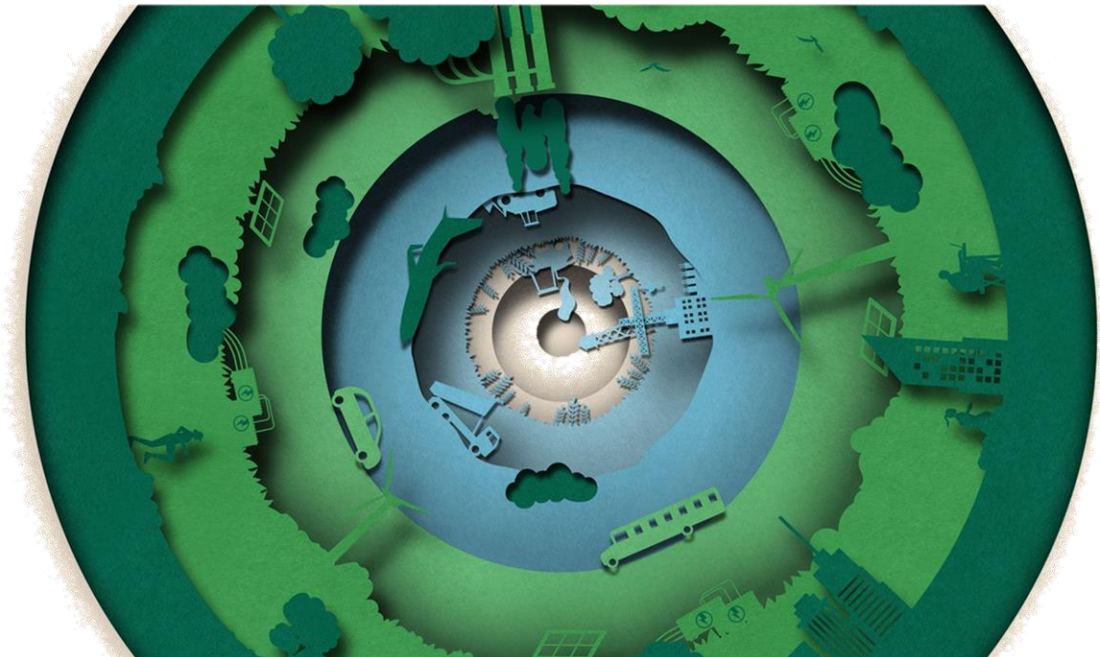


# Breakthrough Energy



**Network of investment funds, philanthropic programs, policy advocacy, etc**

- Breakthrough Energy Catalyst**
- Breakthrough Energy Fellows**
- Breakthrough Energy Ventures (BEV)**
- BEV Europe**
- Breakthrough Energy Sciences**
- Breakthrough Energy U.S. Policy & Advocacy**



# Breakthrough Energy: BE Ventures



## Electricity Storage



## Solar/Wind/Hydro



## New Loads



## Geothermal



## Nuclear Fusion



## Emerging Market



## T&D, Grid Optimization



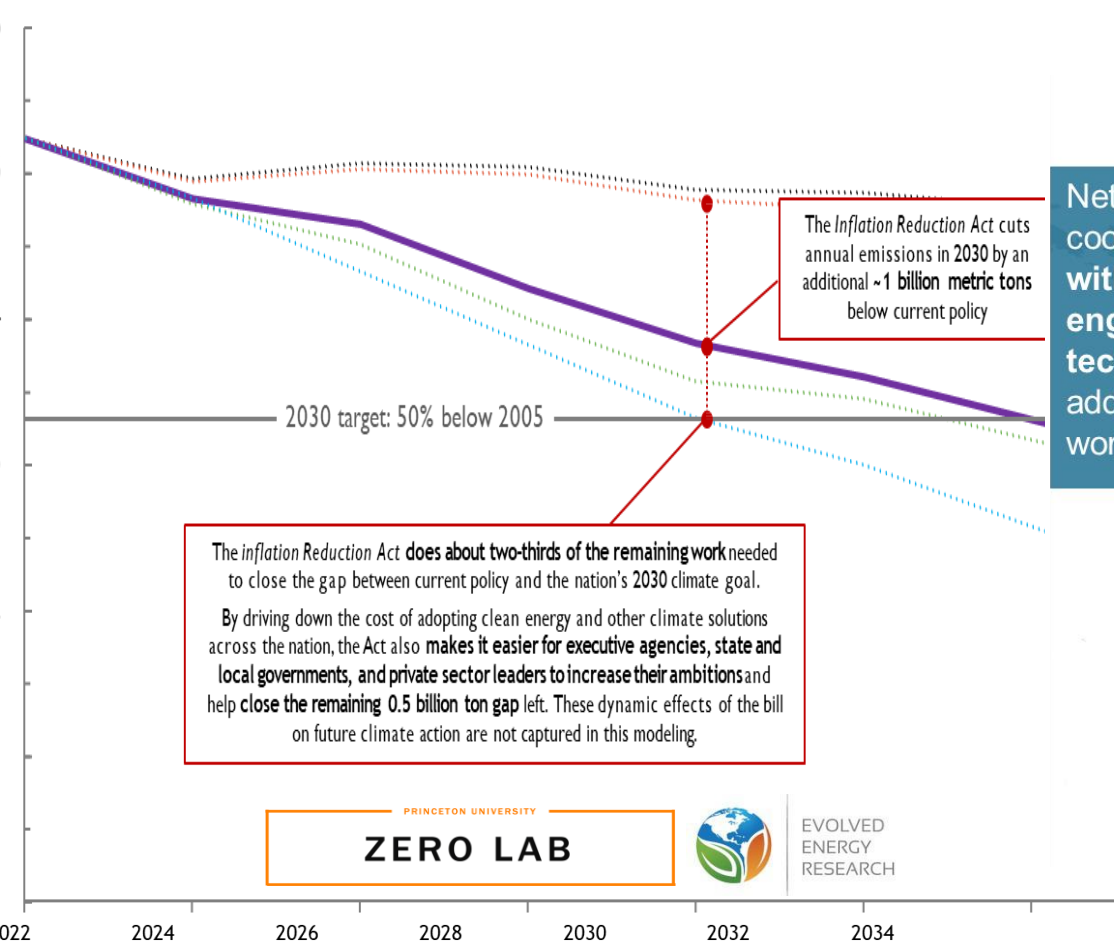
# Breakthrough Energy: Policy & Advocacy



## Policy solutions can lower the Green Premium

### Modeled Net U.S. Greenhouse Gas Emissions (Including Land Carbon Sinks)

billion metric tons CO<sub>2</sub>-equivalent (Gt CO<sub>2</sub>-e)<sup>1</sup>



Net Zero World has deep technical cooperation with 8 partner countries with strong minister level engagement and robust joint technical teams, with the expected addition of Vietnam soon and affiliated work in India and South Africa

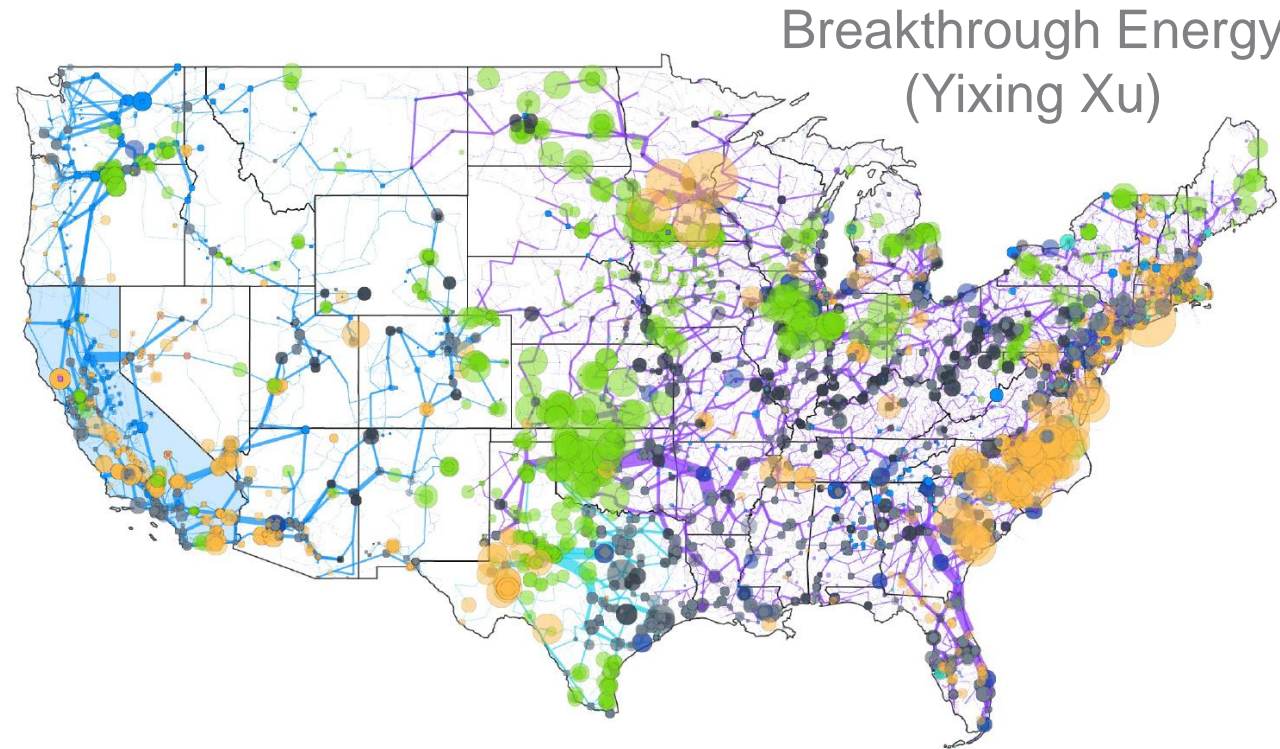


# Breakthrough Energy: BE Sciences

## Open Datasets: Transmission



- **Synthetic** network, not exact replica
- Statistically similar to the real grid (e.g. State level)
- Contains **no confidential data**, all data from publicly available resources (EIA, ISO/RTO, NREL, etc.)
- **High spatial resolution**: Substation from 13.2kV to 765kV in the U.S. system
- 104,122 branches with parameters standardized for power flow analysis
- GIS latitude and longitude information available
- **High temporal resolution**: Hourly demand, wind and solar profiles for one full year ready (10-year data soon)
- Solved using Gurobi (commercial software), year-long full-resolution USA simulations in <24 hours
- Working on **updating the model** with recently released more realistic and open data from Homeland Security



Breakthrough Energy contiguous U.S. grid model:  
82K nodes, 104K branches, 10K+ generators, 40K  
demand buses

<https://zenodo.org/record/3530898>

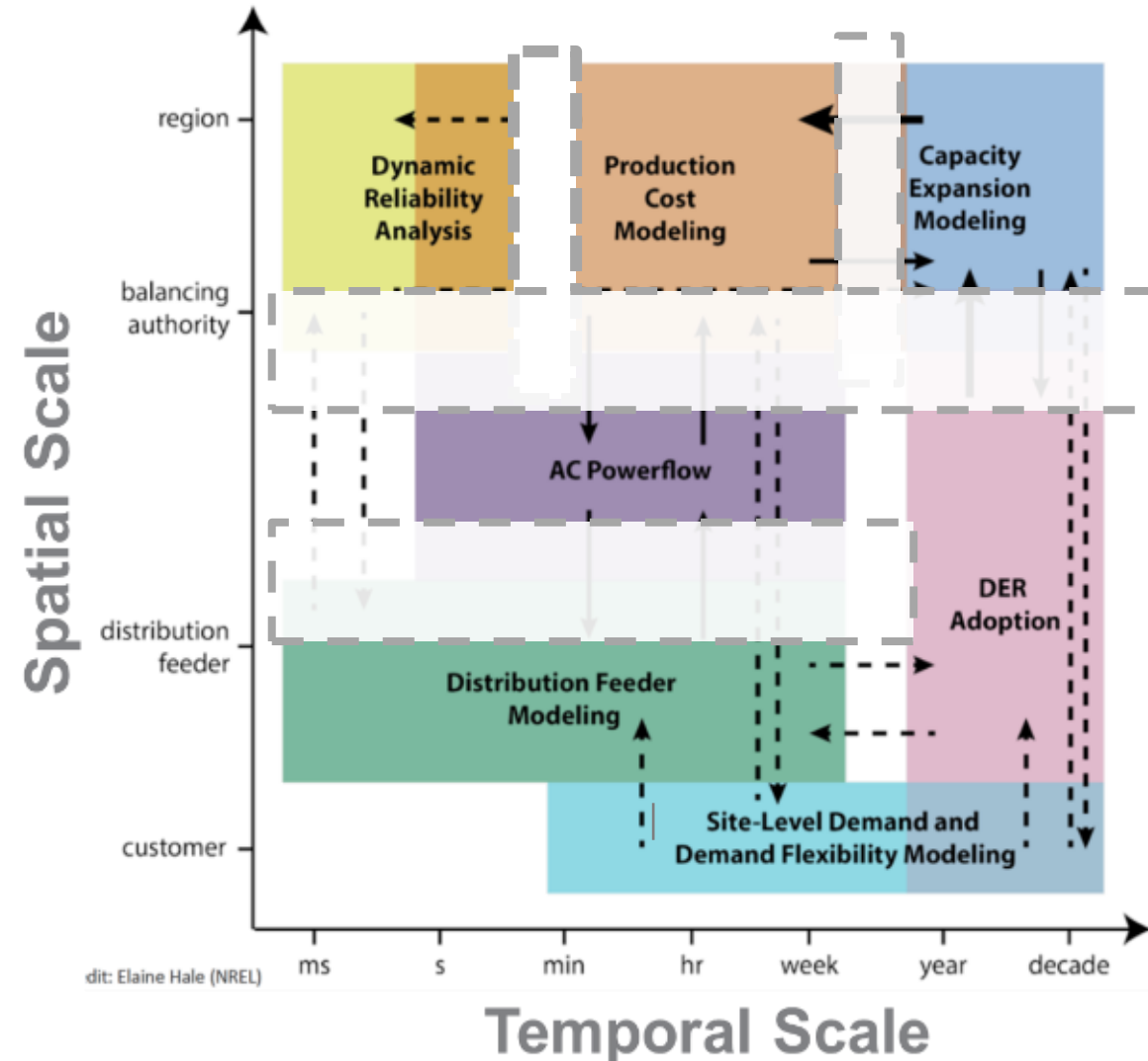


# BE Grid Modeling Initiative

# Grid Modeling Used to Be Easier



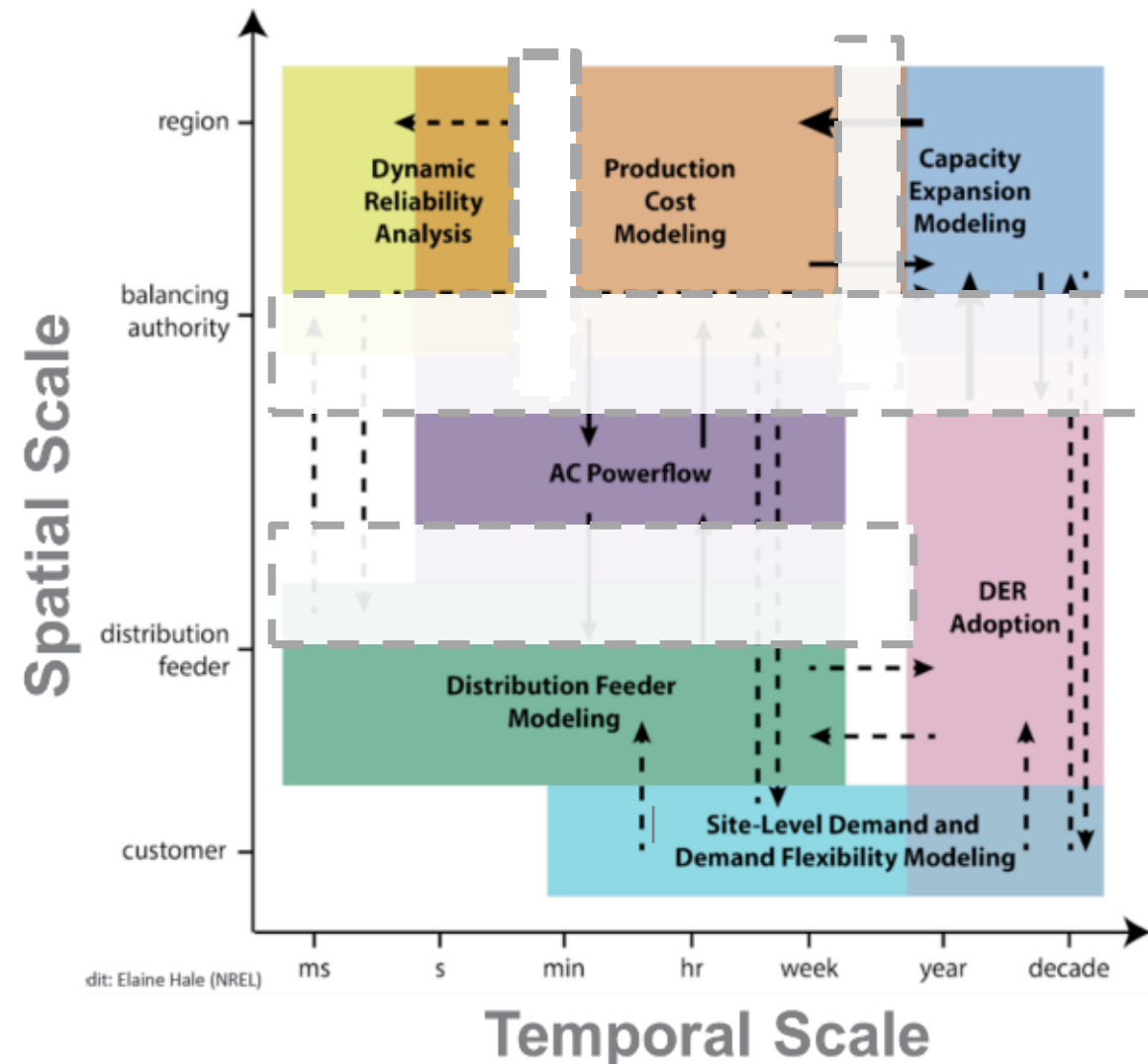
- Mostly dispatchable generation
- Generation connected directly to transmission grid
- Grid inertia from rotating machinery stabilized (short-term) system
- Load variation based mostly on weather and seasons
- Minimal load growth from year to year
- Minimal storage on system
- Minimal cross sector (transportation & heating) coupling



# Zero Carbon Grid is Harder to Model



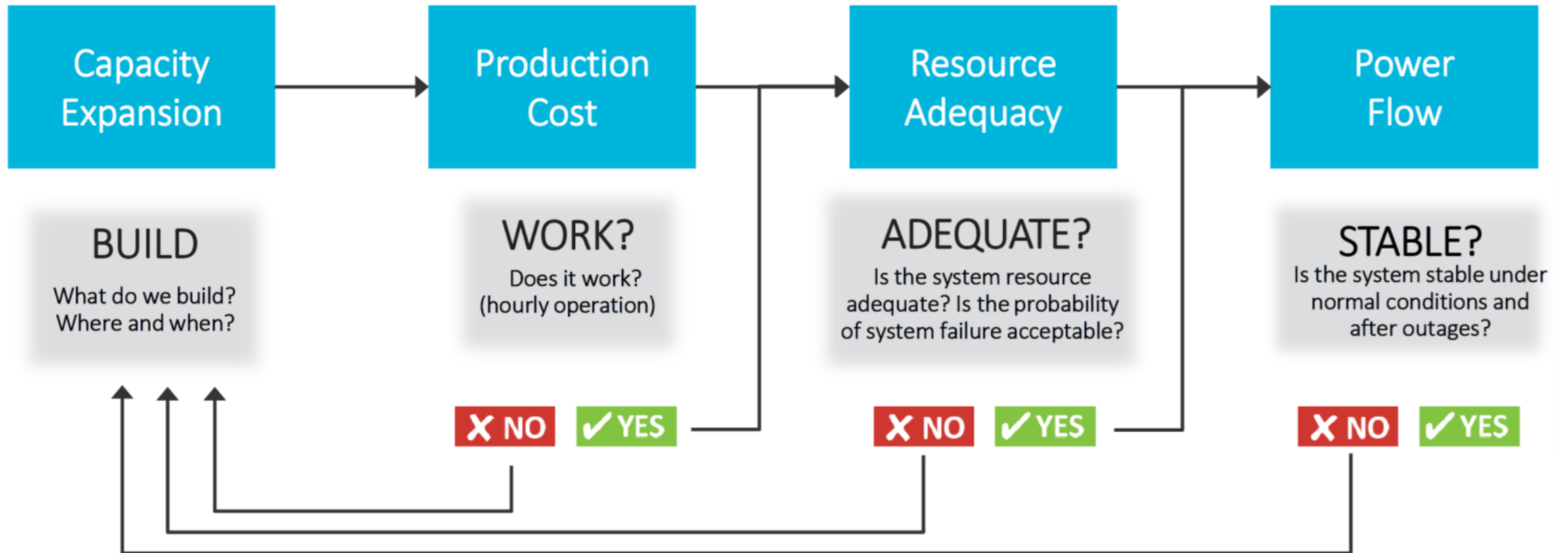
- Large amounts of intermittent generation
- Large amounts of distributed generation
- Little grid inertia (dynamics are faster and stronger)
- Transmission pathways change depending on weather patterns
- New loads change variation patterns dramatically
- Potential significant load growth from year to year
- Large amounts of storage on system
- Significant cross sector coupling
- Larger swings in weather driven by climate change



# Integrated System Modeling

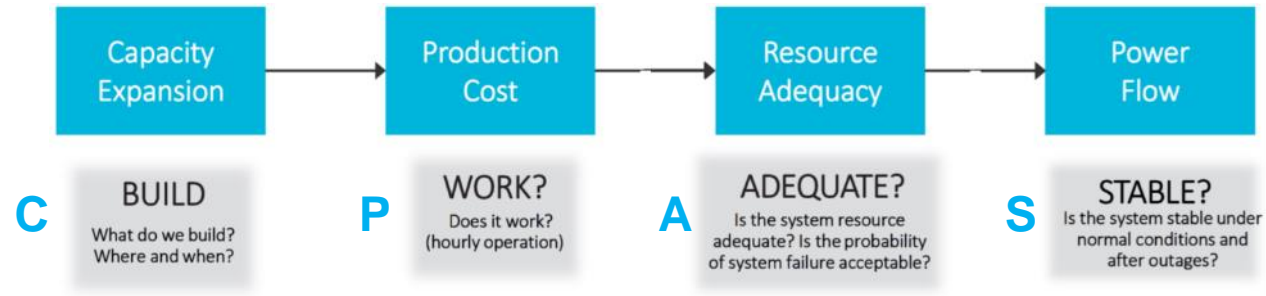


Models





# Stakeholders for Grid Modeling



## International Organizations

World Bank, US AID (CP), Dev Banks (CA)

## National Organizations

Congress (C), FERC, EIA

## Regional Organizations

System Operators (CPA) (S)

## Local Organizations

Utilities (CPA), Public Utility Commissions (CP)

## Individuals

Developers (C), Investors, Technologists, Traders (P)

# Proposed: Meta-Tools



## BEV Recommendation:

- Improve model interoperability across temporal and spatial dimensions
- Communicate results to stakeholder. Promote innovation.

### Linkage Tools

- Open-source model management for interoperability
- Output from one tool processed for input to another tool
- Cloud hosting tools

### Benchmarking

- Cross-platform validation (energy mix, price, dynamics)
- Facilitate exchange of model parameters across groups
- Best practice guidance

### Data Curation

- High spatial & temporal resolution for network and gen
- Integrated, coherent database for tools
- Scenario (or case) design and preparation

### Decision support

- Platforms for visualization
- Standards
- Communication to policy and strategy community

## Linkage Tools

Open-source model management for interoperability

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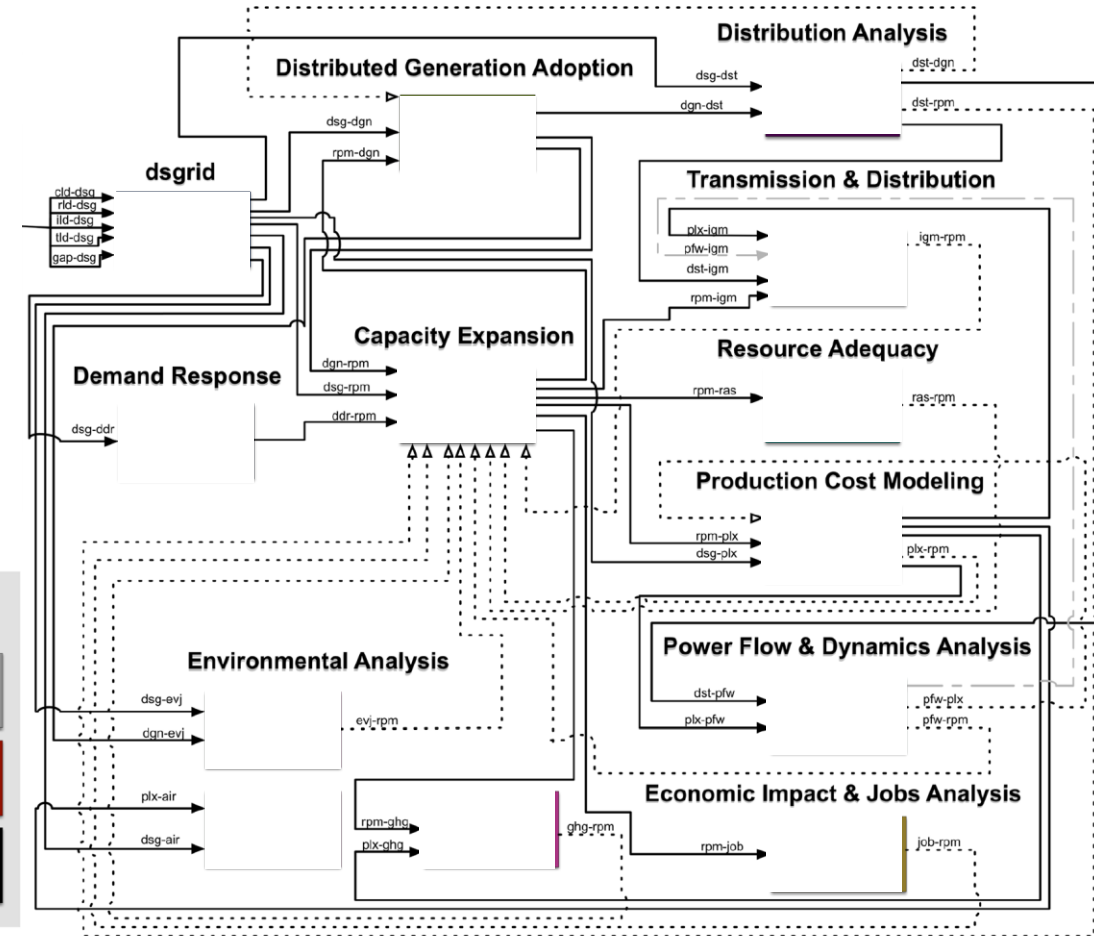
Best practice guidance

## Decision support

Platforms for visualization

Standards

Communication to policy and strategy community





## Integration of Economic and Reliability Tools and Data

**Moderator: Carlo Brancucci**, CEO, encoord

MISO's Renewable Integration Impact Assessment (RIIA)

**Jordan Bakke**, Director of Strategic Initiatives and Assessments, MISO

Discussion Panelists:

**Peter Markussen**, Managing Director, Energinet (Denmark)

**Jason Frasier**, Senior Manager of Transmission Planning, NYISO

**Xiaoyao Zhou**, Engineering Compliance Manager, NG ESO (UK)

**Kelsey Allen**, Principal Engineer, SPP

## Integration of Generation, Transmission, Distribution, and Load

**Arne Olson**, Senior Partner, Energy + Environmental Economics (E3)

LA100: The Los Angeles 100% Renewable Energy Study

**Paul Denholm**, Senior Research Fellow, NREL

Discussion Panelists:

**Ken Aramaki**, Director T&D Planning, Hawaiian Electric Company

**Angie Bond-Simpson**, Senior Director of Resource Management, Salt River Project

**Chris Clack**, Vice President, Integrated Energy Systems Planning, Pattern Energy Group

**PJ Martin**, Vice President of Integrated System Modeling and Analytics, Xcel Energy