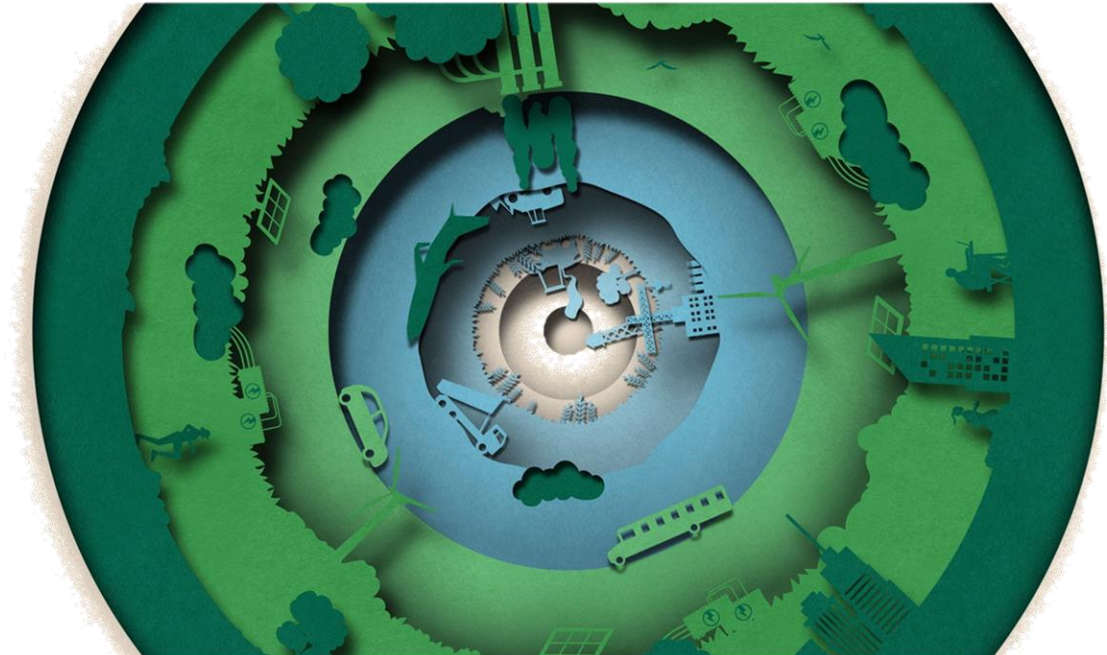


Breakthrough Energy



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



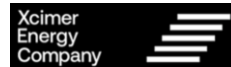
New Loads



Geothermal



Nuclear Fusion



Emerging Market



T&D, Grid Optimization

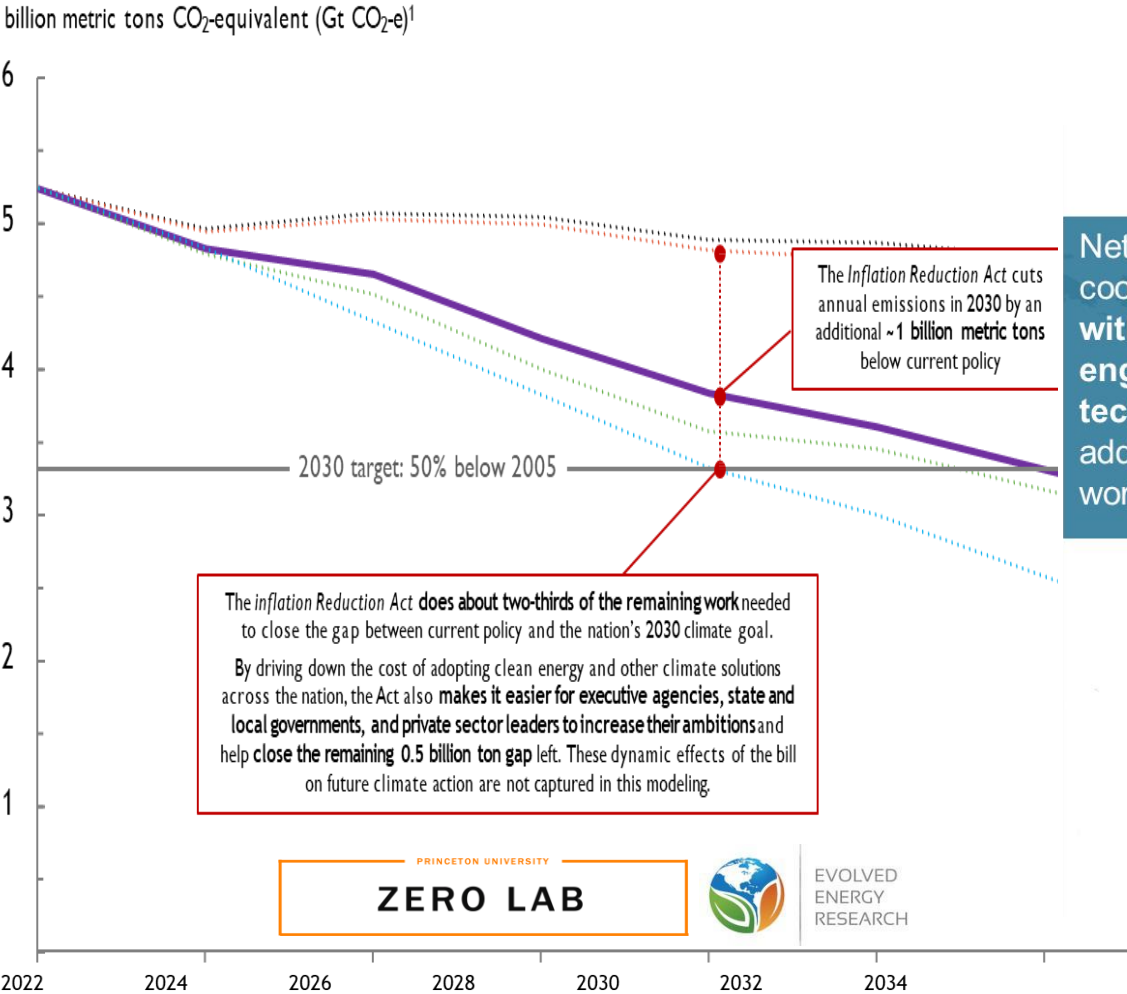


Breakthrough Energy: Policy & Advocacy



Policy solutions can lower the Green Premium

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



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

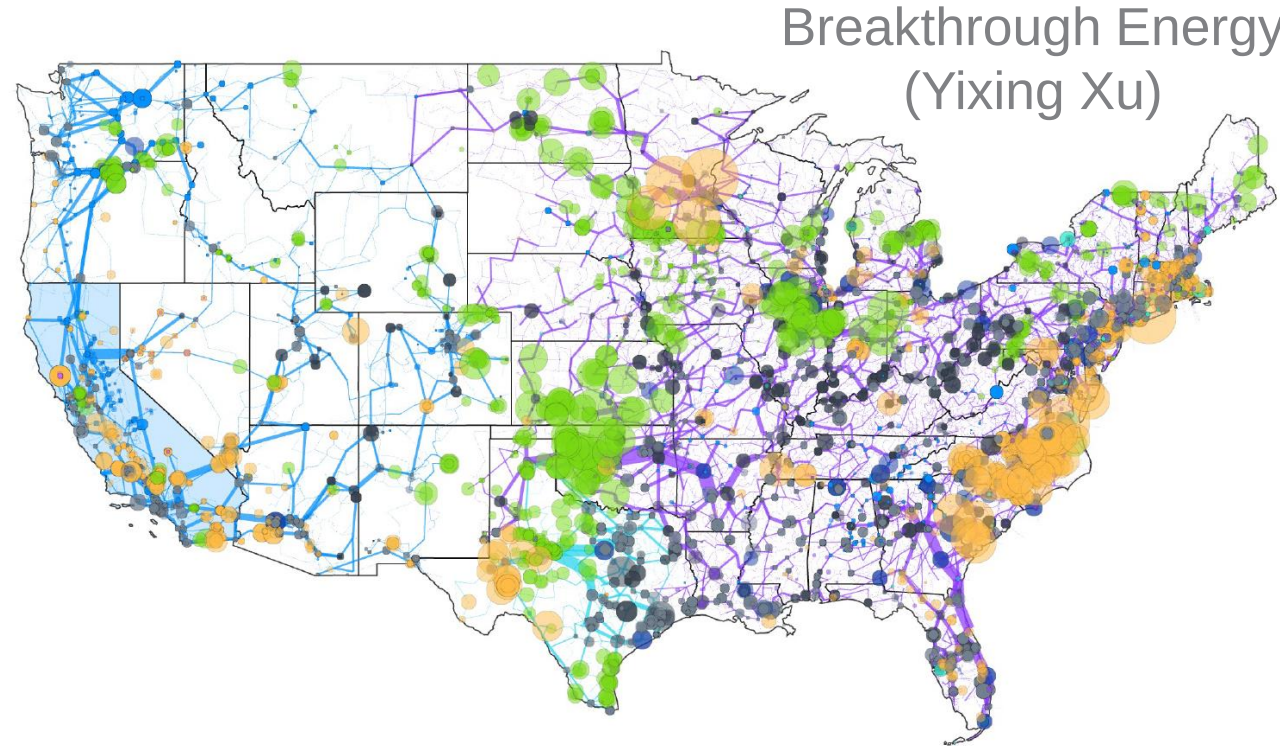


Breakthrough Energy: BE Sciences

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>

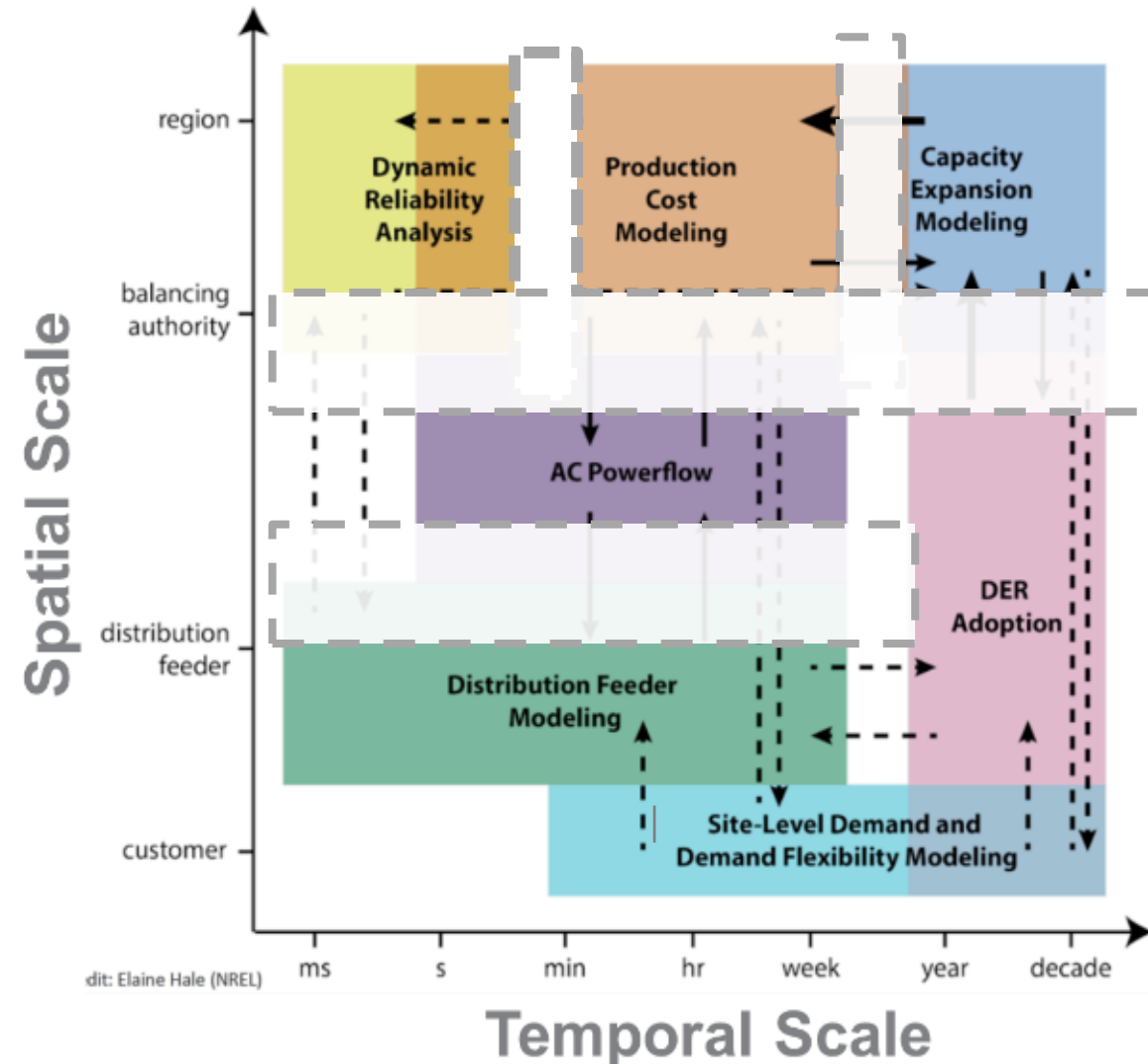


BE Grid Modeling Initiative

Grid Modeling Used to Be Easier



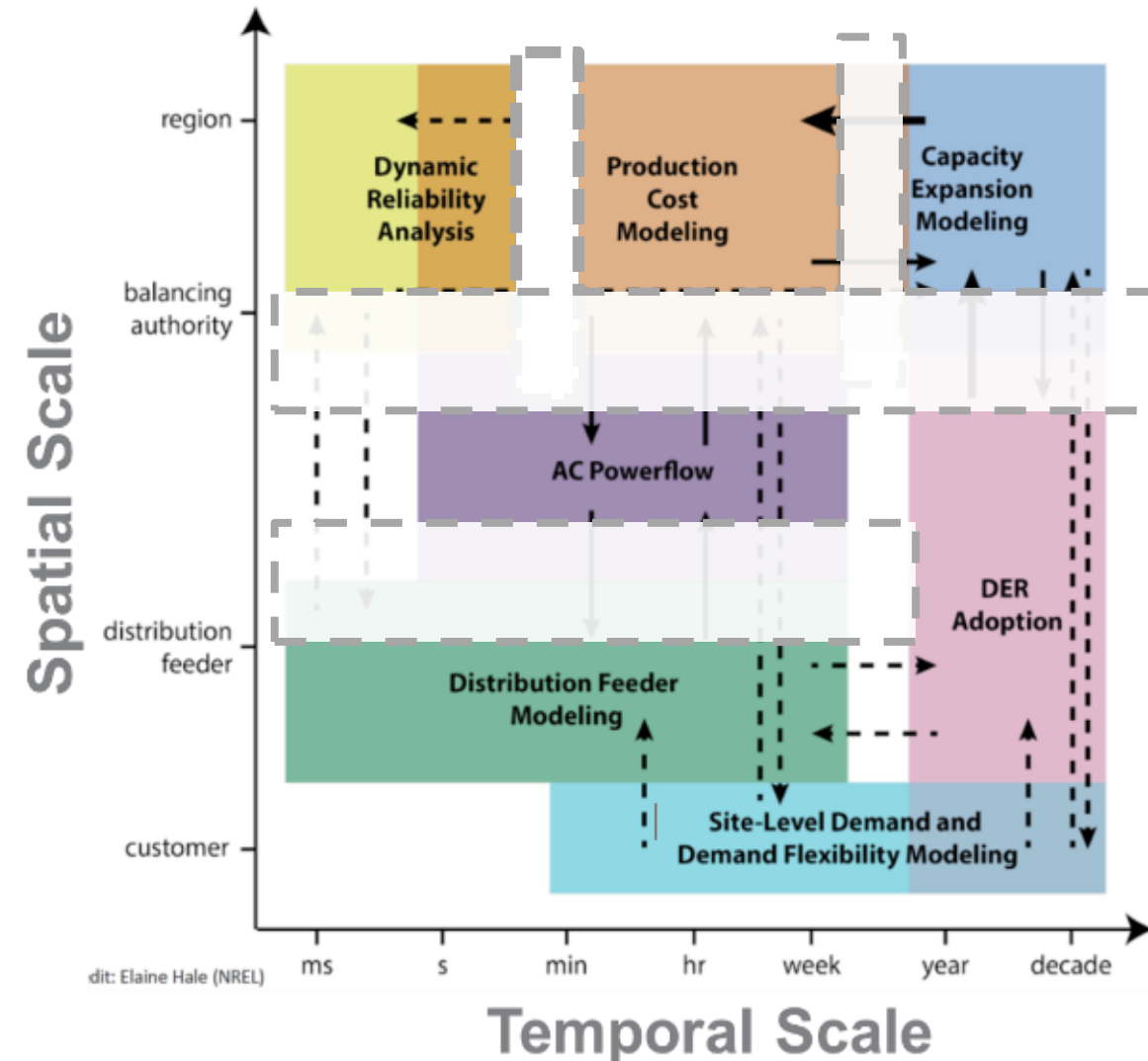
- Mostly dispatchable generation
- Generation connected directly to transmission grid
- Grid inertia from rotating machinery stabilized (short-term) system
- Load variation based mostly on weather and seasons
- Minimal load growth from year to year
- Minimal storage on system
- Minimal cross sector (transportation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



Zero Carbon Grid is Harder to Model



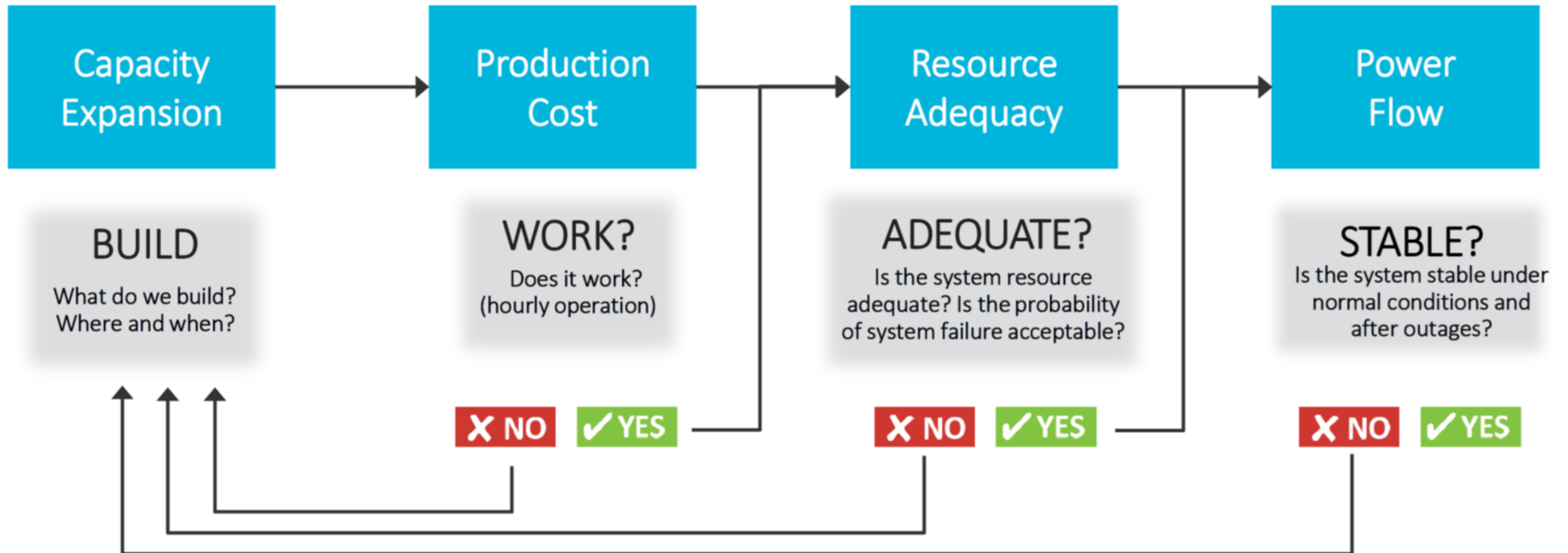
- Large amounts of intermittent generation
- Large amounts of distributed generation
- Little grid inertia (dynamics are faster and stronger)
- Transmission pathways change depending on weather patterns
- New loads change variation patterns dramatically
- Potential significant load growth from year to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



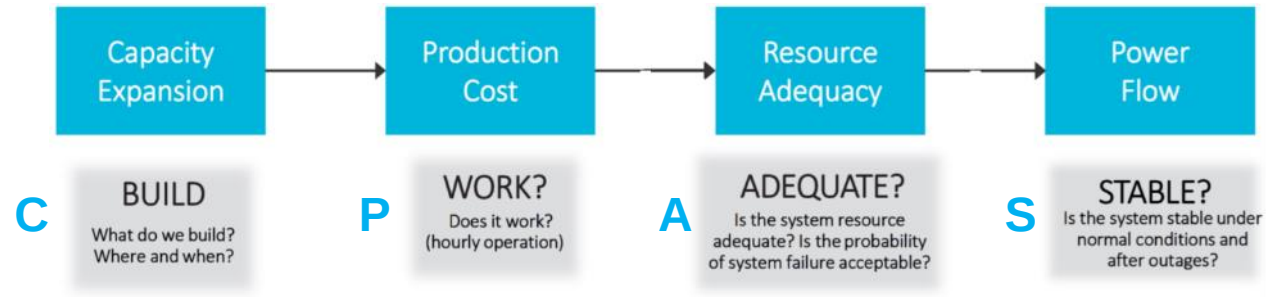
Integrated System Modeling



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

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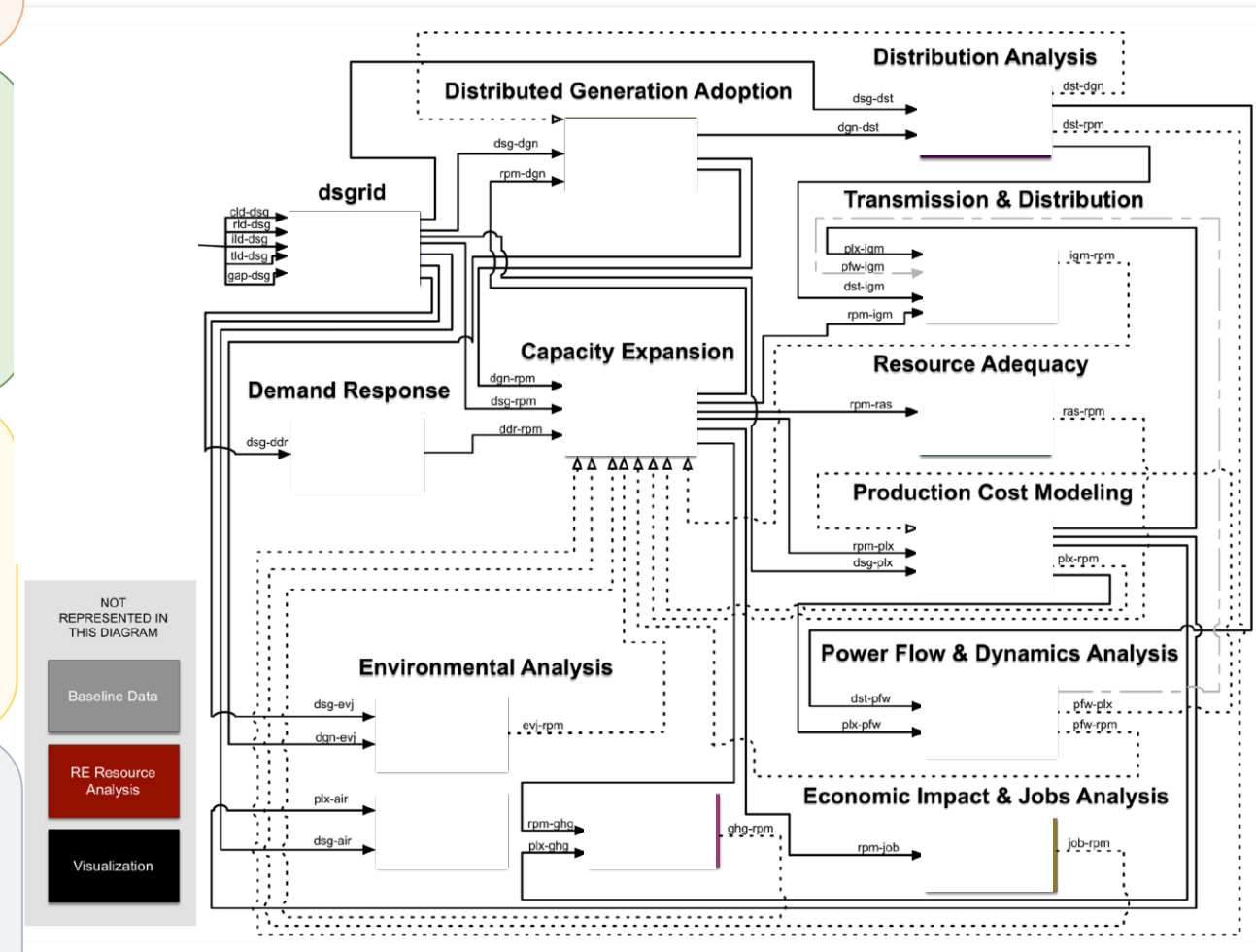
Best practice guidance

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