



City of Los Angeles 100% Renewable Energy Study
Advisory Group Meeting #2
Thursday, August 3, 2017

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Agenda

Today's Primary Agenda Topics

- Advisory Group member introductions and identification of alternates
- Protocols and operating principles for Advisory Group
- Study overview and potential challenges
- Data, modeling, and analysis
- Discussion/Q&A throughout meeting and at end

Website almost ready for launch!

www.ladwp.com/CleanEnergyFuture

Advisory Group Introductions

- Provide expanded overview of the resources your organization can contribute to the study and Advisory Group
- Identify your alternate

Protocols and Operating Principles for Advisory Group

Protocols and Operating Principles for Advisory Group

<u>What</u>

A document that establishes: 1) the role of Advisory Group in the study, 2) general parameters for Advisory Group communication, meetings, etc.

<u>Why</u>

To provide a "road map" for members in order to anticipate involvement and contributions, and to ensure that meetings and overall process are productive for all members.

Protocols and Operating Principles for Advisory Group

Contents

- Introduction
- Purpose of the Advisory Group
- Charter
- Participation and collaboration principles
- Advisory group composition
- Advisory group working teams
- Research partners
- Primary members and alternates
- Meeting schedules, locations, agendas and summaries
- Information sharing
- Email communication
- Media interaction
- Public involvement in the study
- Point of contact for Advisory Group Members
- Attachments: City Council Motion and Process Map

LADWP System

- Transmission
  - High Voltage Direct Current Transmission (HVDC)
    - Pacific DC Intertie
    - Intermountain Power Project DC Line
  - High Voltage Alternating Current
    - Strong connections to Arizona, Nevada, Oregon
- Flexible Generation
  - Castaic Pumped Storage Hydro Facility
  - Aqueduct Hydroelectric Generation System

Figure 1 LADWP's External System

Recent Investments continue the trend

- Recent Investments
  - Wind
  - Solar
  - Geothermal
  - EV Charging
- Distributed Energy Resources
  - Get the amount of installed capacity
- Demand Response Program
- Time of use retail rates


Current Events

- Energy Imbalance Market (EIM)
- LADWP Once Through Cooling Study (OTC Study)
- California Senate Bill 100
  - If enacted, would establish a 100% Renewable Portfolio Standard (RPS)
- Oregon
  - 50% RPS
- Arizona and Washington
  - 15% RPS

Pop Quiz

- How many miles of power lines are controlled by LADWP?

  3,637 miles of transmission and 10,378 miles of distribution

- What is the number one source of renewable energy in LADWP?

  Wind provides 11% of LADWP Generation

- What is the Peak Load?

  6,343 MW in 2014

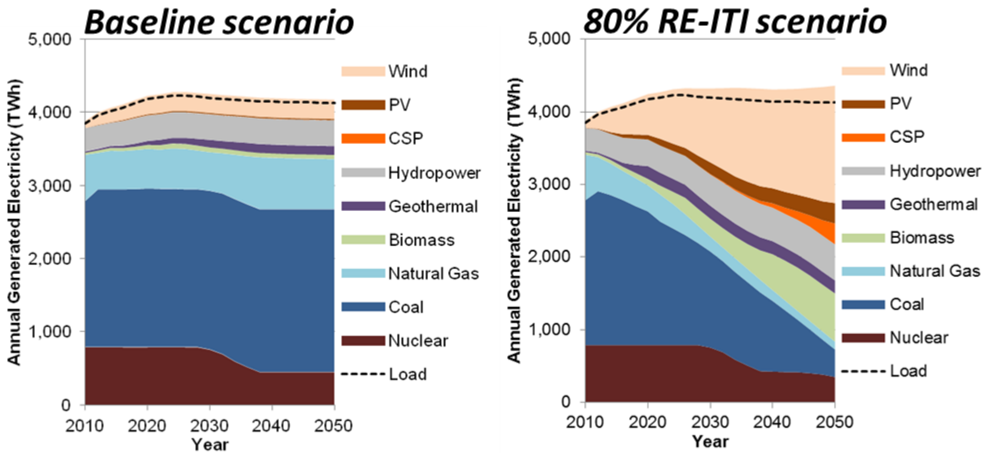
- What percent of the load is commercial/residential?

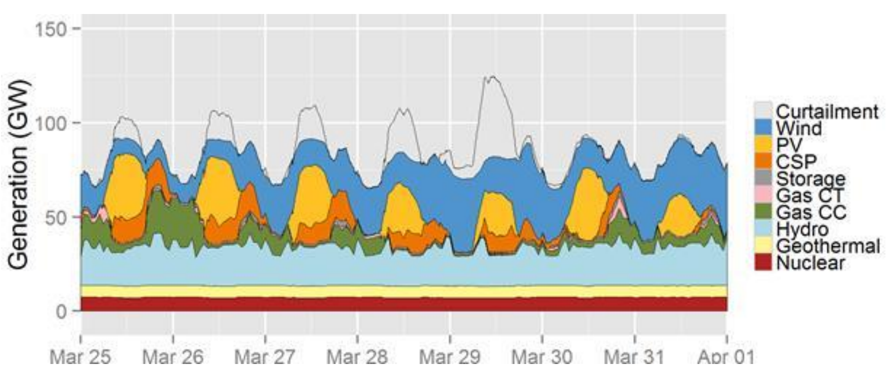
  70% Commercial, 30% Residential

What might a renewable future look like?

National scale analysis of renewable electricity in 2050

- Renewable Electricity Futures Study (REF)
  - Published 2012
  - First national analysis of 80% renewables
  - 60% wind and solar can technically be balanced
- REF Western Interconnection
  - Published 2015
  - Sub hourly ~50% wind and solar
- REF Eastern Interconnection
  - Published 2017
  - Sub hourly ~70% wind and solar





High profile research on 100% renewable electricity

LA DWP

- 100% Wind, Water, and Solar
  - Stanford 2015
  - The U.S. can reach 100% on wind, water and solar
  - Subject of considerable debate

This Article | Info for Authors | Subscribe | About

PNAS

Proceedings of the National Academy of Sciences of the United States of America

Proc Natl Acad Sci U S A. 2015 Dec 8; 112(49): 15060–15065. PMCID: PMC4679003
Published online 2015 Nov 23. doi: 10.1073/pnas.1510028112
Sustainability Science

Low-cost solution to the grid reliability problem with 100% penetration of intermittent wind, water, and solar for all purposes

Mark Z. Jacobson,[a,1] Mark A. Delucchi,[b] Mary A. Cameron,[a] and Bethany A. Frew[a]

- Future Cost Competitive Electricity Systems
  - NOAA 2016
  - 80% renewables is economically feasible with HVDC critical technology

Future cost-competitive electricity systems and their impact on US CO_2 emissions

Alexander E. MacDonald, Christopher T. M. Clack, Anneliese Alexander, Adam Dunbar, James Wilczak & Yuanfu Xie

Affiliations | Contributions | Corresponding authors

Nature Climate Change 6, 526–531 (2016) | doi:10.1038/nclimate2921
Received 02 September 2015 | Accepted 15 December 2015 | Published online 25 January 2016

- Evaluation of a proposal for reliable low-cost grid powered with 100% wind, water, and solar
  - Clack et al. 2017
  - Debunks Stanford 2015

This Article | Info for Authors | Subscribe | About

PNAS

Proceedings of the National Academy of Sciences of the United States of America

Proc Natl Acad Sci U S A. 2017 Jun 27; 114(26): 6722–6727. PMCID: PMC5495221
Published online 2017 Jun 19. doi: 10.1073/pnas.1610381114
Sustainability Science, Environmental Sciences

Evaluation of a proposal for reliable low-cost grid power with 100% wind, water, and solar

Christopher T. M. Clack,[a,b,1,2] Staffan A. Qvist,[c] Jay Apt,[d,e] Morgan Bazilian,[f] Adam R. Brandt,[g] Ken Caldeira,[h] Steven J. Davis,[i] Victor Diakov,[j] Mark A. Handschy,[b,k] Paul D. H. Hines,[l] Paulina Jaramillo,[d] Daniel M. Kammen,[m,n,o] Jane C. S. Long,[p,3] M. Granger Morgan,[d] Adam Reed,[q] Varun Sivaram,[r] James Sweeney,[s,t] George R. Tynan,[u] David G. Victor,[v,w] John P. Weyant,[s,t] and Jay F. Whitacre[d]

Significant debate about 100% renewable electricity

Can the U.S. Grid Work With 100% Renewables? There's a Scientific Fight Brewing

By Peter Fairley
Posted 19 Jun 2017 | 19:00 GMT

Energy wonks have a meltdown over U.S. going 100% renewable — why?

Joshua D. Rhodes
Monday, July 3, 2017 - 2:00am

ENERGY & ENVIRONMENT

Fisticuffs Over the Route to a Clean-Energy Future

Eduardo Porter
ECONOMIC SCENE JUNE 20, 2017

GRID OPTIMIZATION

100% Renewables Plan Has 'Significant Shortcomings,' Say Climate and Energy Experts

Sustainable Energy

Scientists Sharply Rebut Influential Renewable-Energy Plan

Nearly two dozen researchers critique a proposal for wind, solar, and water power gaining traction in policy circles.

by James Temple June 19, 2017

JUN 26, 2017 @ 06:00 AM 18,160

Debunking The Unscientific Fantasy Of 100% Renewables

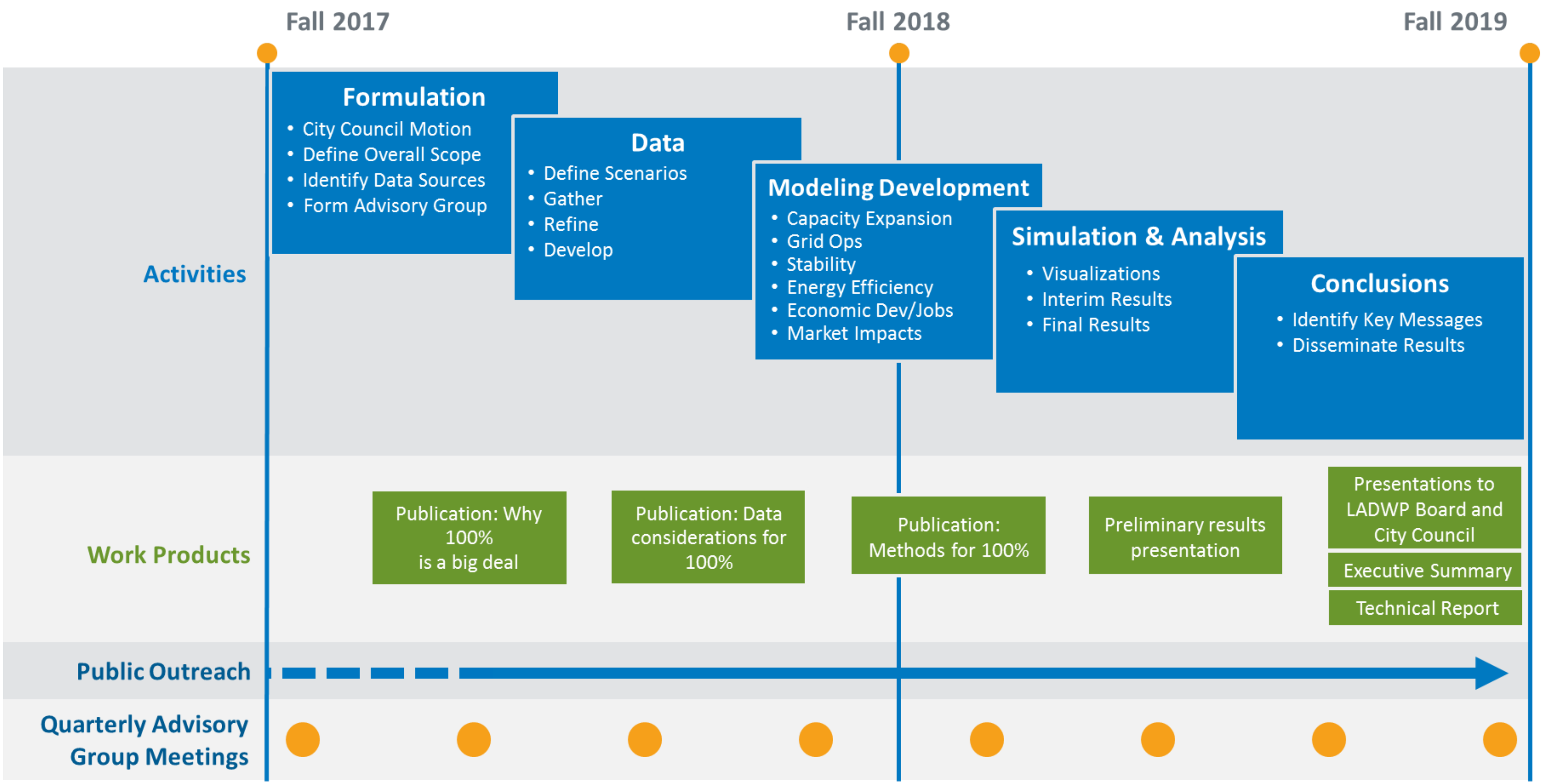
Nevertheless

- U.S Cities
  - Creating new goals for 100%
  - Pushing the boundaries of financial tools
  - The Energy Gang Podcast: The Inconvenient Truth About City Climate Goals
    - https://www.greentechmedia.com/articles/read/the-inconvenient-truth-about-city-climate-goals
- Hawaii
  - 100% renewable portfolio standard
  - Power System Improvement Plan
    - https://www.greentechmedia.com/articles/read/hawaiian-electric-100-renewable-energy-plan-green-light

Why 100% Renewable Energy Los Angeles is Unique

- It's a large scope
  - Includes analysis of physical and financial options for 100% renewable generation
- It's a large system
  - 1.4 million power customers
  - Expansive transmission system
  - Second highest Gross Domestic Product in U.S.
  - Largest municipal utility
- LA has the vision and potential to reach that goal
  - Unlike most cities, LA is responsible for running a real power system with the associated responsibilities and resources
- Discussion

Los Angeles 100% Renewable Energy Study – Conceptual Process Map



NREL Team Leads

- Scott Haase
  - Project Sponsor
- Aaron Bloom
  - Project Manager
- Paul Denholm
  - Principal Technical Lead
- Dan Steinberg
  - Planning Lead
- Jennie Jorgenson
  - Production Cost Lead
- Kara Clark
  - Stability Lead
- Bryan Palmintier
  - Distribution systems Lead
- Bri-Mathias Hodge
  - Integrated Systems Lead
- Craig Christensen
  - Energy Efficiency Lead
- David Keyser
  - Jobs and Economic Development

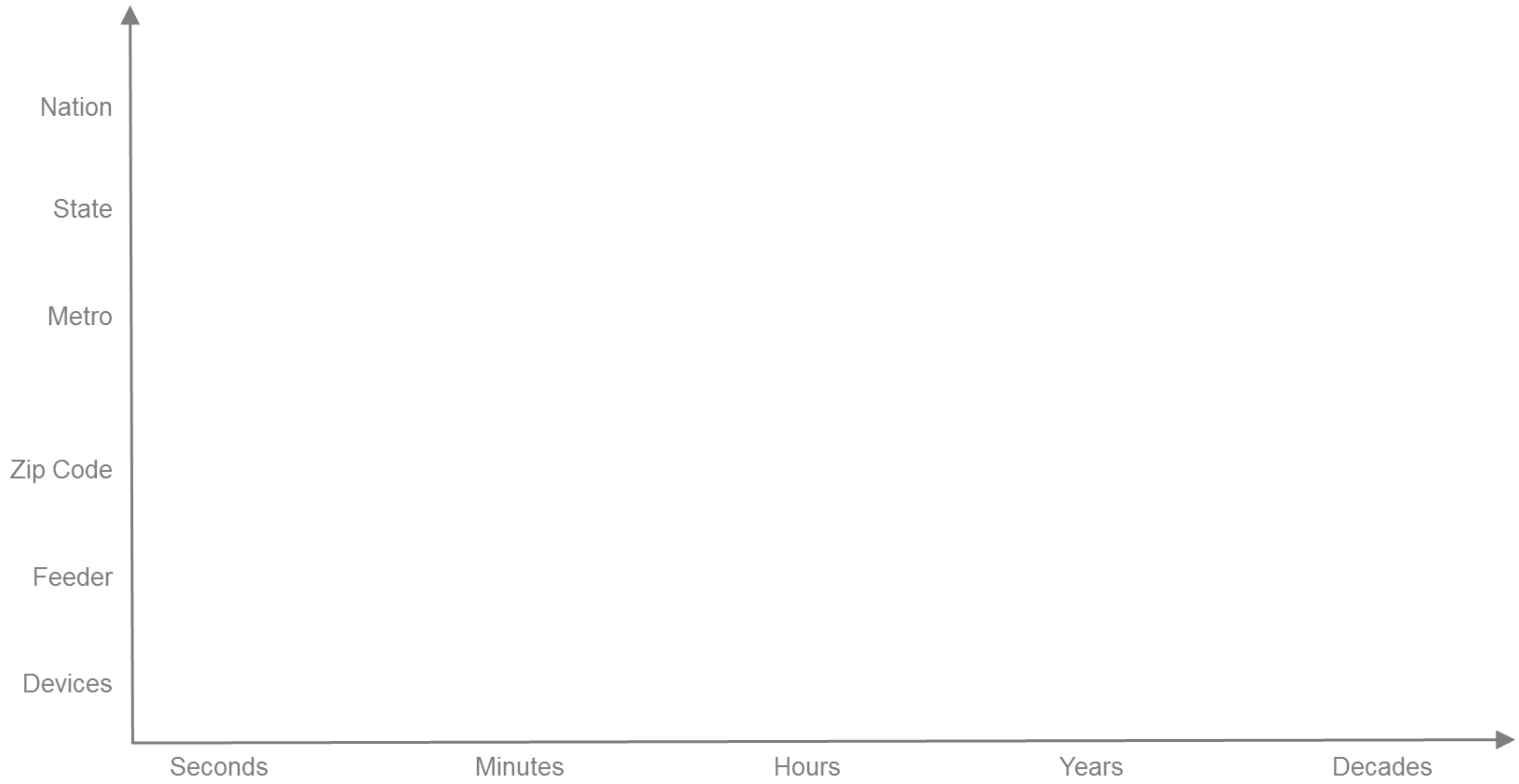
Modeling 100% Renewable Energy

This Discussion

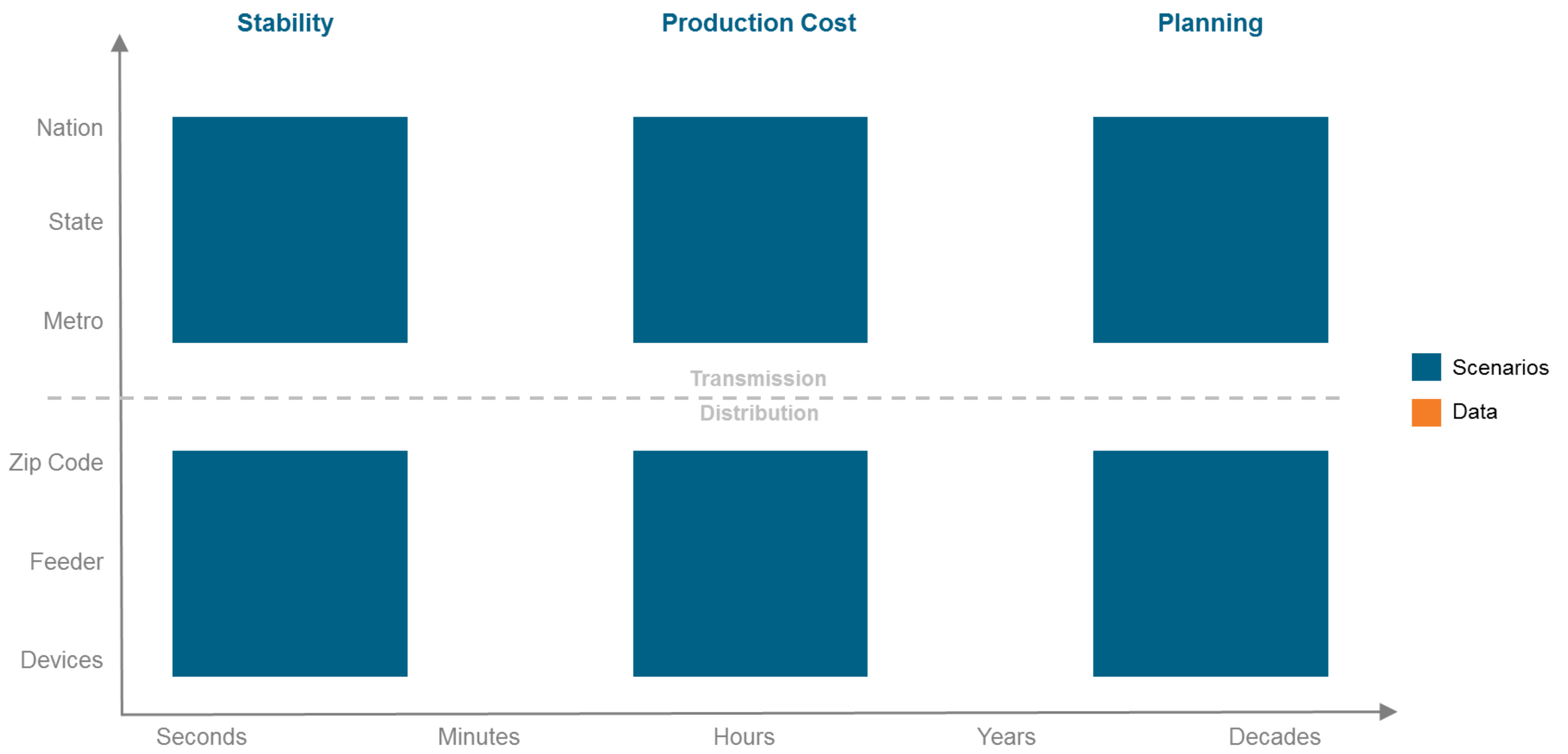
Overview of power system modeling approach

- Types of models
- What they do
- How they fit together

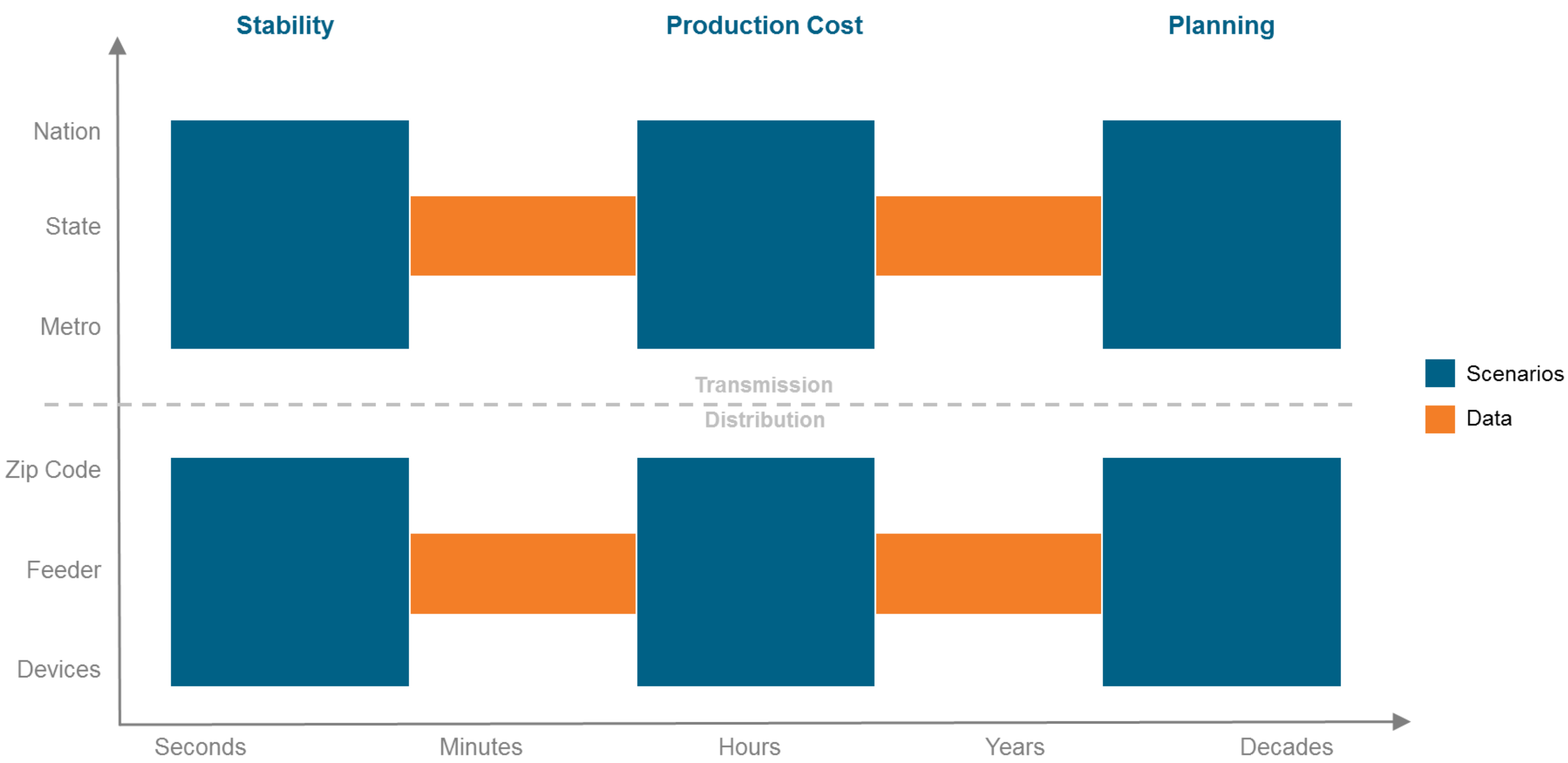
Technical Analysis: Planning Reliable Power Systems



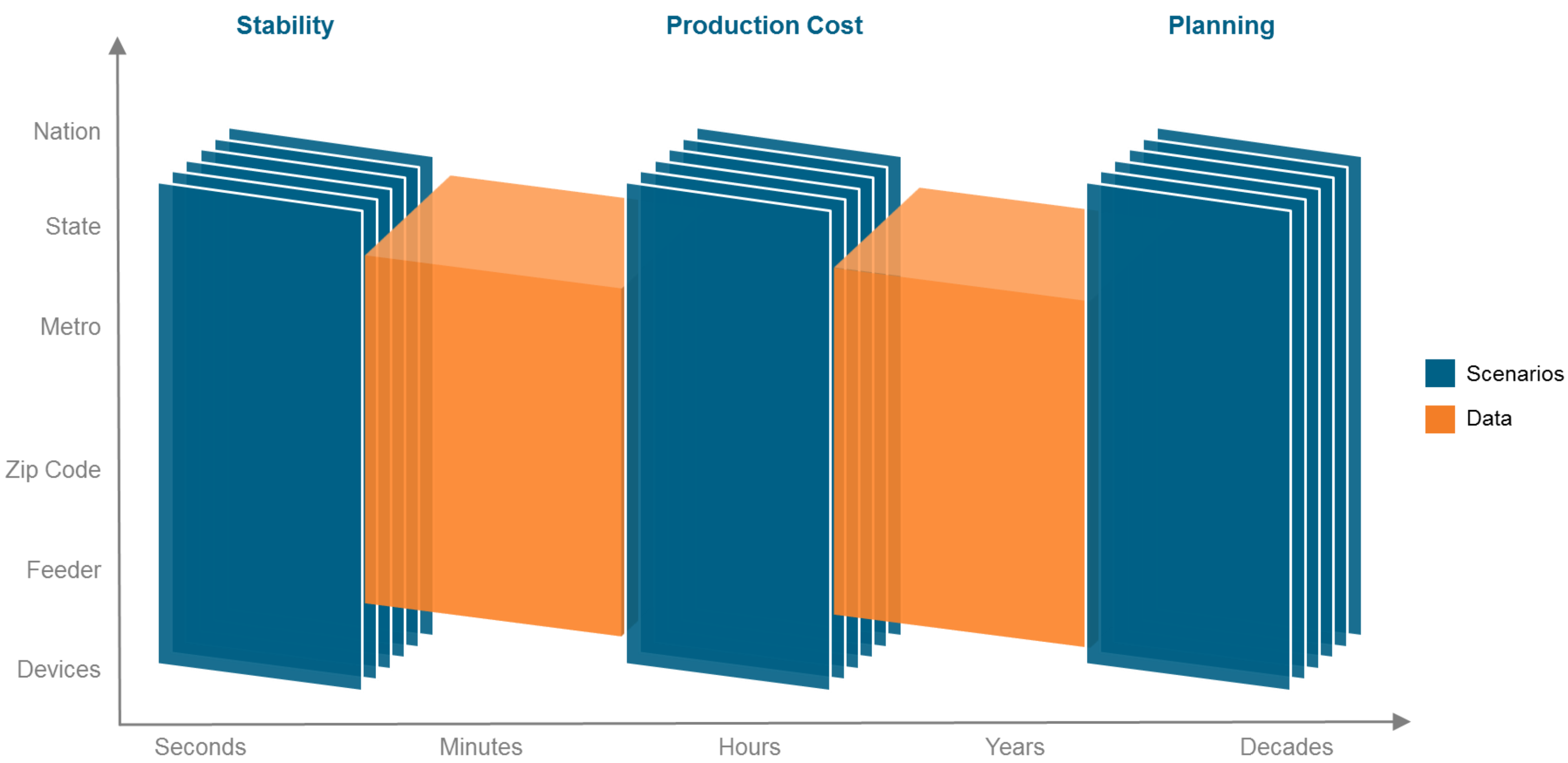
Traditional areas of power system modeling



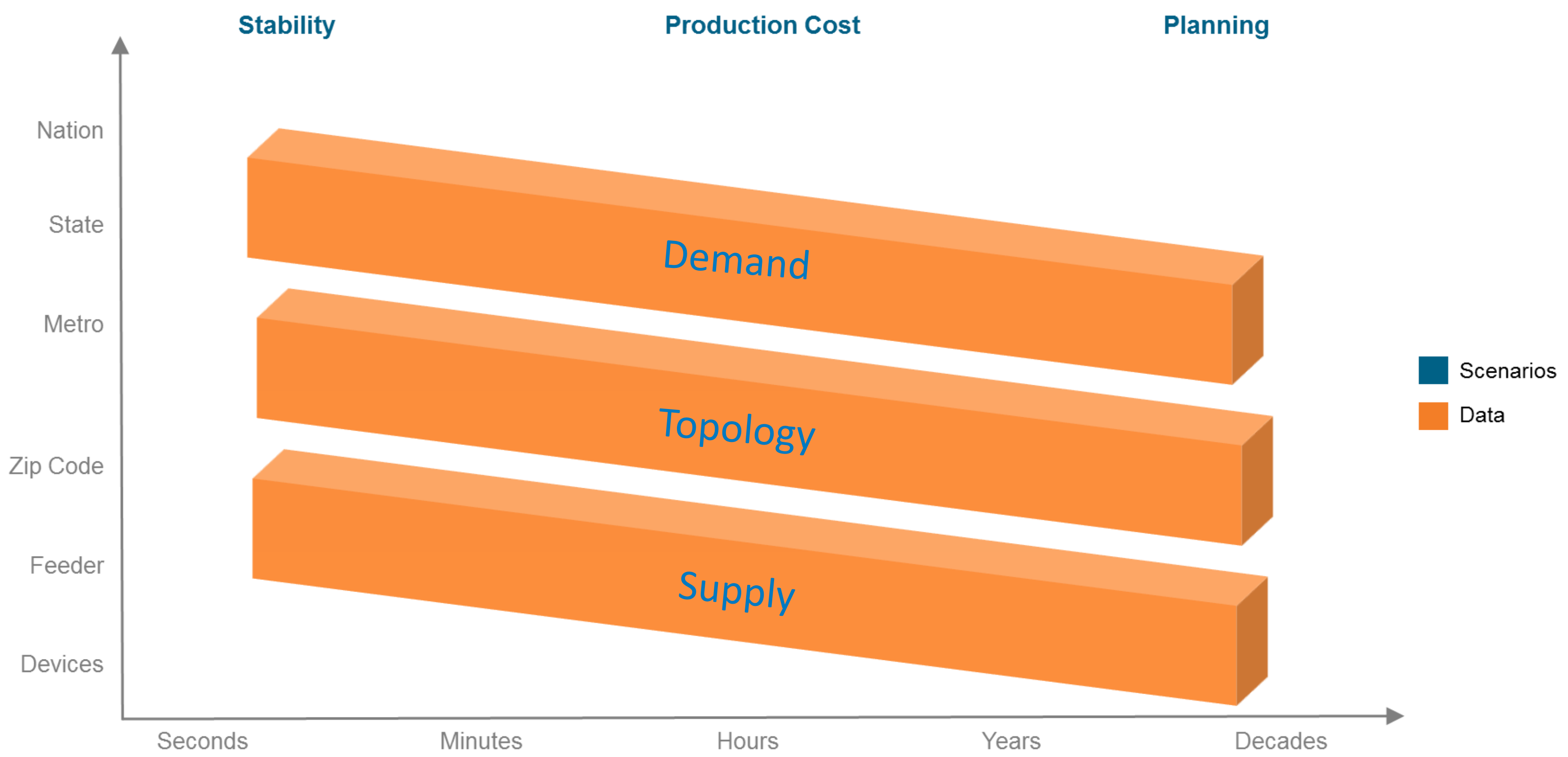
Linking data across tools is of critical importance



Modern power systems need comprehensive tools and data



Data Needs


Stability
Production Cost
Planning
Nation
State
Metro
Zip Code
Feeder
Devices
Demand
Topology
Supply
Seconds
Minutes
Hours
Years
Decades
Scenarios
Data

Demand Data

- Demand can change considerably over time
- Demand Data
  - Starts with historical data records (the more the better)
  - Evolves based on:
    - Commercial and residential buildings
    - Adoption of energy efficiency technologies
    - Adoption of electric vehicles
- Demand Response "Resource"
- Storage as demand vs Storage as supply

ResStock + **Com**Stock

FREE & OPEN SOURCE

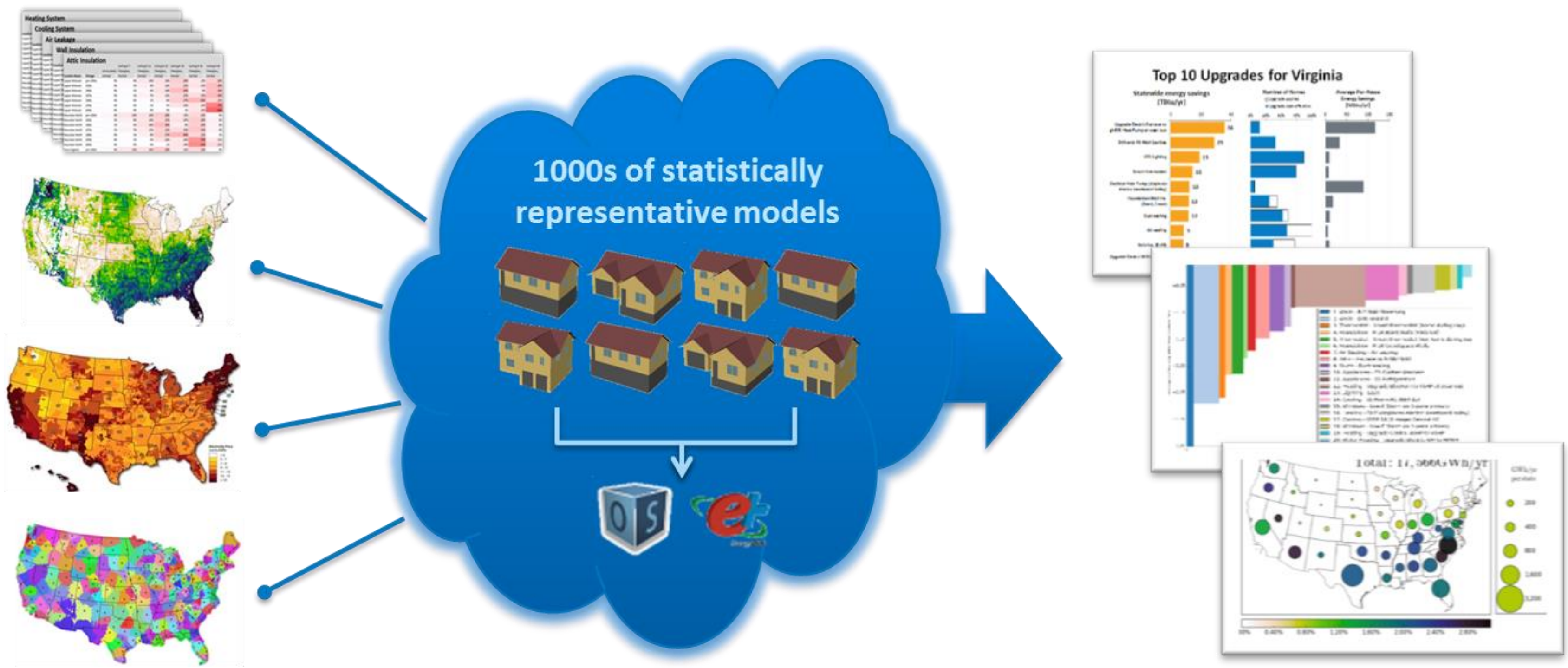
Physics-based simulation of the U.S. Residential and Commercial building stocks

using **large public and private datasets** and **modern scientific computing resources**

to achieve unprecedented **granularity** in modeling building energy use and demand

Large scale building analysis

ResStock: Highly Granular Modeling of the U.S. Existing Building Stock



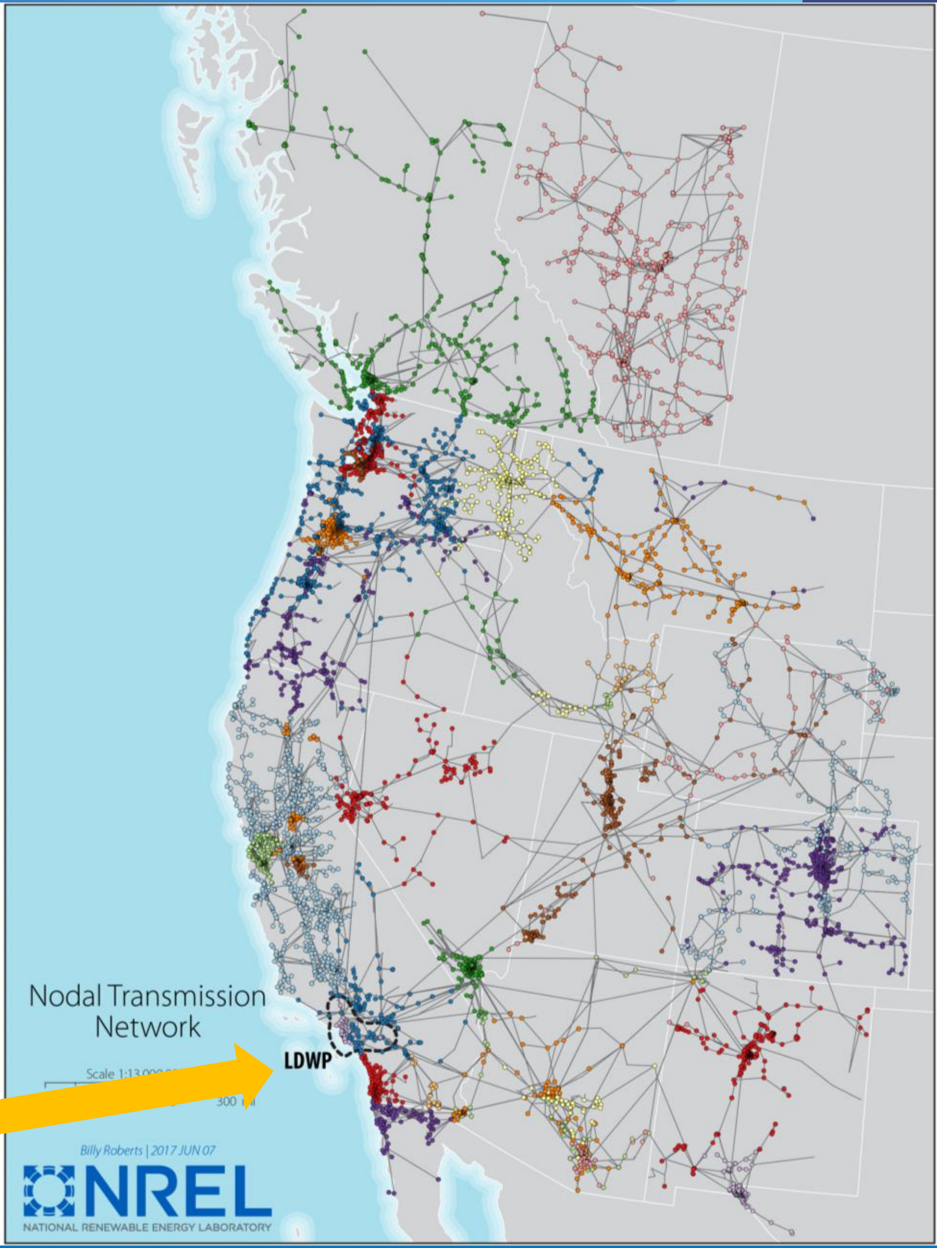
Input Data Sources
Building Characteristics
Climate Locations
Energy Costs
Census Data

Cloud-Based Simulations
Baseline Buildings
Efficiency Upgrades

Output Visualizations
State Fact Sheets
Supply Curves
Maps

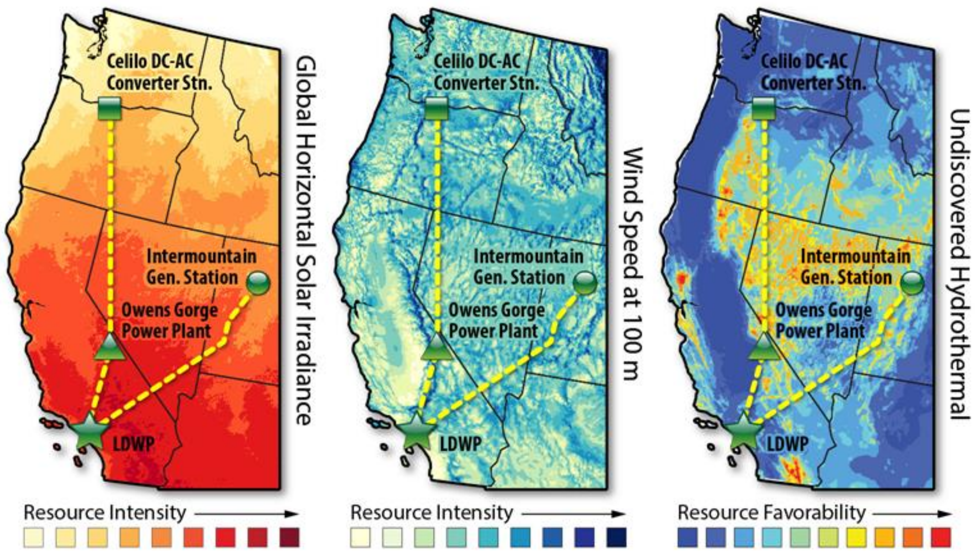
Topology Data

- Two types of lines/topologies in power systems
  - Transmission
  - Distribution
- A variety of industry vetted transmission topology data available
  - Western Interconnection
    - WECC TEPPC
- Distribution topology is harder
  - Availability
  - Complexity

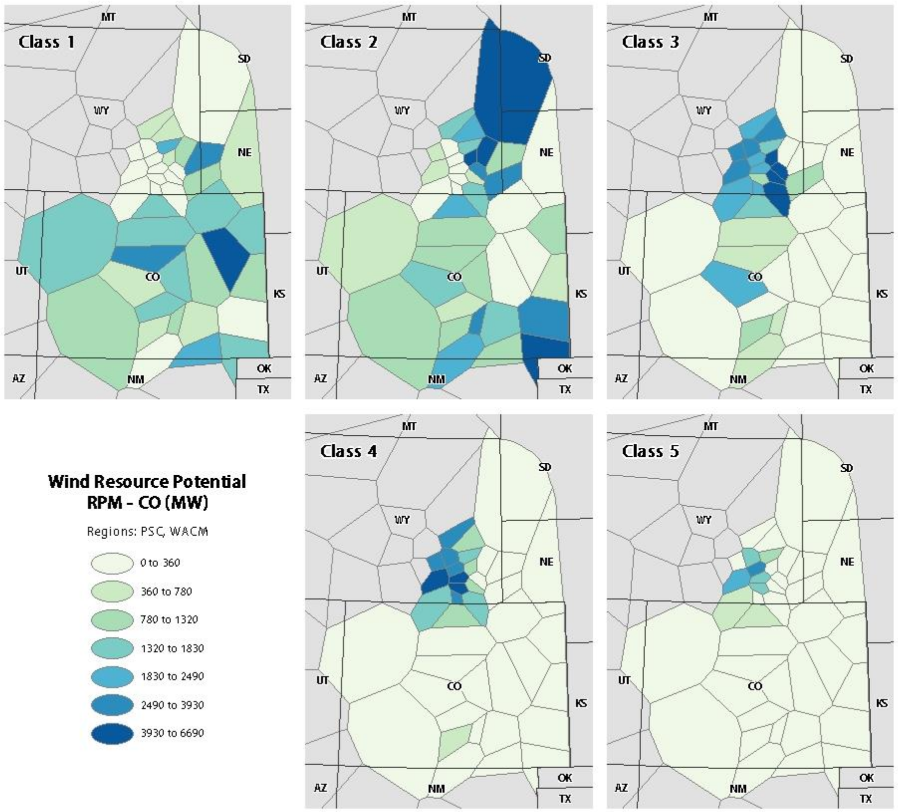


Supply Data

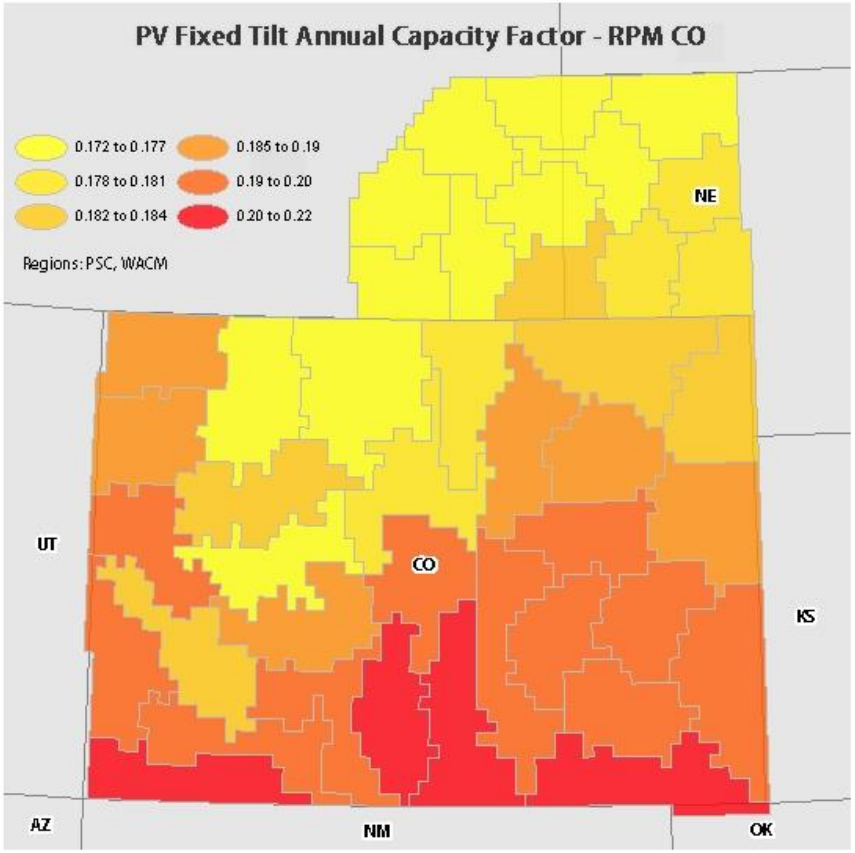
- Wide range of technologies that can supply generation
  - Traditional: Gas, Nuclear, Coal, Hydro, Pumped Storage
  - Renewables: Wind and Solar, Geothermal
  - Potential Resources: Battery Storage, Offshore wind, Hydrogen, Hydro Kinetic, Tidal
- Critical components
  - Capital costs
  - Production costs
  - Operating characteristics
  - Resource availability



High spatial resolution modeling to accurately represent renewable resource potential and quality

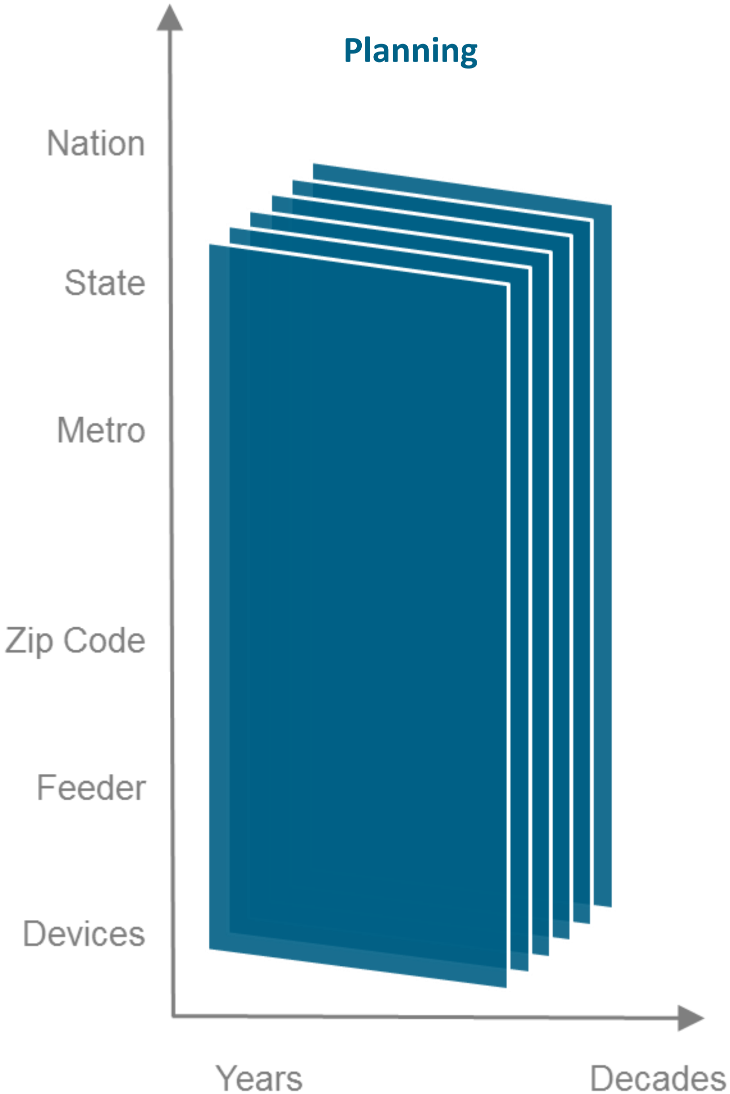


Examples from Colorado model



Clustering techniques are applied to develop renewable resource zones that have similar output characteristics. Each zone is characterized by:
(1) resource potential, (2) hourly profiles, and (3) grid interconnection costs

Planning – what you build, when, and where



- Co-optimizes generation and transmission to determine retirements and additions
- Top down utility scale expansion
- Bottom up distributed technology expansion
- Long term NERC reliability metrics
  - LOLP
  - ELCC
- Explicit consideration of policy and neighbors
- Capital Costs
  - Generation
  - Transmission
  - Energy Efficiency
  - Storage

Resource Planning Model (RPM)

Capacity expansion model for a *regional* electric system over a utility planning horizon (through 2030).

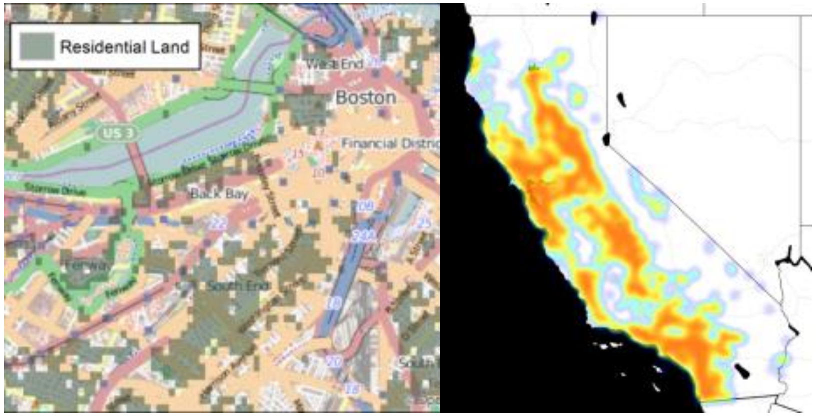
Key features:

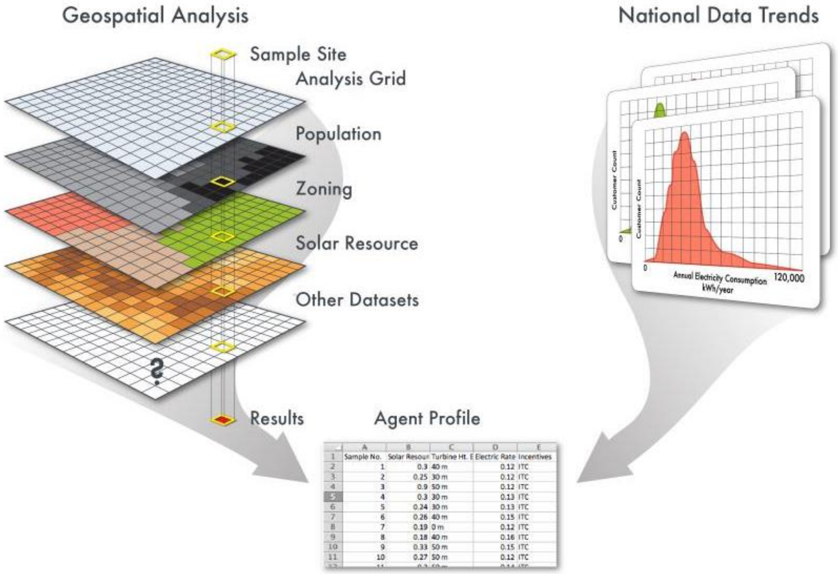
- Individual generation unit and transmission line representation
- Hourly chronological dispatch and detailed system operation representation
- High spatial resolution informs generator siting options, particularly for renewable resources
- Flexible data structure to develop models for customized regions
- *New*: Models the cost and value of storage and other enabling technologies

http://www.nrel.gov/analysis/models_rpm.html

Distributed Technology Diffusion (dGen)

- Forecasts adoption of distributed generation technologies by sector in the continental U.S. through 2050
- Agent-Based Model simulating consumer decision-making
- Incorporates detailed spatial data to understand regional adoption trends

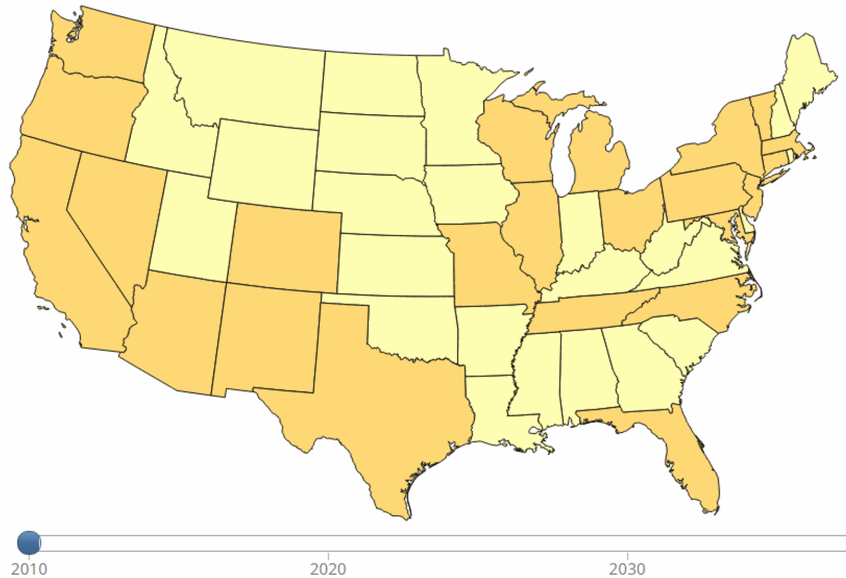




Example Visualization of Planning results

2016 Standard Scenarios Results Viewer

Link to Standard Scenarios



Scenario 1: 80% National RPS

Scenario 2: None

Capacity (2010):
Utility PV (GW)

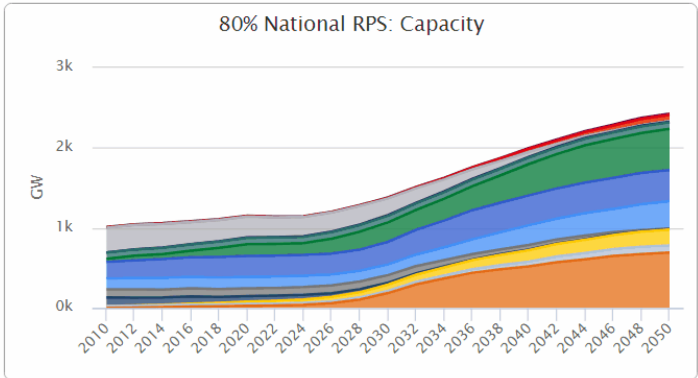
Capacity | Utility PV

Compare Technologies | System Metrics

View and compare the contributions of each technology category to the total estimated generation or capacity.

Select All | Clear All

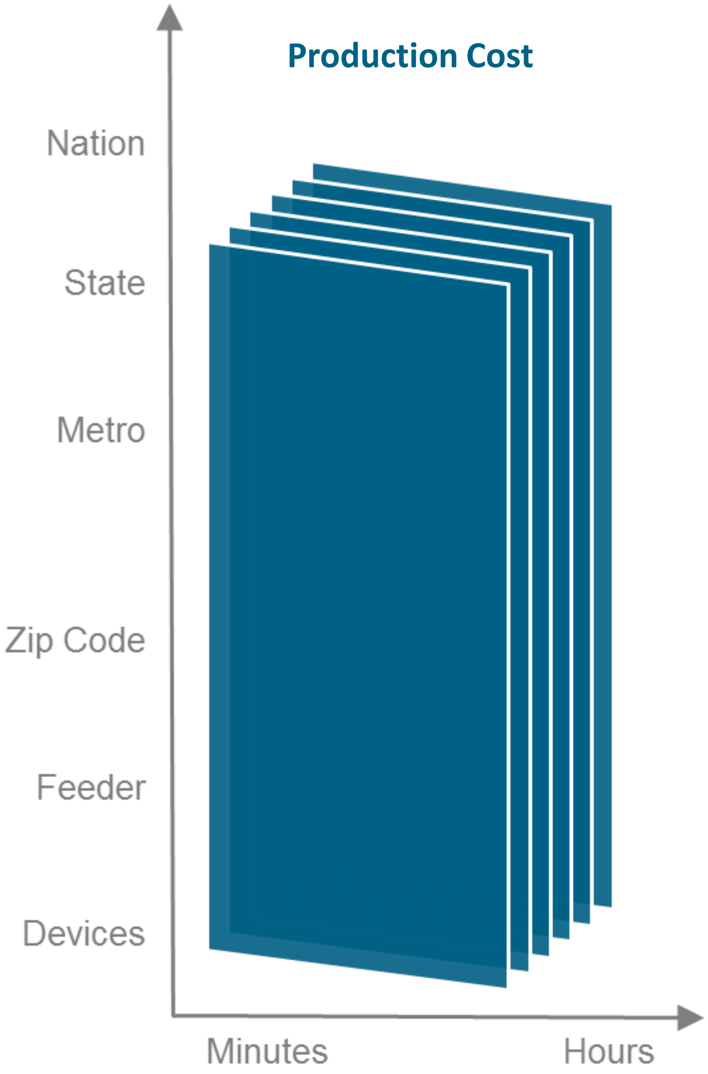
- Biopower
- Coal
- Hydro
- NG-CC
- Nuclear
- Rooftop PV
- Utility PV
- CSP
- Geothermal
- Land-based Wind
- NG-CT
- Oil-Gas-Steam
- Storage



Recommended Citation:

Cole, Wesley, Trieu Mai, Jeffrey Logan, Daniel Steinberg, James McCall, James Richards, Benjamin Sigrin, and Gian Porro. 2016. 2016 Standard Scenarios Report: A U.S. Electricity Sector Outlook, Golden, CO: National Renewable Energy Laboratory. NREL/TP-6A20-66939. http://www.nrel.gov/analysis/data_tech_baseline.html.

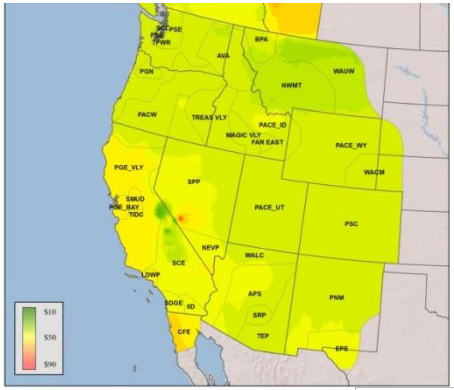
Production Cost – how the system operates



- Co-optimizes the commitment and dispatch of the power system
- Sub-hourly scheduling generation to meet demand
- Integrated approach to modeling generation, transmission, and distribution

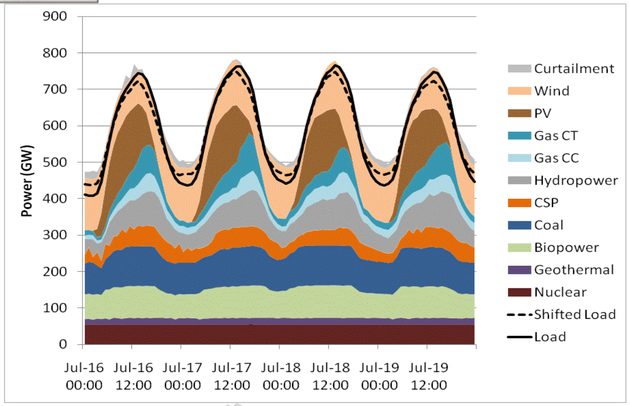
PLEXOS production cost model

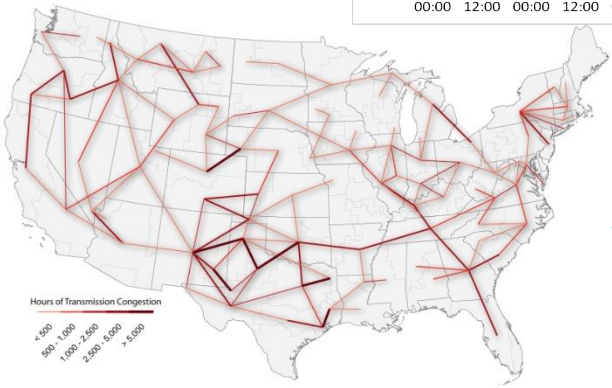
- Hourly or sub-hourly chronological
- Commits and dispatches generating units based on:
  - Electricity demand
  - Operating parameters of generators
  - Transmission grid parameters
- Used for system generation and transmission planning
  - Increasingly used for real-time operation



Locational prices, production cost

Dispatch information, fuel usage



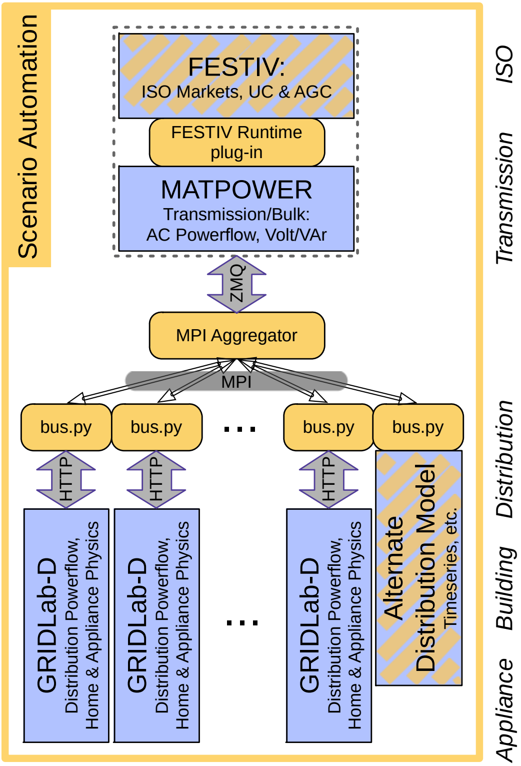


Transmission congestion

Integrated Grid Modeling System (IGMS)

- <u>Purpose</u>: Co-simulation of transmission and distribution systems for the purpose of analyzing power system technologies expected to have multiscale impacts (e..g. distributed PV).

- 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



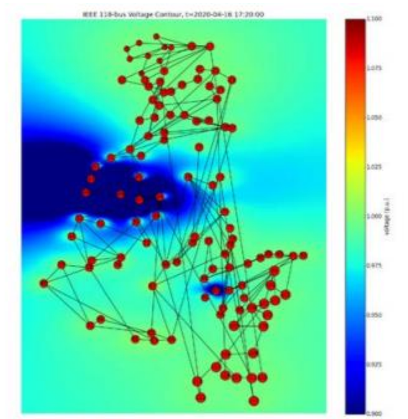
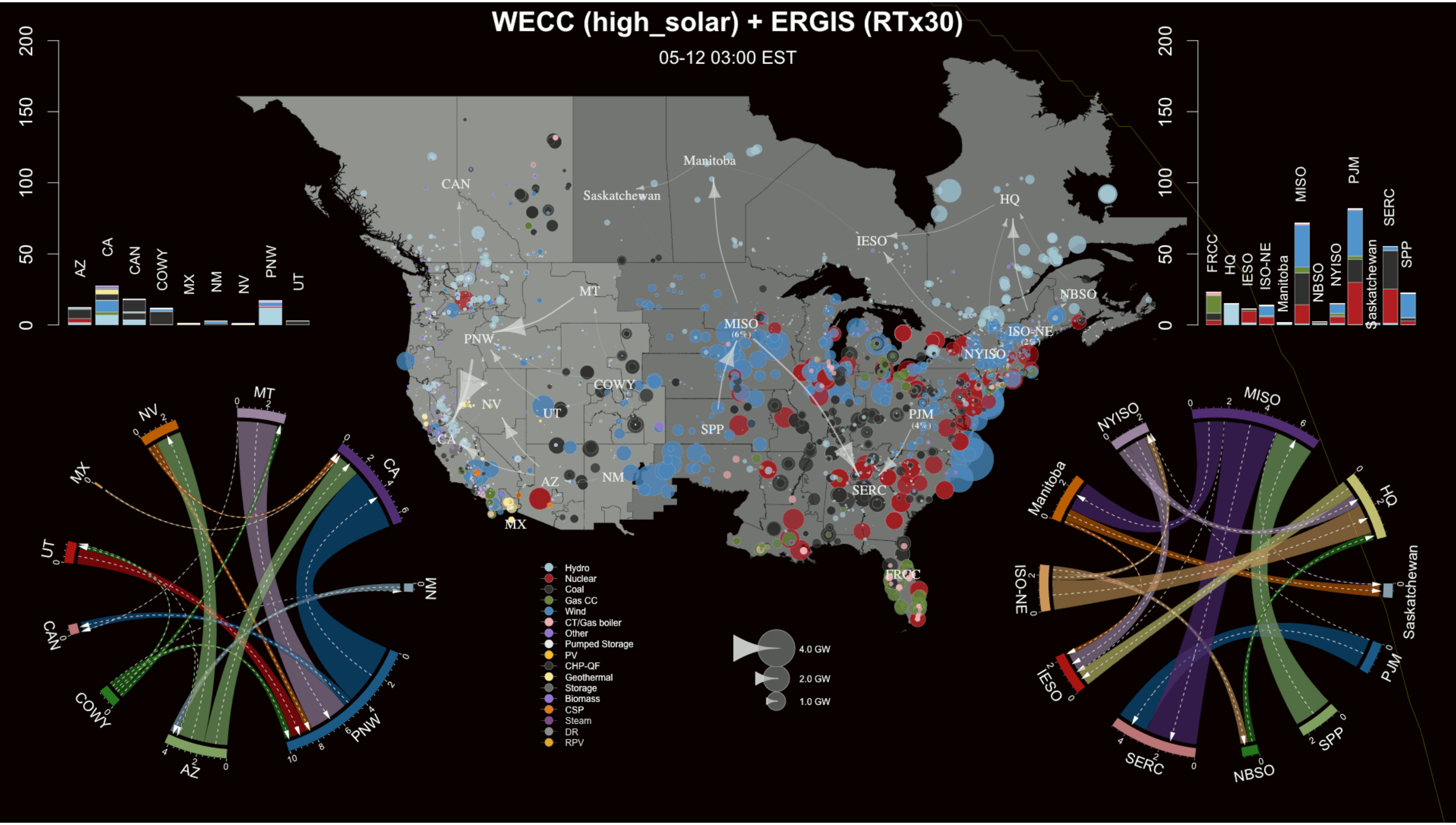


Figure 4. Spatial voltage plot for IEEE-118 bus test run

Example visualization of Production Costs



Distribution: Duke Energy Project

Wrap Up

<u>Next Advisory Group Meeting (tentative)</u>

- Monday, November 13th, 8:45 am – 1:00 pm
- Focus: Input on Scenario concepts and public outreach plan

<u>Interest in Study Group?</u>

<u>Homework from NREL</u>

- Check out Energy Gang podcast, including "Inconvenient Truth about Cities and Sustainability"
- https://soundcloud.com/the-energy-gang

www.nrel.gov

NATIONAL RENEWABLE ENERGY LABORATORY