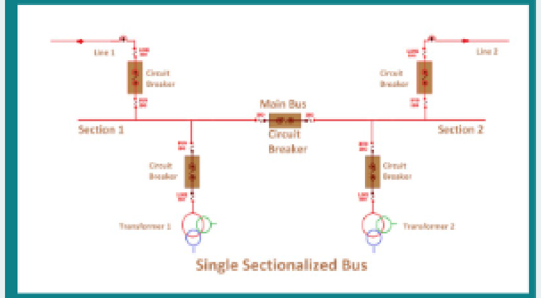
Bus-Branch

- load and generation at electric buses
- transmission modeled as branches with impedance
- ↓ Some representation of physics



Node-Breaker

- Load, generation and transmission similar to Bus-Branch
- Breakers states capture substation reconfiguration



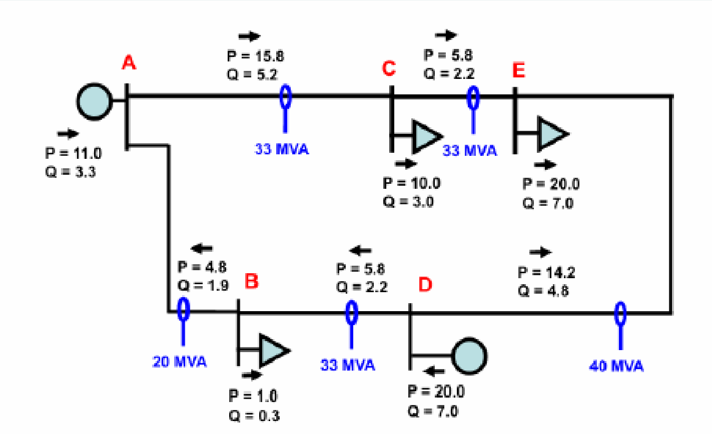
Tool Examples

- Capacity Expansion Tools
- Production Cost Tools
- Power Flow Tools

Component Models & Data Types

Static (Snapshot)

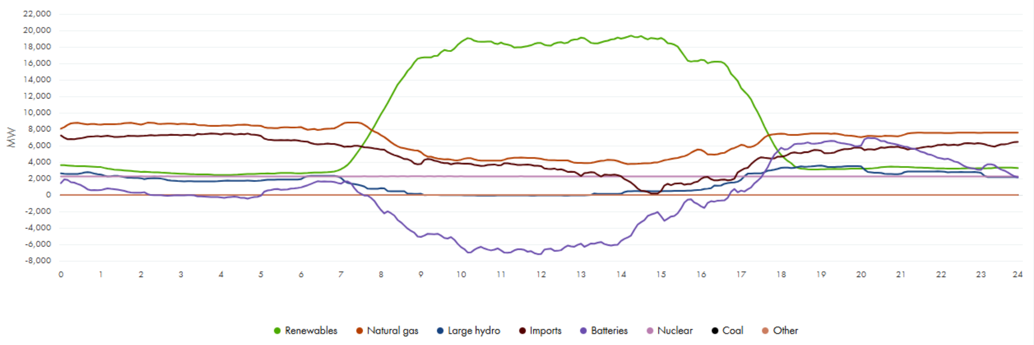
- Single value
- E.g., load or generation set point



Source: https://www.southeasternrtp.com/docs/general/2025/2025_SERTP_1st_Qtr_Presentation.pdf

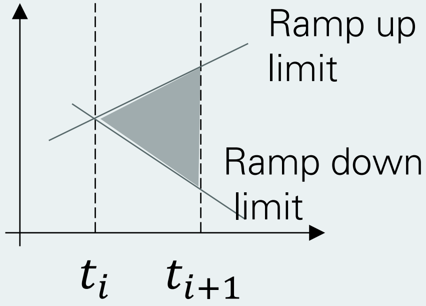
Time Series

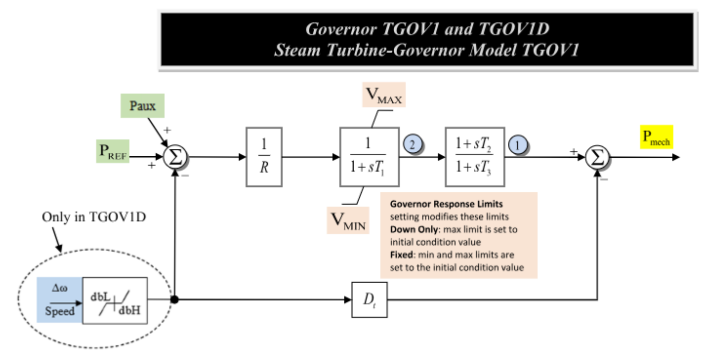
- Multiple values at some resolution
- E.g., hourly resources, loads, etc.



Dynamic

- Values evolve through **differential** or **difference** equations
- Differential: turbine, generator, and motor models
- Difference: ramp rates, charging rates

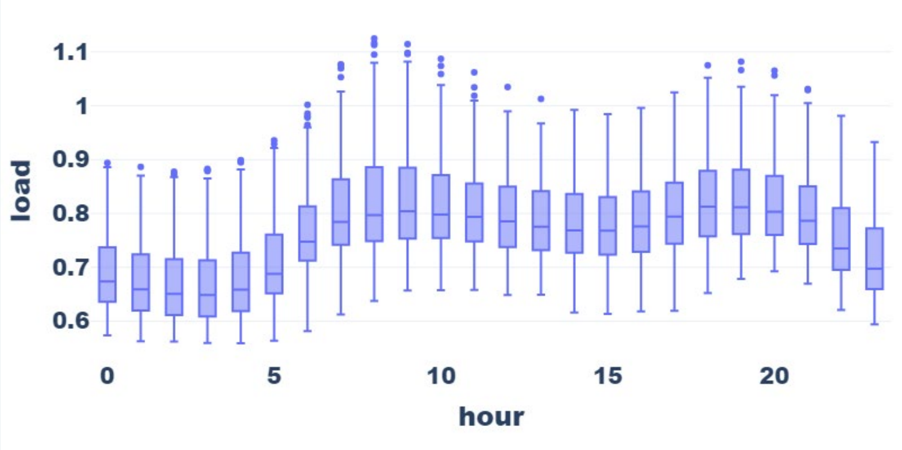




Source: https://www.powerworld.com/WebHelp/Content/TransientModels_HTML/

Probabilistic

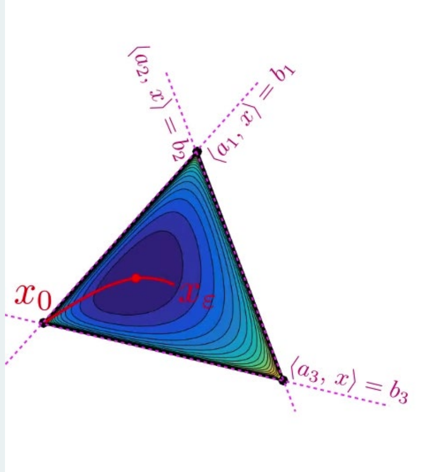
- Static or time series distribution of values
- E.g., p10, p50, p90 load forecasts, or scenarios



Solution Methods

Optimization Models (Deterministic)

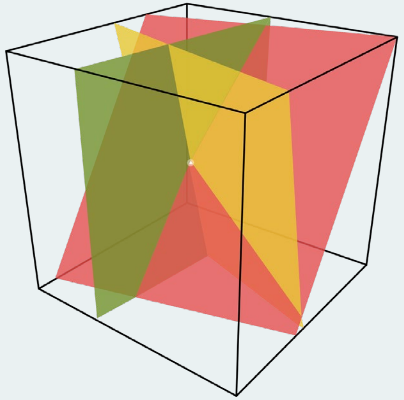
- Include a cost function on variables (e.g., capital costs)



Source: https://en.wikipedia.org/wiki/File:Interior_Point_Trajectory.webm

Simulation Models (Deterministic)

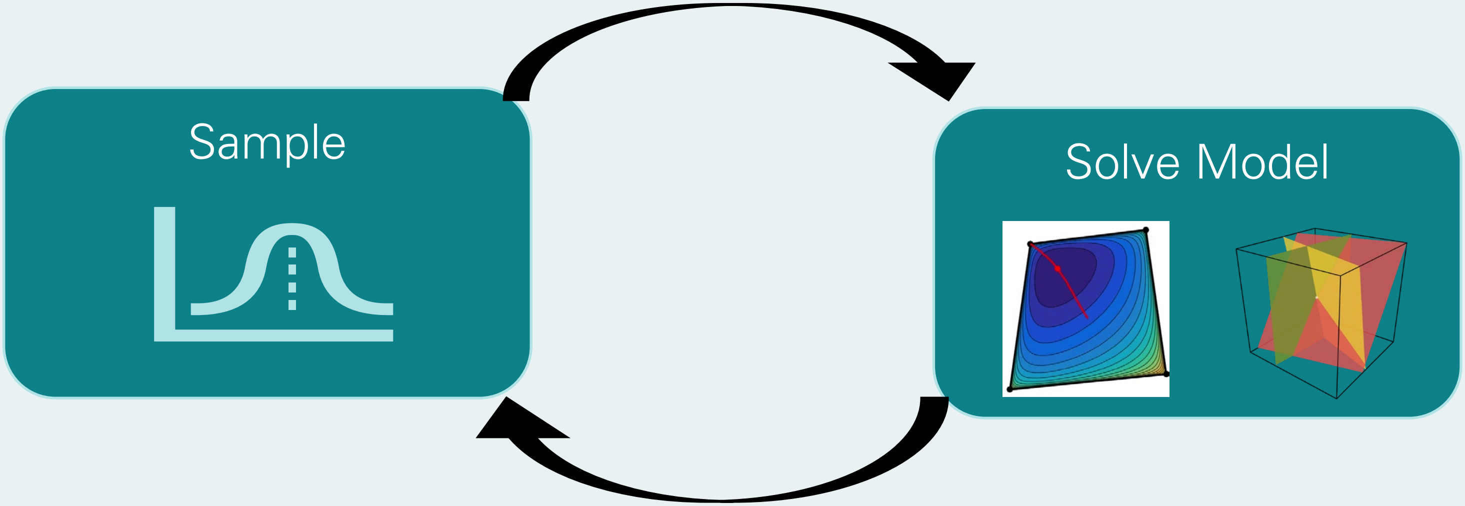
- Solve a set of equations to determine system state (e.g., system voltages and flows)



Source: Fred the Oyster, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=35349662

Probabilistic/Stochastic

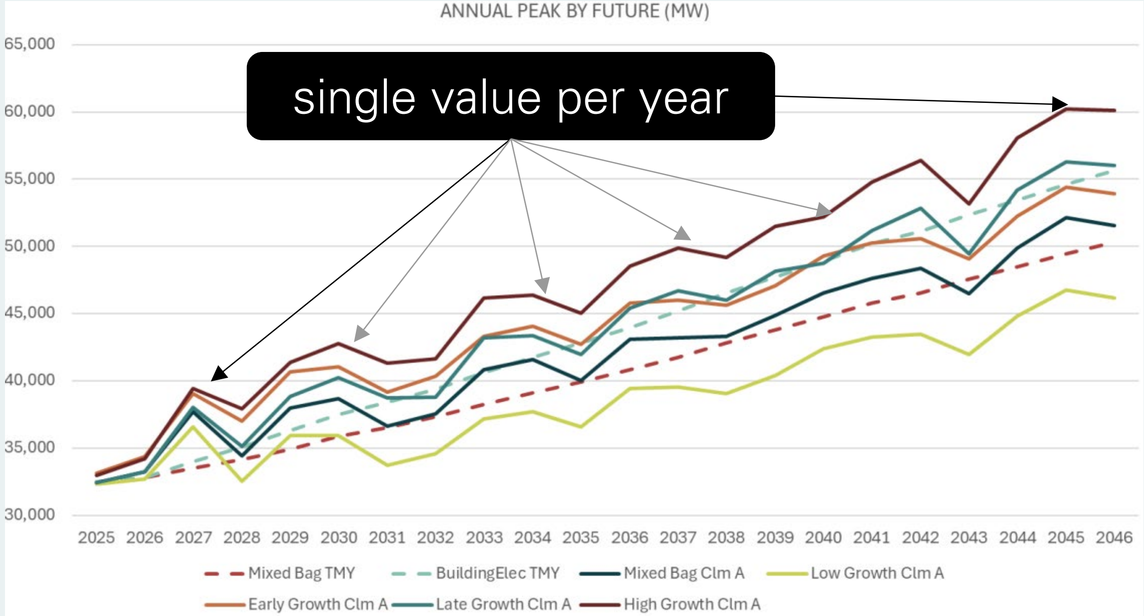
- Iteratively solve models using samples from probabilistic model data
  - Load
  - generation forced outage rate (FOR)
  - other



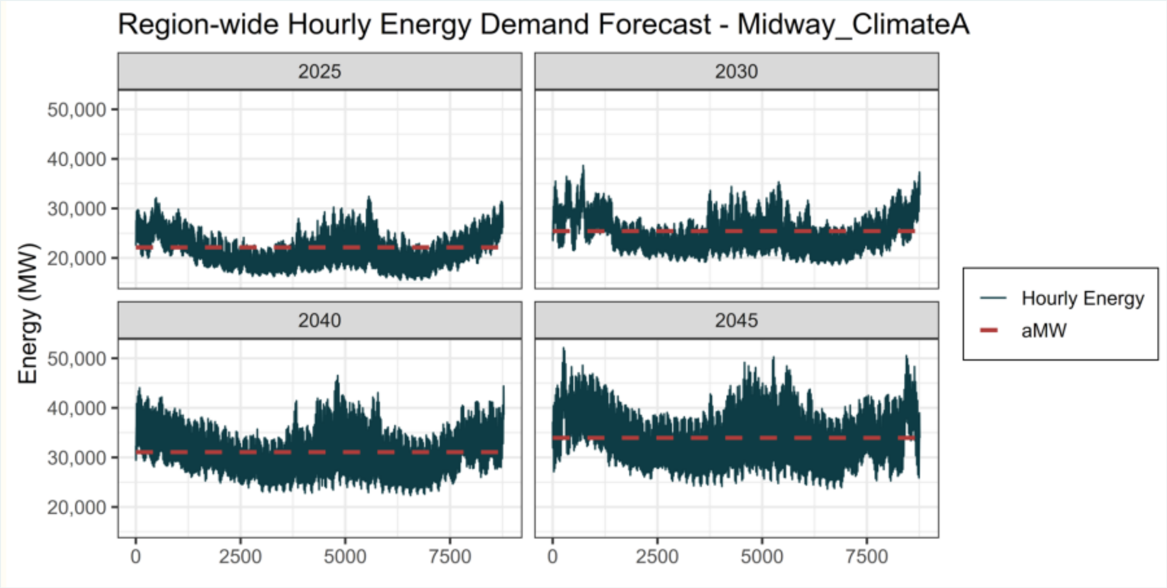
Load Model Example

- NW Power and Conservation Council's 9th Power Plan Demand Forecast

Static/Snapshot Peak Load



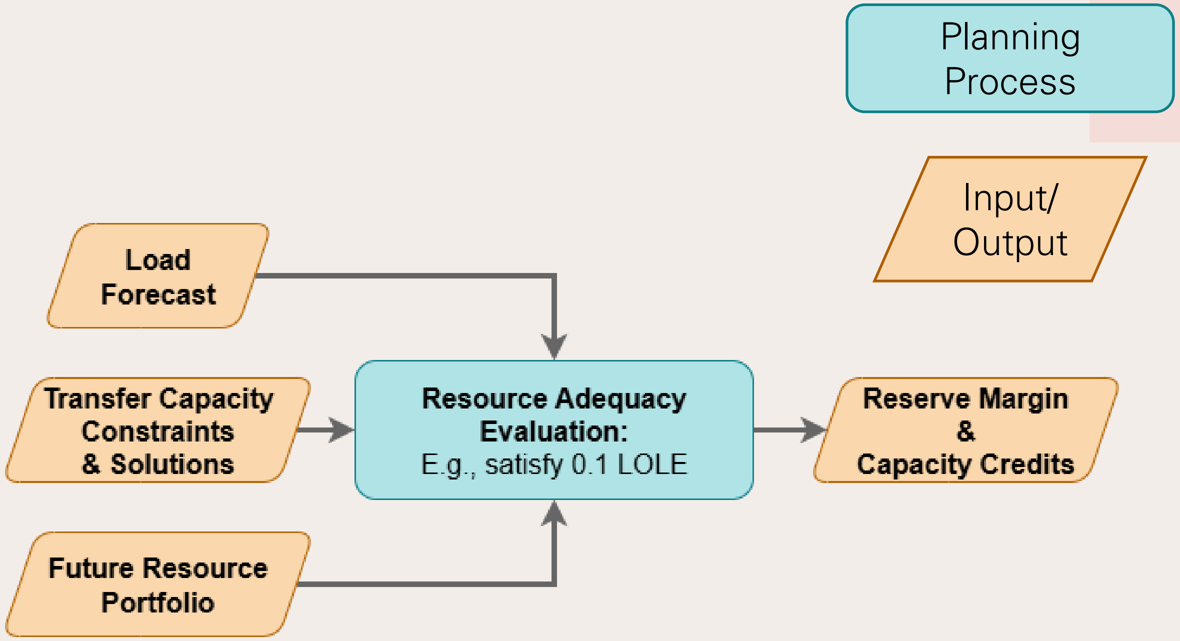
Time Series Hourly Load



8760 values per year

Source: https://www.nwcouncil.org/fs/19380/2025_0429_2.pdf

Resource Adequacy



Objective: planning reserve margin and capacity certification

System Model: pipe & bubble

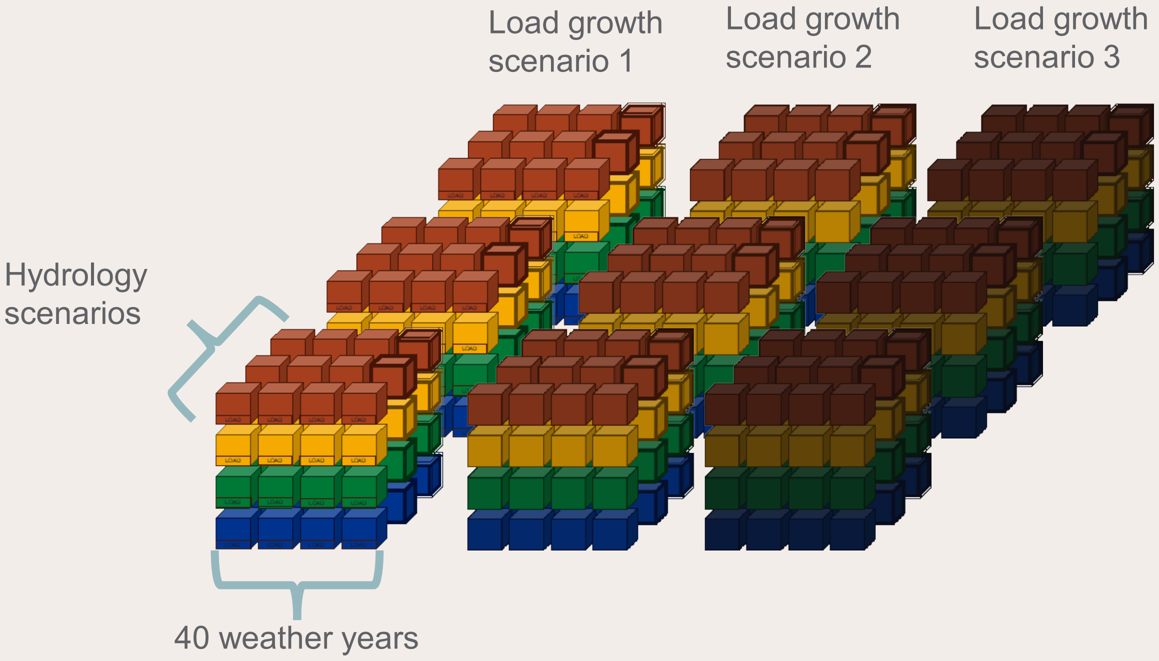
- Pipe & bubble at regional level

Component Models:

- Hourly time-series load and generation inputs
- Monte Carlo for probabilistic results
- Dynamic time difference resource constraints (e.g., ramp-rates)

Solution Methods: probabilistic + (optimization)

- Sample from load distributions, generator outages, generation profiles, etc.
- Evaluate for unserved load (optimization or other dispatch approach)

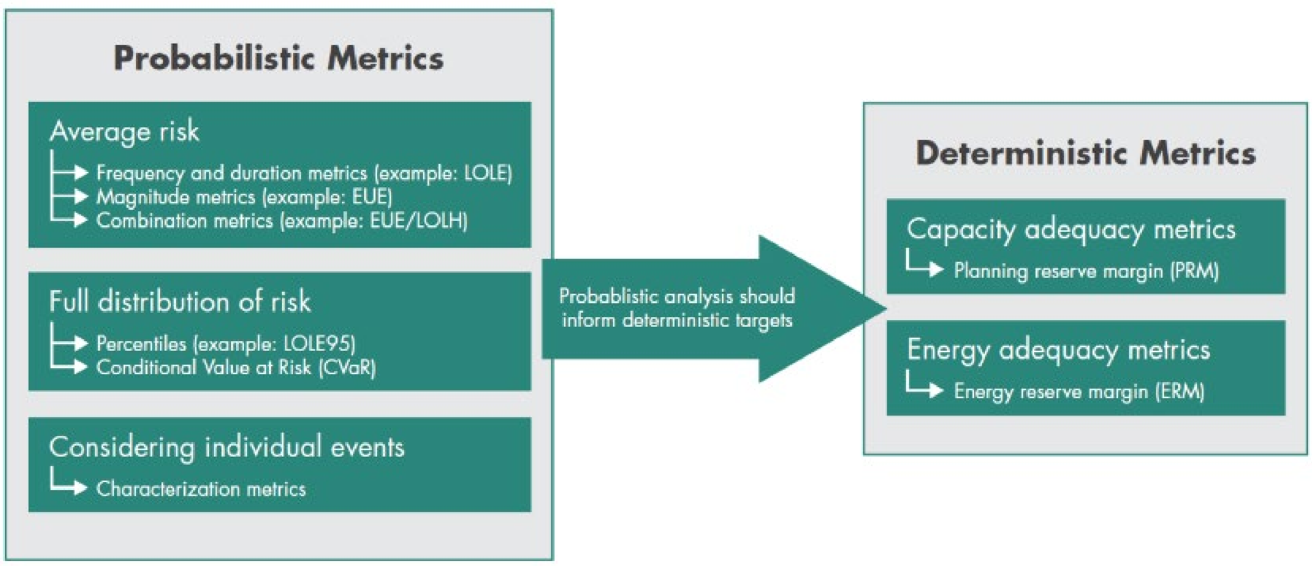


Rich datasets to capture possible outcomes

Dimensions of RA-Related Reliability Metrics

Industry standard for reliability is Loss of Load Expectation (LOLE), where on average the entire system can withstand **one** day with **any amount** (frequency, duration) (LOLD) of unserved load in **10 years**.

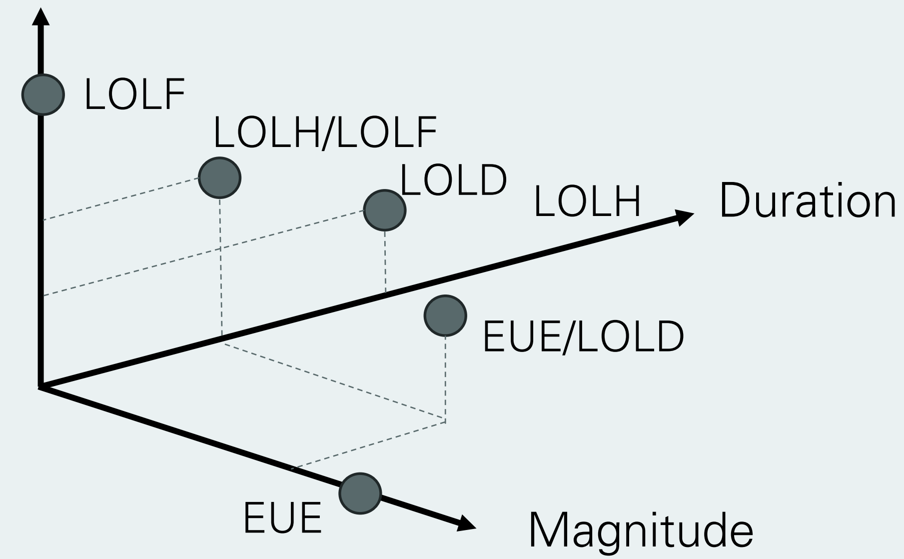
Expected Unserved Energy (EUE) can help to communicate the **total impact** of any single event to the full system.



Source: https://msites.epri.com/resource-adequacy/metrics/metrics-explainers

Probabilistic metrics are translated to deterministic requirements in resource expansion

Metric	Symbol	What it measures
(Normalized) Expected Unserved Energy	(n)EUE	Expected annual unserved energy, (normalized by system peak load).
Loss of Load Hours (Form of LOLE)	LOLH	Expected count of event hours per study period
Loss of Load Days (Form of LOLE)	LOLD	Expected count of event days per study period
Loss of Load Frequency (Form of LOLE)	LOLF	Expected count of events per study period



Capacity Expansion Models: Resource Planning

Objective: used to explore investments decision over years to decades planning horizon.

- What technologies to build and how much of each?
- When to build those technologies?
- Where to build those technologies?

Input Data:

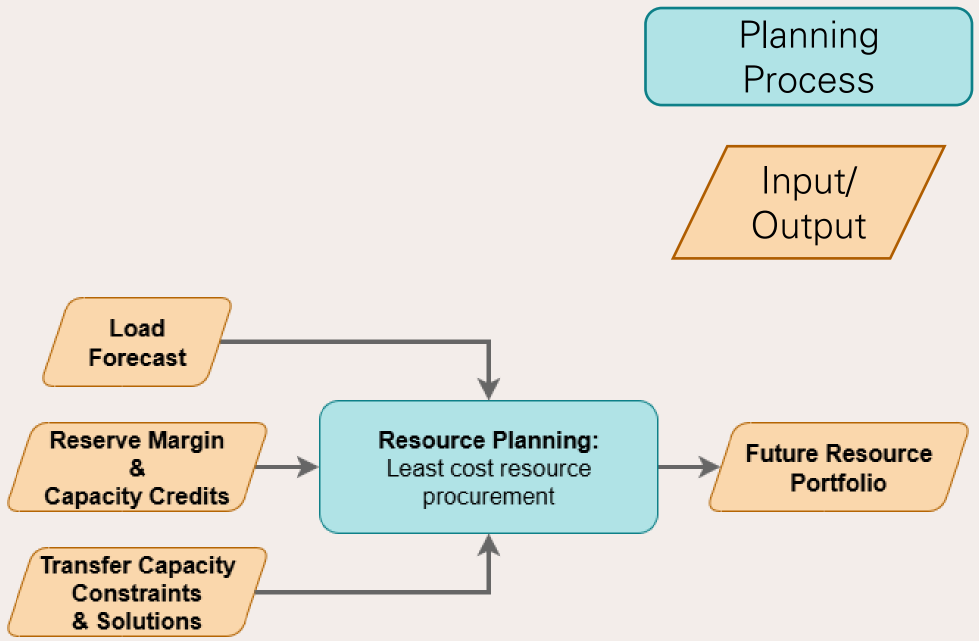
- Receives forecasted load, reserve margin (RA) and transmission capacity (Transmission planning)
- Additional: policy requirements, cost projections

Requires tradeoffs between model fidelity and computational complexity

- **System Model**: typically pipe & bubble
- **Component Data**: semi-time series (characteristic hours of year rather than 8760)

Solution Method: Optimization

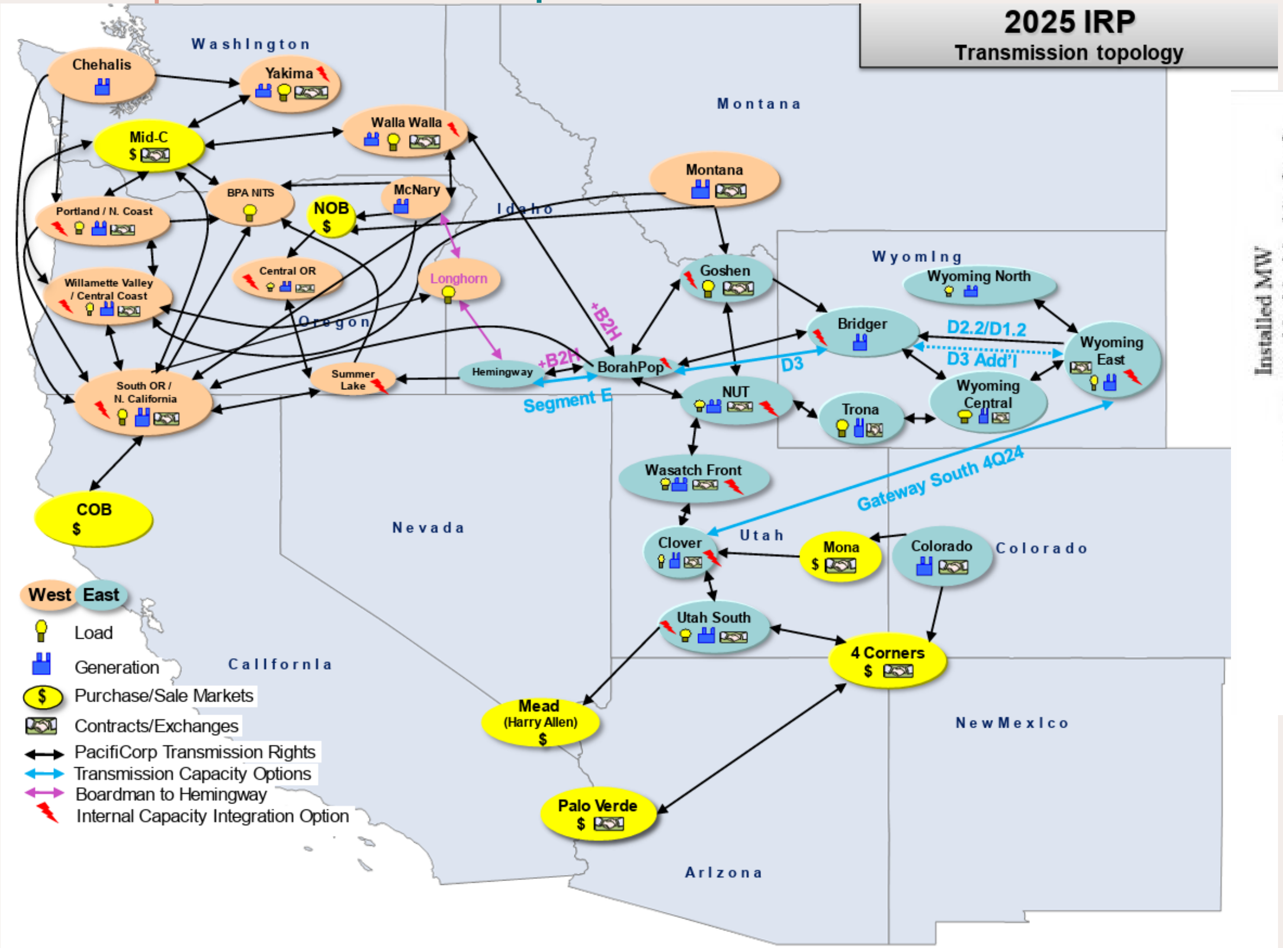
- Some scenario analysis



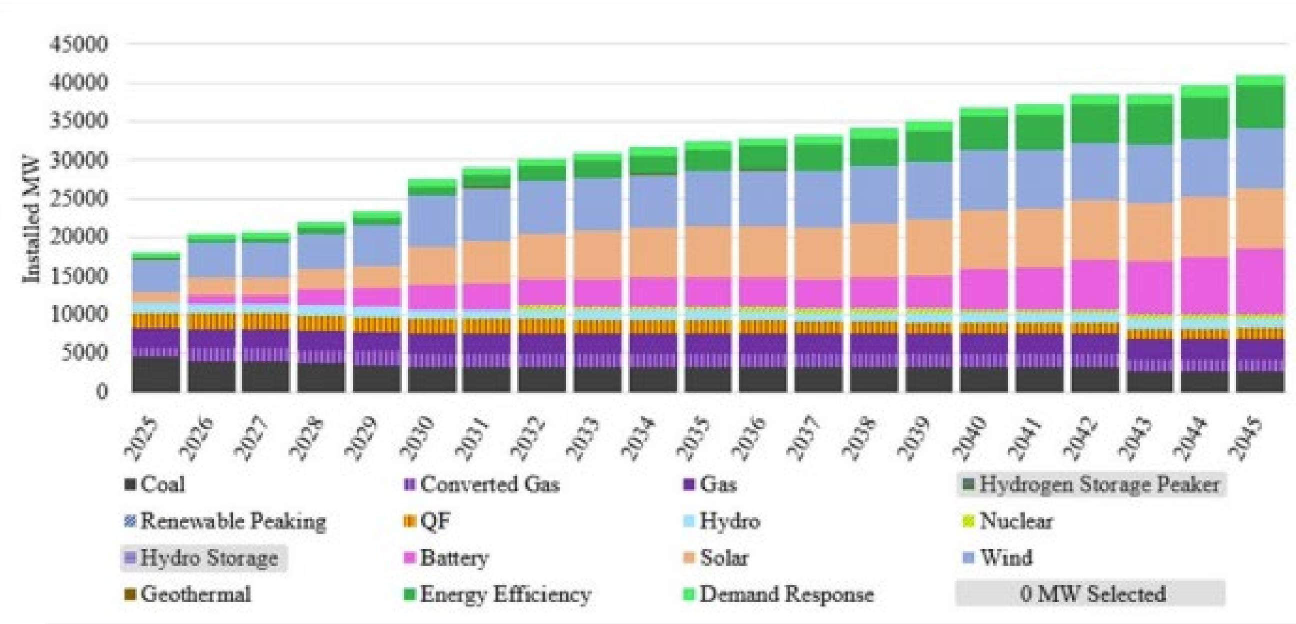
Source: https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/integrated-resource-plan/2025-irp/2025_IRP_Vol_1.pdf

Capacity Expansion Models: Resource Planning Examples (PacifiCorp 2025 IRP)

Pipe & bubble representation with transmission options and constraints



Selected Resource Portfolio



Source: https://www.pacificorp.com/content/dam/pcorp/documents/en/pacificorp/energy/integrated-resource-plan/2025-irp/2025_IRP_Vol_1.pdf

Production Cost Models

Objective: operate the system at minimum cost

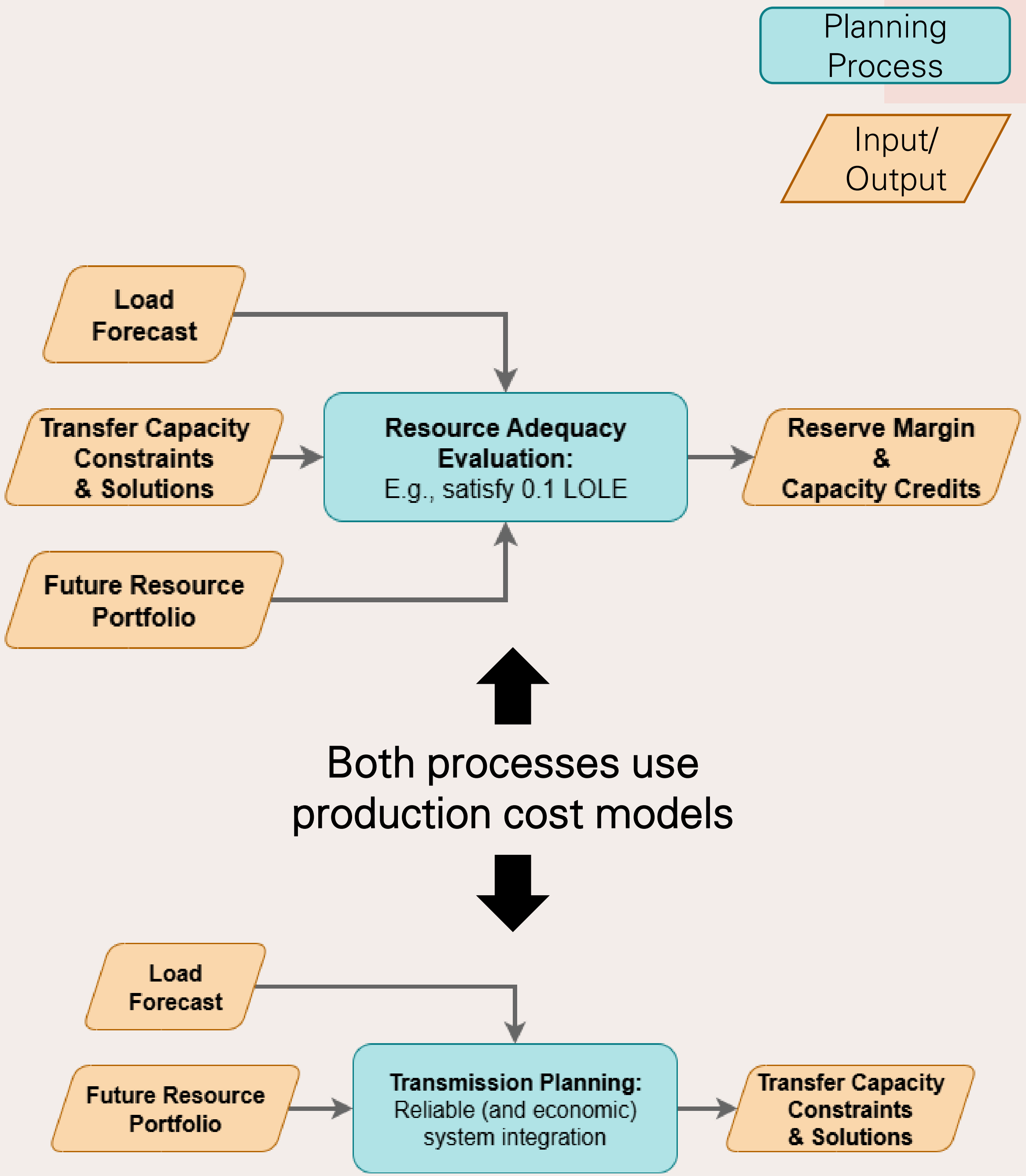
System Model:

- **Pipe & Bubble**: underlying model for RA tools like SERVM
- **Bus-Branch**: economic evaluation of proposed transmission projects

Component Data:

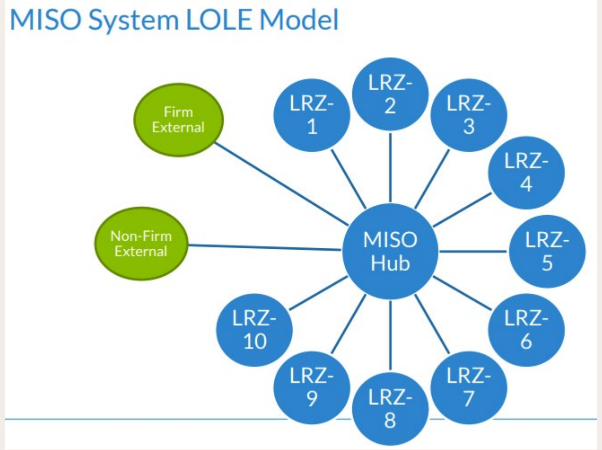
- Hourly time-series load and generation inputs
- Distribution + Monte Carlo for probabilistic results
- Dynamic time difference resource constraints (e.g., ramp-rates)

Solution Method: optimization



Production Cost Models: Examples

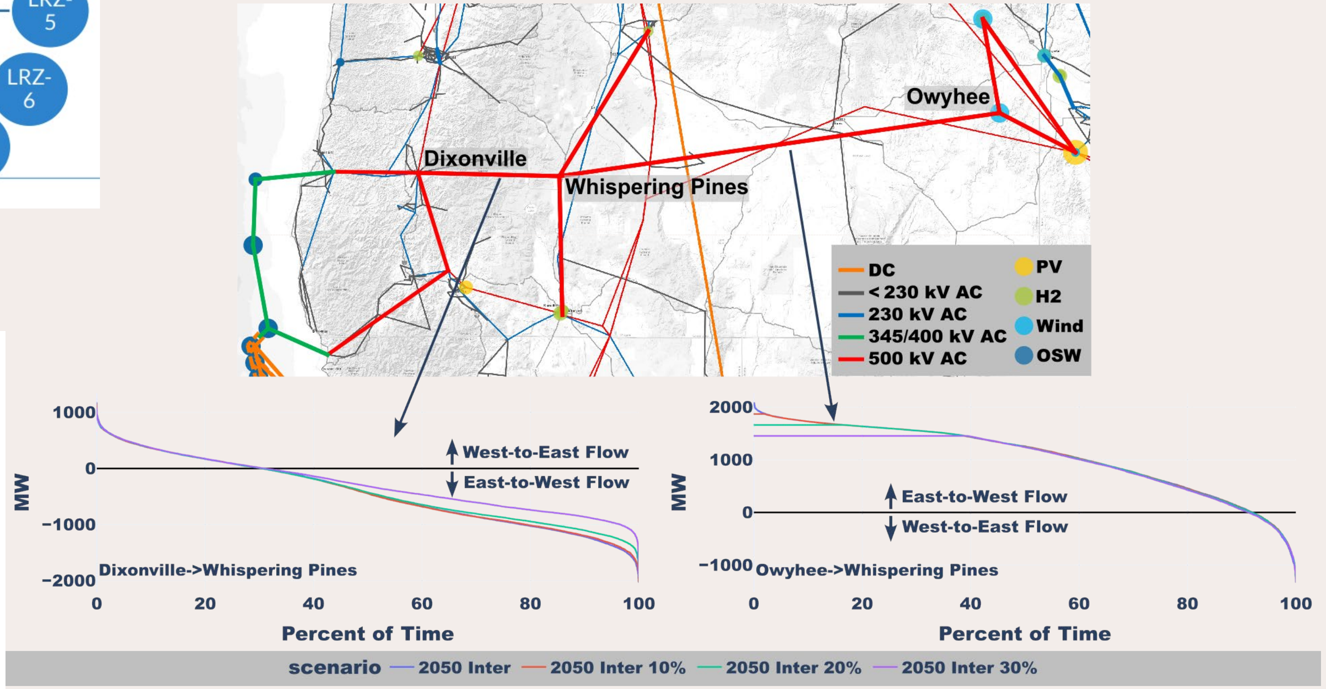
MISO calculates load loss risk at hourly and zonal resolution using pipe & bubble system model



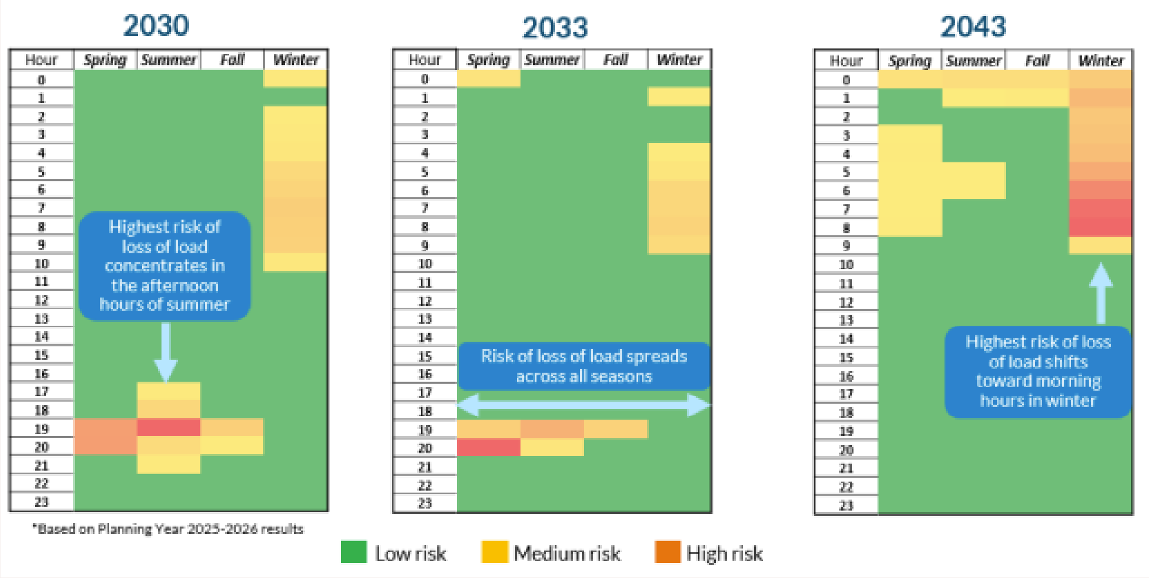
(typical RA context)

Hourly and nodal resolution capture detailed congestion patterns

(Transmission planning context)

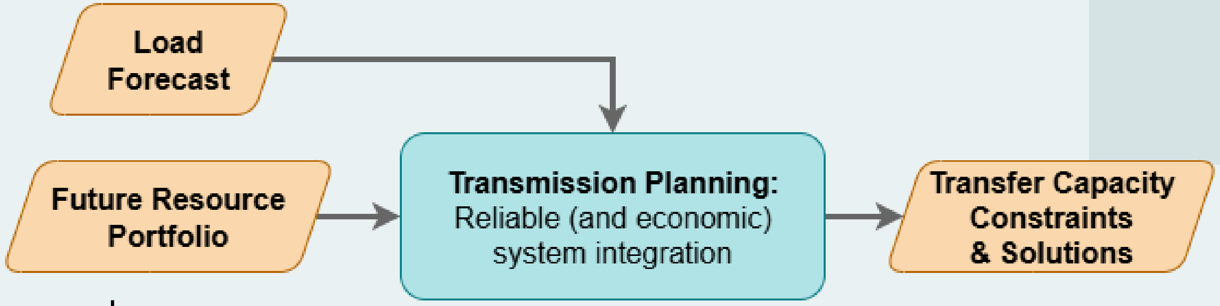


T. C. Douville et al., "West Coast Offshore Wind Transmission Study," Pacific Northwest National Laboratory (PNNL), Richland, WA (United States), Jan. 2025 [Online]. Available: https://www.osti.gov/biblio/2500279

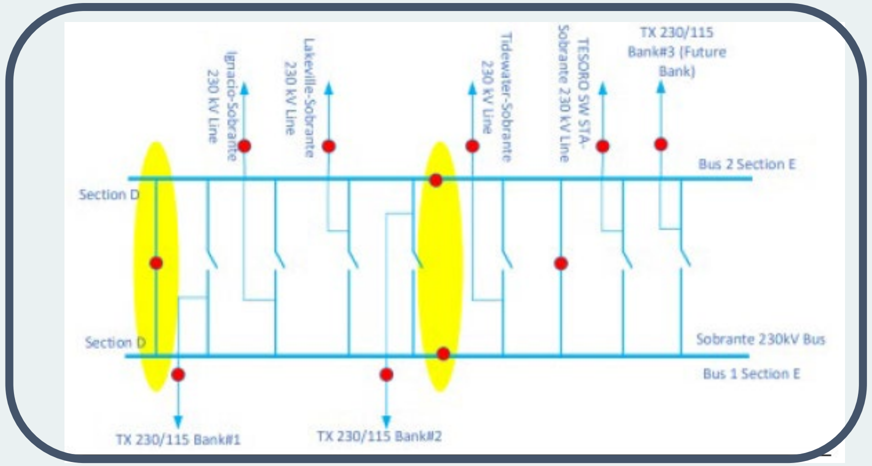


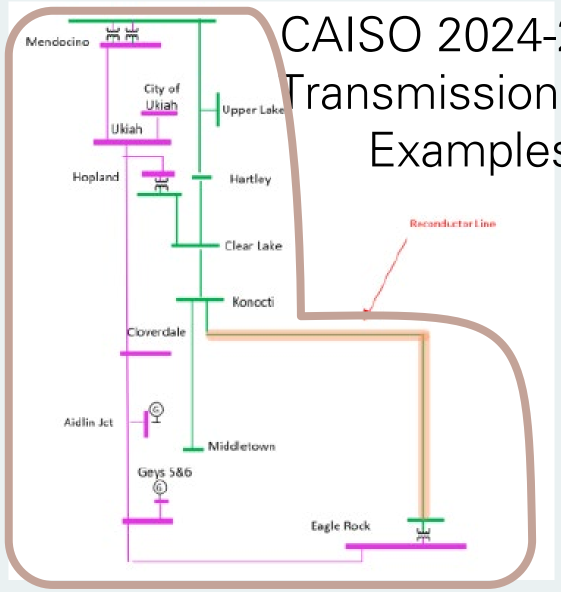
Source: https://cdn.misoenergy.org/2024%20RRA%20Report_Final676241.pdf

Transmission Planning



- **Objective**: Integration of resources, reliable and economic delivery
- System Model
  - Bus-branch and node-breaker
- Component models
  - Static and dynamic
  - Time series for PCM
- Solution Methods:
  - Simulation (power flow tools): to capture system behavior
    - Power flow studies
    - Contingency analysis
    - Dynamic studies
  - Optimization (PCM tools): to evaluate economics of operation





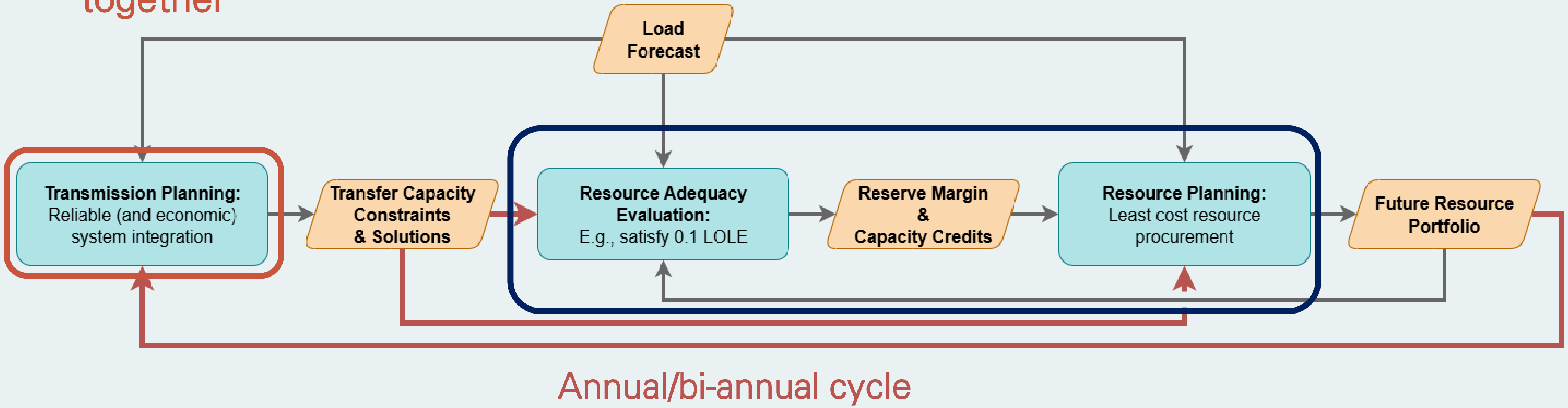
CAISO 2024-2025 Transmission Plan Examples

Note that RA outputs are currently **not** reflected as inputs into transmission planning

Source: https://stakeholdercenter.caiso.com/InitiativeDocuments/BoardApproved-2024-2025-TransmissionPlan.pdf

Current Debate: Accounting for the RA Value of Transmission

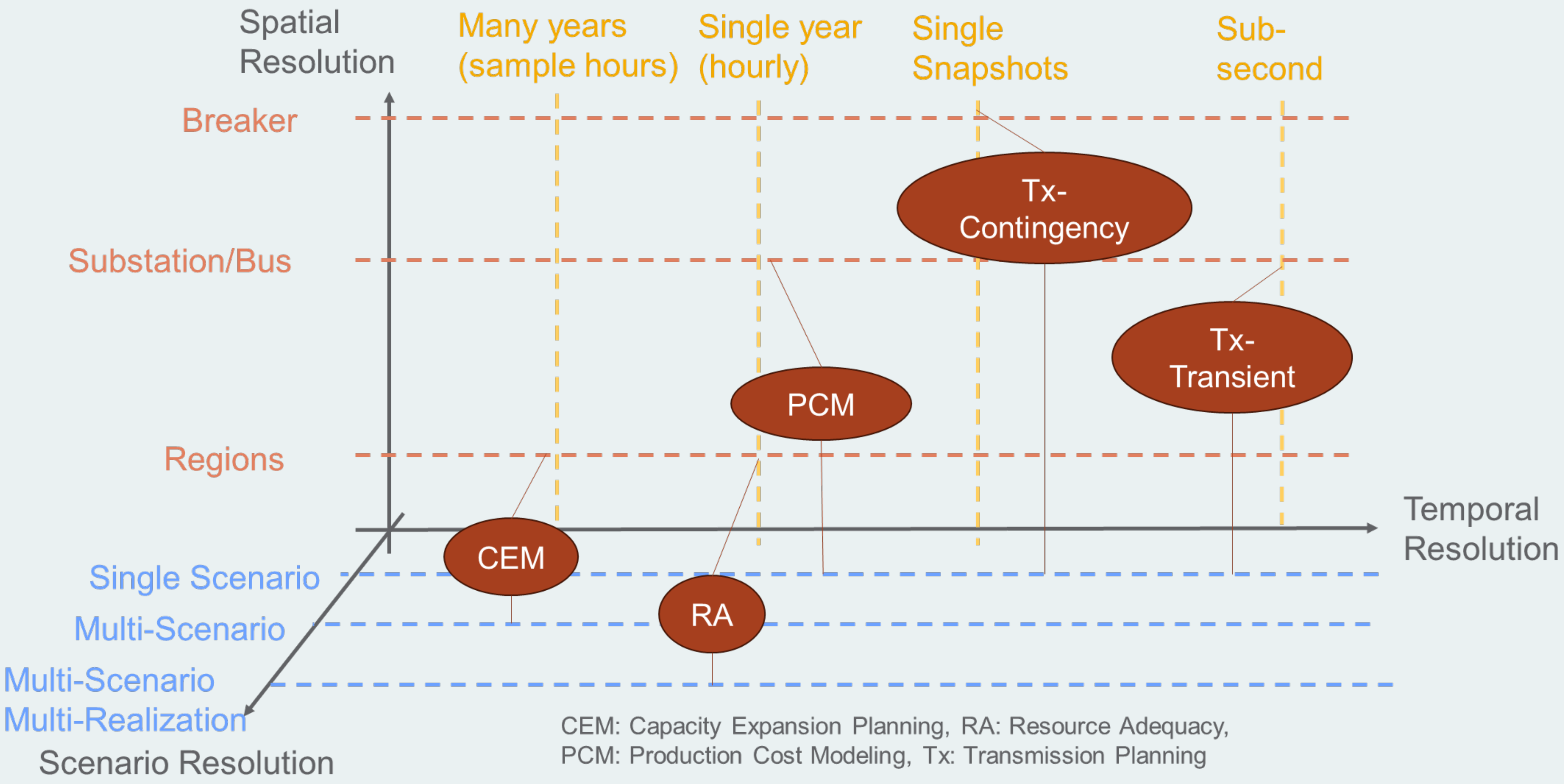
- Current processes have a time lag between the transmission and resource portions
  - Transmission inputs to RA are **fixed**
  - Resource inputs to RA are (largely) **fixed***
- There is no straight-forward process to evaluate **RA benefit** provided by **new transmission** to access **new and different resources** → Coupling all three process together



*MISO has recently introduced a calibration loop between the resource expansion and resource adequacy assessment

Core challenge of linking planning processes is reconciling very different scales (time, spatial, and futures) on multiple dimensions

Modeling Dimensions



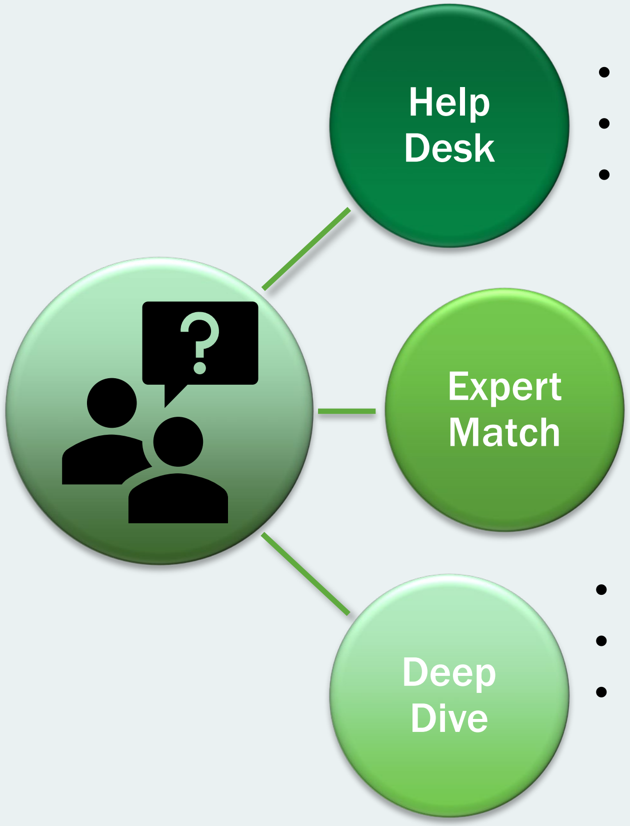
CEM: Capacity Expansion Planning, RA: Resource Adequacy,
PCM: Production Cost Modeling, Tx: Transmission Planning

Summary

- **Utility planning processes may vary** by state based on regional or organizational constructs.
- **Load forecasting is central** to all three types of utility planning; generation/resource, transmission, and distribution system planning.
- **Resource adequacy analysis** is the process of making sure you can serve the load everywhere, all the time, under different conditions.
- Different plans and **planning processes feed into each other.**
- Planning processes **inform each other.**
- Planning processes and underlying models **operate at different time and spatial granularity**, which necessitate different assumptions and can complicate coordination.
- The degree to which **transmission and resource planning interact** impacts the types of solutions that can be chosen to address RA.
  - This is still an **active area** of debate and innovation.

DOE-funded Resources and Assistance for State Energy Offices and Regulators Program

https://StateTAProgram.lbl.gov



Help Desk

- Online intake form w/ rolling review
- SME provides up to **4 person-hours of support**
- Intake form and support available now

Expert Match

- Online intake form w/ rolling review
- SME provides up to **100 person-hours of support**
- Intake form and support available now

Deep Dive

- Detailed application form in planned ~6-month cycle
- Team of SMEs provide **100+ person-hours of support**
- Detailed online application available soon

Pacific Northwest
NATIONAL LABORATORY

Juliet Homer | Juliet.Homer@pnnl.gov

Eran Schweitzer | Eran.Schweitzer@pnnl.gov