GRID MODERNIZATION INITIATIVE PEER REVIEW

Multi-scale Production Cost Modeling 1.4.26

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Sheraton Pentagon City – Arlington, VA

Multi-scale Production Cost Modeling
High Level Summary

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Project Description

The goal of this project is to dramatically reduce the time required by industry to analyze future power system scenarios through production cost modeling (PCM), while considering higher-fidelity representations of the underlying systems.

Value Proposition

- ✓ Improve commercial tools through advanced use
- ✓ Provide deeper insights into how systems should be modernized
- ✓ Enable broader economic competitiveness

Project Objectives

- ✓ Develop new modeling algorithms
- ✓ Expand research domain by using high performance computing
- ✓ Deploy capabilities and data to industry

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Multi-scale Production Cost Modeling
Project Team

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Project Participants and Roles

Project Management: NREL, SNL
- Stakeholder engagement
- Implements project plan

Deterministic PCM: NREL, ANL
- Geographic Decomposition
- MIP Warm-Start

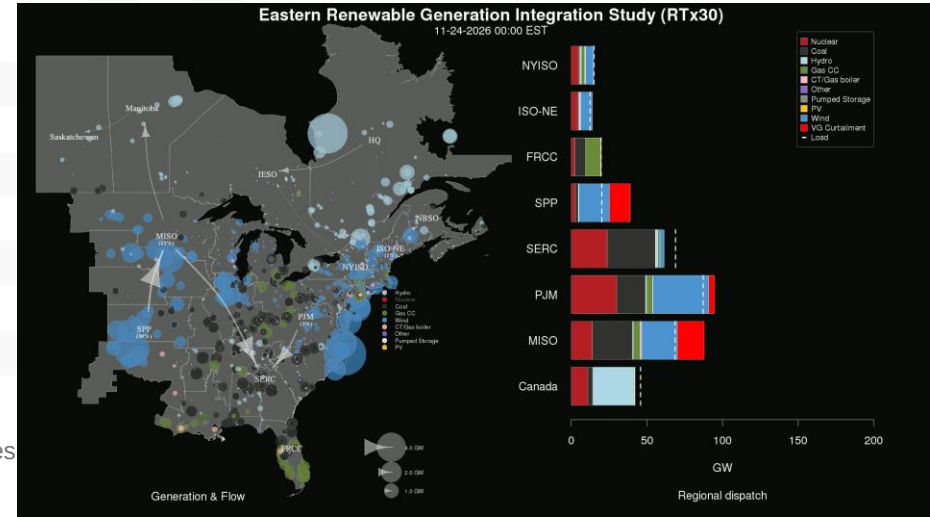
Stochastic PCM: LLNL, SNL
- Stochastic Data
- Stochastic Tools

Advisory: PNNL

PROJECT FUNDING			
Lab	FY16 $	FY17$	FY18 $
NREL	300K	360K	360K
SNL	269K	235K	235K
ANL	270K	235K	235K
LLNL	130K	139K	139K
PNNL	31K	31K	31K

Technical Review Committee:
SPP, MISO, PJM, ERCOT, Energy Exemplar, PSO, ABB, GE, NextEra, Xcel, Great River Energy, OSU, UC Berkley, UChicago, EPRI, National Grid, PNM, FERC

Technical Review Committee members participate in a workshop to learn how to use visualization tools.



Multi-scale Production Cost Modeling
Relationship to Grid Modernization MYPP

MYPP Vision: The future grid will solve the challenges of seamlessly integrating conventional and renewable sources, storage, and central and distributed generation (…)

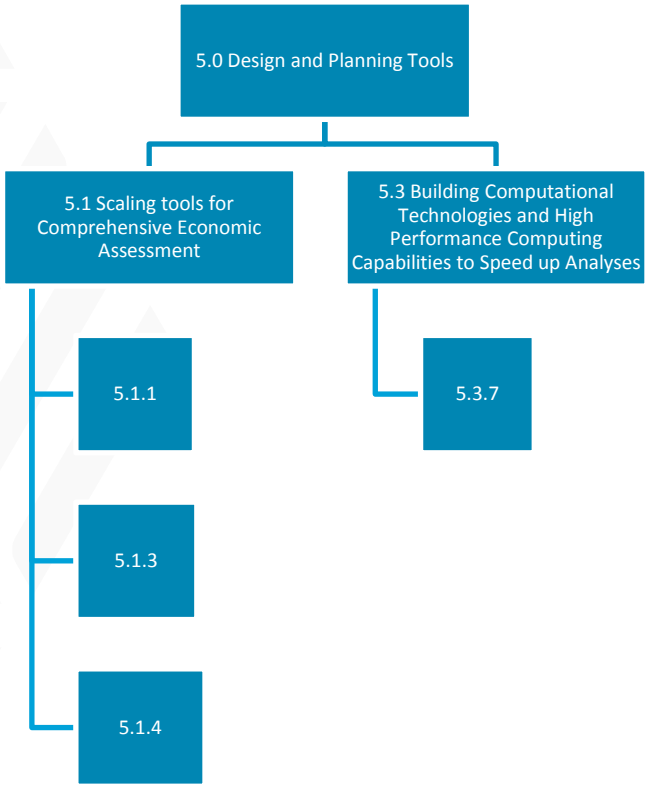
Direct relationship to MYPP vision by delivering a tool to ***estimate the value of national transmission planning***

5.1.1 – Task 5.1.1: Improve computational performance of production cost modeling for year-long sub-hour time resolution by decreasing run times from 2+ weeks to less than 1 day for (1) stochastic transmission and (2) deterministic combined transmission-distribution

5.1.3 – Develop advanced capacity expansion planning for generation, transmission, and distribution that captures operational flexibility, long and short term uncertainties, distributed energy technologies, market and policy impacts, and coupled network and generation optimization.

5.1.4 – Identify and classify data sources, define templates, and develop databases for new grid technologies, generation, load, and other components that compatible with modeling for high performance computers

5.3.7 – Implement "prototype to practice" program. Competitive process will be used to solicit important challenge problems, form teams comprised of GMLC members and problems owner



Multi-scale Production Cost Modeling
Approach

Accelerating deterministic production cost modeling

- Geographic decomposition (NREL)
  - Decompose large (e.g., eastern interconnect) planning models into geographically distinct regions (e.g., by ISO)
  - Iteratively solve smaller planning models in a coordinated manner, to accelerate mixed-integer solve times
- Sequential warm-starting (ANL)
  - Leverages similarity between unit commitment inputs and solutions for sequential days and/or historically similar days
  - Exploit similarity to accelerate mixed-integer solve times, e.g., by providing a near-optimal starting solution
- Temporal decomposition (ANL)
  - Decompose 48-hour or 72-hour unit commitment models into a sequence of linked, smaller unit commitment models
  - Iteratively solve smaller models in an coordinated manner, to accelerate mixed-integer solve times

Accelerating and evaluating stochastic production cost modeling

- Decomposition via Progressive Hedging (SNL and LLNL)
  - Objective is to tune decomposition algorithms to solve stochastic commitment models within a reasonable factor (e.g., 5 or 10) of the time required to solve deterministic commitment models
  - Advanced scenario-based decomposition using modest-scale parallelism for tractable run times
- Evaluation of stochastic on ERGIS sub-regions (SNL and LLNL)
  - Using realistic (ERGIS) planning models with high renewables penetration, rigorously evaluation the performance of stochastic versus deterministic commitment models for production cost modeling

Multi-scale Production Cost Modeling

Key Project Milestones

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Milestone (FY16-FY18)	Status	Due Date
Deliver the ERGIS database to Energy Exemplar for public hosting and sharing across project team.	100%	8/30/16
Coordinate and host at least 1 TRC meetings with other GMLC projects, i.e. Midwest Regional Partnership, and North American Renewable Generation Integration Study. Meetings should have at least 10 non-lab participants.	100%	10/31/16
Improve functionality of existing NREL temporal decomposition methods through improved software tools for running PLEXOS in Linux	100%	10/31/16
Submit a document for DOE review that quantifies differences in production cost model results under zonal vs. nodal transmission assumptions.	100%	10/31/16
Complete literature review on general MIP warm-starting techniques and field knowledge on expediting deterministic sequential UCs.	100%	8/30/16
Identify warm-starting techniques that are ready to implement in sequential deterministic UCs; implement and test the performance of the preliminary warm-starting techniques on small-scale test system. 2) Develop and implement a temporal decomposition method based on well-known techniques (e.g., Lagrangian relaxation); collect and analyze the performance of the preliminary results from the method on small-scale test systems.	100%	10/31/16
Identify ERGIS sub-region for stochastic analysis, and convert database into use with PRESCIENT stochastic production cost model.	100%	8/30/16
Integrate relevant WIND and SIND data from NREL into PRESCIENT, and demonstrate ability to generate stochastic renewables production scenarios.	100%	10/31/16
Identify stochastic decomposition scheme to develop/extend, and coordinate with SNL to utilize same stochastic production cost model for LLNL algorithms	100%	8/30/16
1) Participate in technical review committee meeting, and coordinate stochastic renewable generation scenarios with SNL. 2) Test stochastic decomposition schemes for real-world but smaller scale instances than the ERGIS scenarios.	100%	10/31/16
Enable external access to Peregrine HPC to enable workshop participants to execute test runs using NREL temporal decomposition and data management tools developed by research team by hosting at least 1 deployment workshop.	100%	2/28/17
Document the findings from the initial development and testing of warm-start and temporal decomposition methods in two conference/journal papers.	100%	2/28/17
1) Participate in advanced PCM workshop, and document initial work in technical reports. 2) Create stochastic PCM models derived from SNL models for LLNL decomposition schemes.	100%	2/28/2017

Multi-scale Production Cost Modeling
Accomplishments to Date

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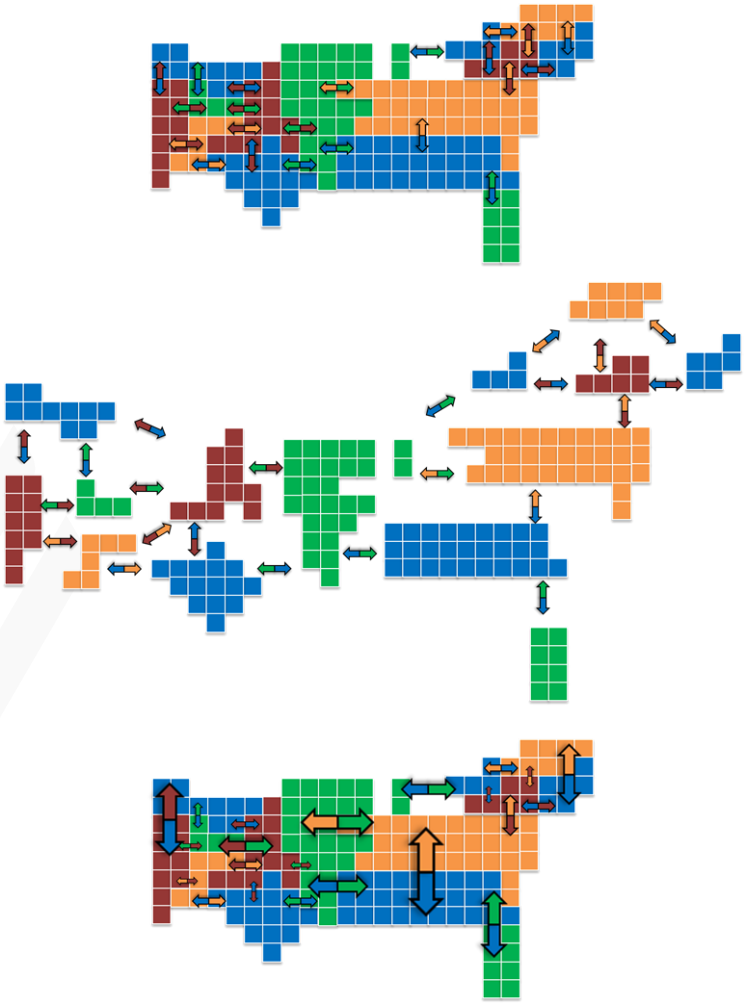
Geographic Decomposition

- Increasing accuracy reducing solve time
- Three steps
  - Interchange Forecast
  - Regional Day Ahead
  - Joint Redispatch
- Preliminary testing = 50% reduction in solve time

Model Phase	Centralized UC	Geographic Decomposition UC
Simplified Day-Ahead	10 hours	10 hours
Day-Ahead	50 hours	1-5 hours/region run in parallel
Real-Time	10 hours	10 hours
Total	60 hours	25 hours



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Accomplishments to Date

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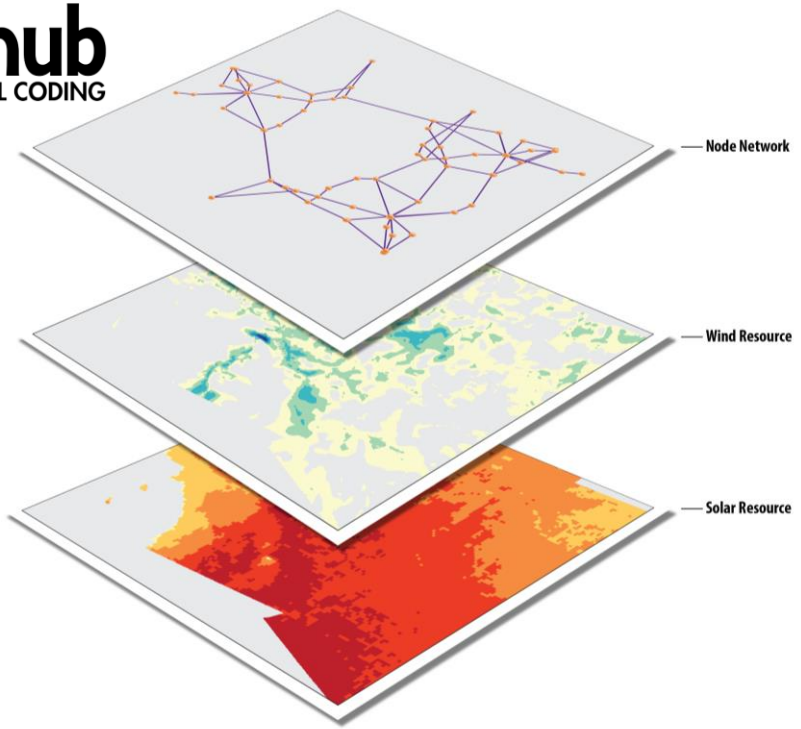
Technical Review Committee

- In-person TRC meeting, October 2016
  - 30 participants
- Advanced PCM Workshop May 16, 2017
  - Deployed tools to industry and software developers

Reliability Test System (RTS-GMLC)

- IEEE asked for help to update RTS-96
- Critical updates
  - Addition of modern natural gas generation
  - Spatial and temporal diversity for load, wind and solar
- Online collaborators from industry, software, and academia: GE, UT, ISU, IEEE, NAU, PSO, Energy Exemplar

github SOCIAL CODING



Multi-scale Production Cost Modeling
Accomplishments to Date

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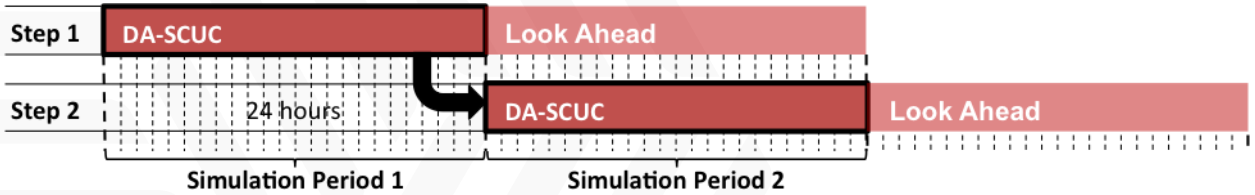
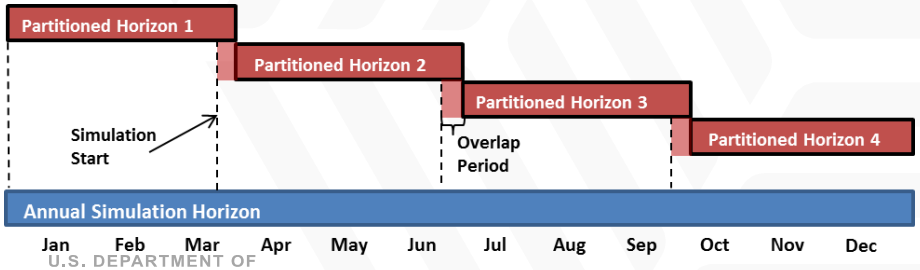
Problem: PCMs repetitively solve **similar** MIPs on **sequential** time steps

- Yesterday's schedule constrains today's operations
- Yesterday isn't that different from today



► Temporal Decomposition

- Parallelizing solution by decomposing MIP step sequence
- Implemented using open source software packages (Julia w/ DSP and Coin-Alps)
  - Easy to try different formulations (with different constraints and variables)



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► MIP Warm-Starting

- *Warm-start*: accumulates useful information (branch-and-bound tree, cuts, feasible solutions, etc.); used to expedite next solves

Case	Instance	% Improvement with Warm-starting
Diff. loads (pure Branch & Bound)	30-bus	~38%*
Diff. objective coeff. (Branch & Cut)	30-bus	~59%

- Directions for future work:

  Enhancements: cut modifications, improved branching strategies, etc.

  Transferability: facilitate performance improvements to commercial solvers

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Accomplishments to Date

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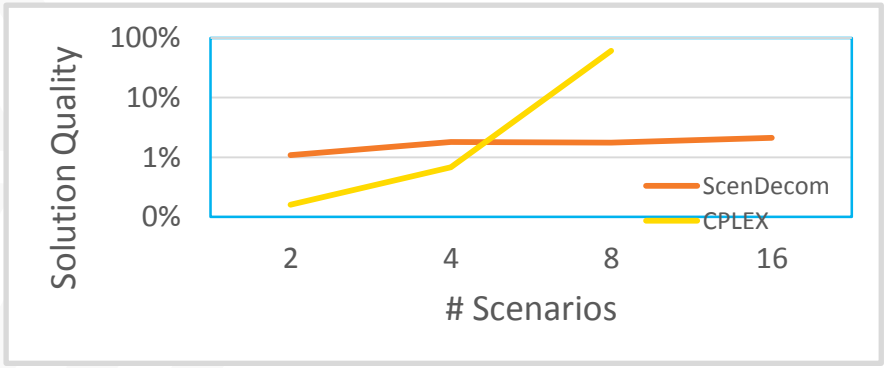
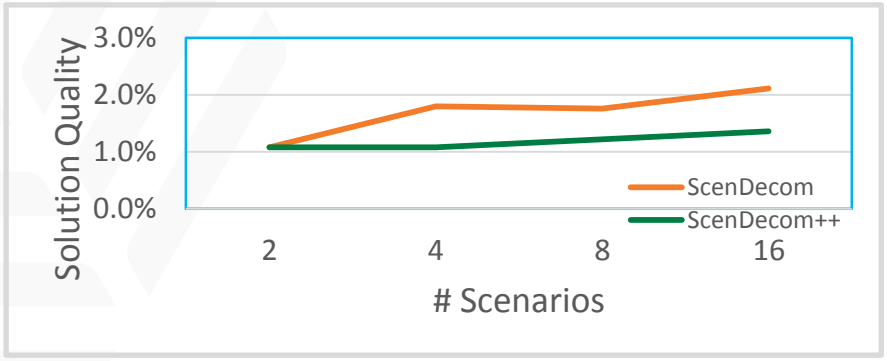
Accelerating Stochastic PCM and Enabling Stochastic vs. Deterministic PCM Evaluation

- **Scenario Decomposition and Grouping for Stochastic Unit Commitment**
  - Parallelizing solution by decomposition
  - CWE (Central-Western Europe) instances
    - 679 nodes and 1037 lines, 637 thermal units
  - Goal: Provide guarantee on solution quality
  - MIP solvers scale exponentially!
  - ScenDecom scales almost linearly!



- **Optimal Scenario Grouping Techniques Improve Scenario Decomposition schemes by 40%**
  - Provides higher-quality solutions



- **Probabilistic renewables production forecasts from NREL WIND and SIND toolkits**
  - Integrated in Prescient PCM simulator
- **Improved stochastic PCM solvers in Prescient by 25%**
  - Achieved by leveraging advanced Python bindings available in commercial MIP solvers

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Response to December 2016 Program Review

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Recommendation	Response
Please move forward in developing a GitHub site for the GMLC.	The GitHub site for the RTS-GMLC is live and already has several users from academia, industry, and software developers.
Please decide on a framework for sharing the results of this project with industry.	We will use a direct industry engagement framework that depends on presentations at leading industry events such as IEEE, UVIG, CIGRE, SC
Should there be a focus on U.S. industry only?	This area of the scope could be expanded but may be difficult to prioritize with current funding

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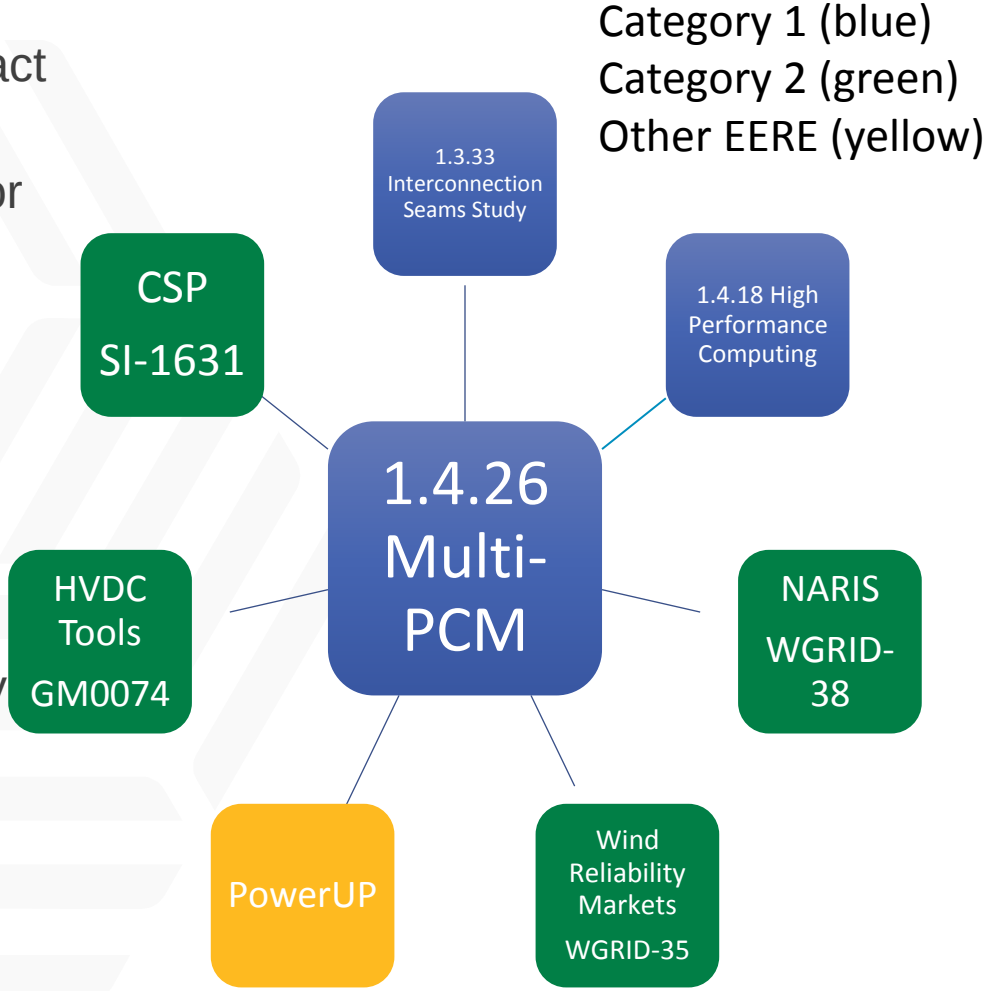
Project Integration and Collaboration

Advanced PCM capabilities directly impact other GMLC and related ”study” projects

- Reduced simulation times required for at-scale deterministic PCM studies
- Facilitates more extensive sensitivity analyses

Improvements in the fidelity of PCM simulations (e.g., directly accounting for uncertainty) translate into improved confidence that long-term planning study outcomes reflect future power system realities



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Past and Planned Presentations

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Past

- Utility Variable Generation Integration Group
  - NREL
  - March, 2017
- INFORMS Annual Meeting
  - LLNL, SNL, ANL
  - November, 2016
- INFORMS Computing Society
  - LLNL, ANL
  - January, 2017

Planned

- Joint TRC Meeting
  - Entire team
  - May 16-18
- IEEE PES
  - NREL, SNL, LLNL, ANL
  - July 2017
- SIAM Optimization
  - ANL, SNL, LLNL
  - May 2017
- FERC Software Conference
  - SNL, ANL, NREL
  - July 2017
- INFORMS
  - SNL, ANL
  - October 2017

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Next Steps and Future Plans

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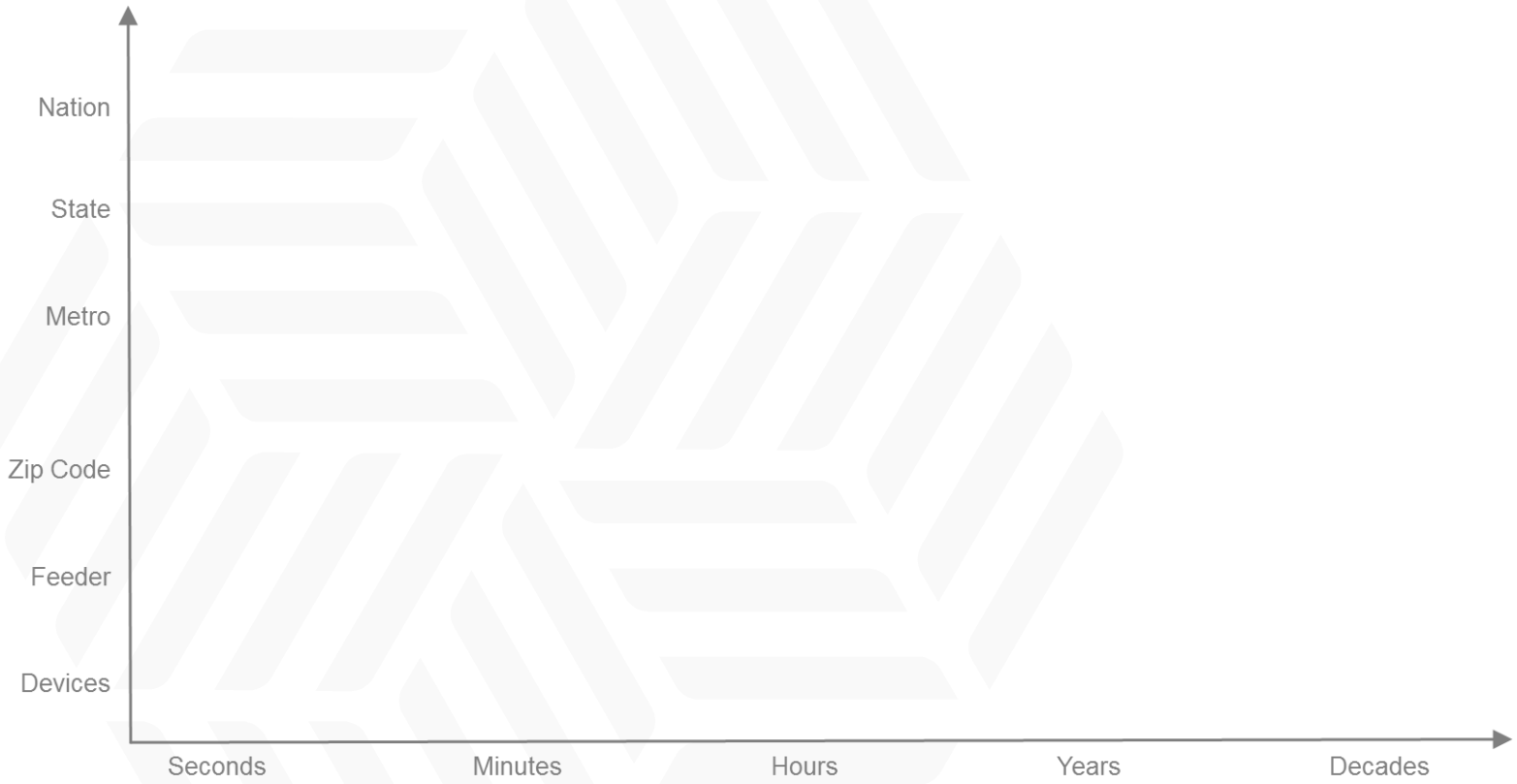
Next Steps

- Combine temporal and geographic decomposition
- Deploy combined decomposition methods to the Interconnections Seams Study
- In-person TRC meeting
- Submit paper to IEEE for RTS-GMLC
- Submit papers on temporal decomposition and MIP warm-starting/improved UC formulations
- Complete initial comprehensive stochastic “versus” deterministic PCM study
- Complete stochastic version of RTS-GMLC
- Submit paper on scenario grouping and decomposition techniques

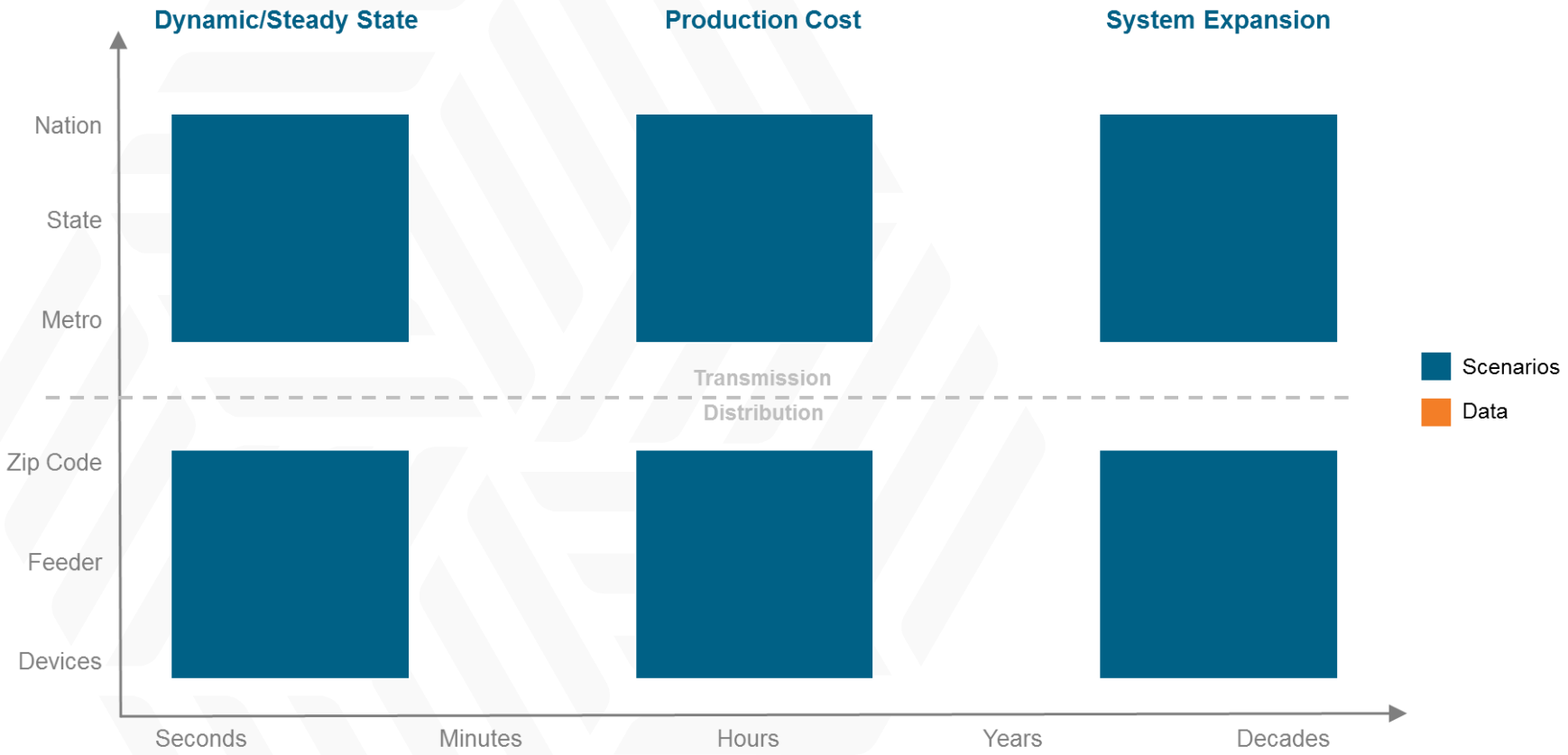
Wish List

- Get inside the black boxes
  - Create open source production cost model (Prescient?, PSST?)
- Journal of Supercomputing
- Bigger computers!!!

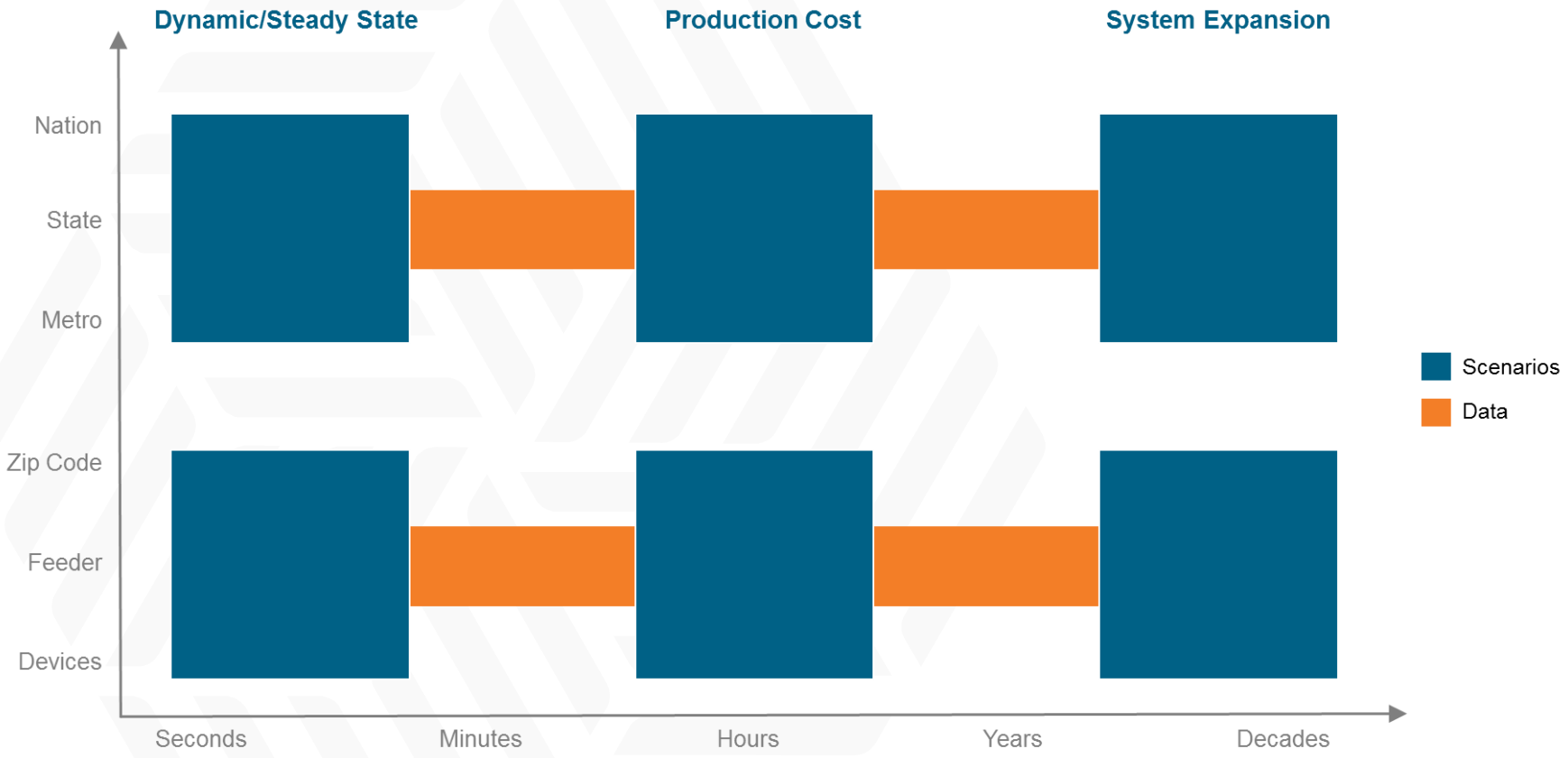
Scales of Reliability and Efficiency



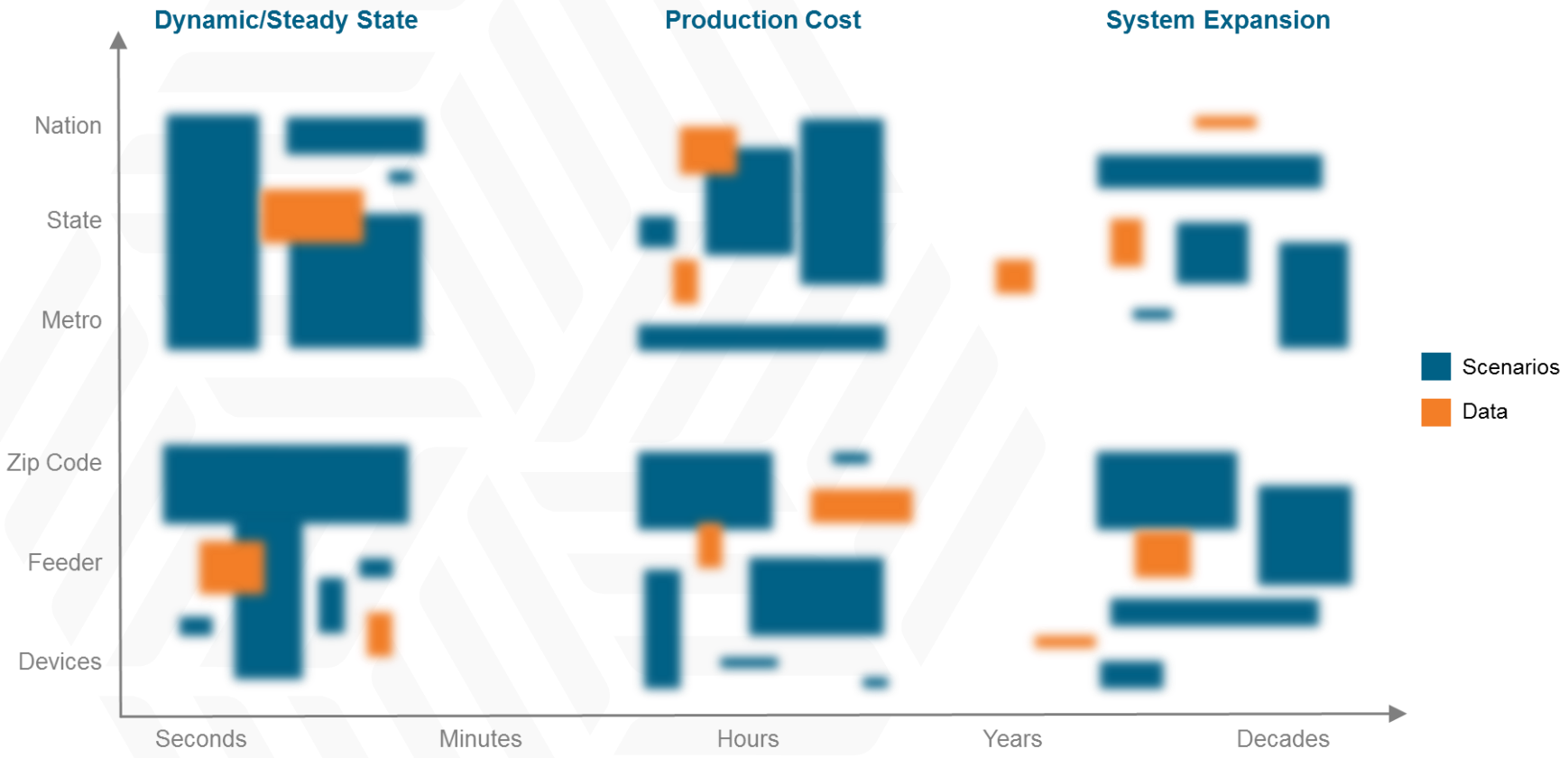
Power System Planning Models



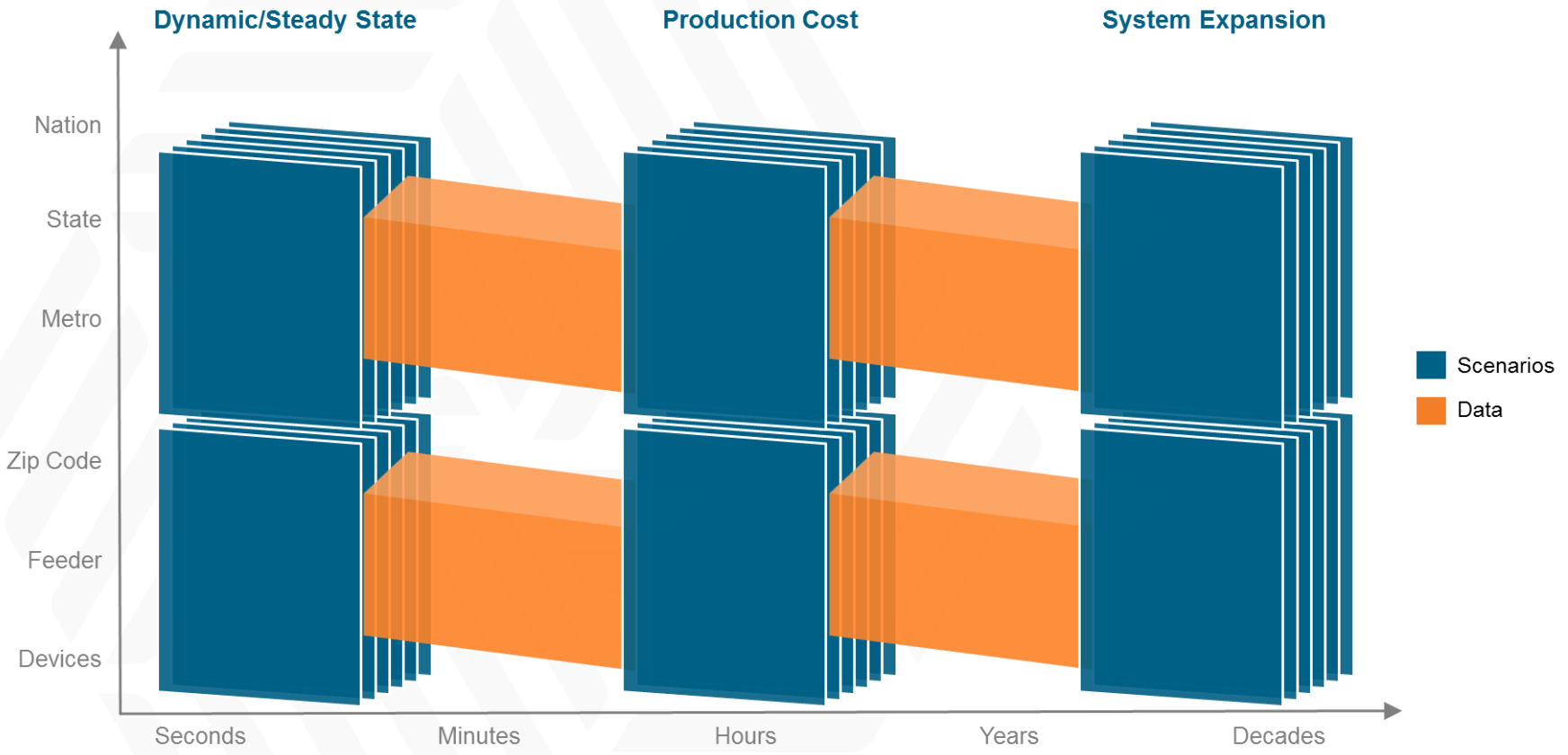
Current Practice, hopeful



Current Modeling, more accurate



Near Term Modeling Goal



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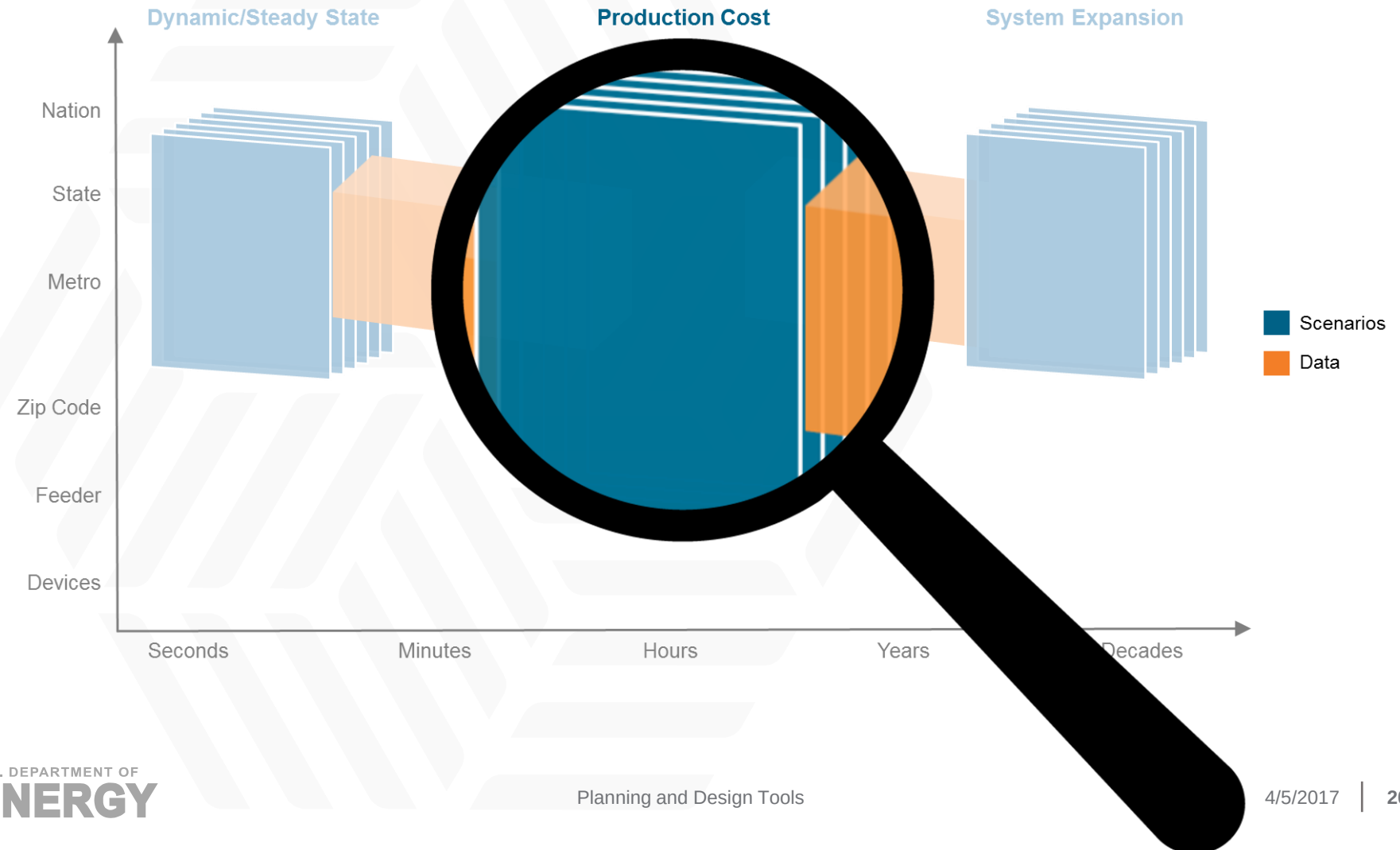
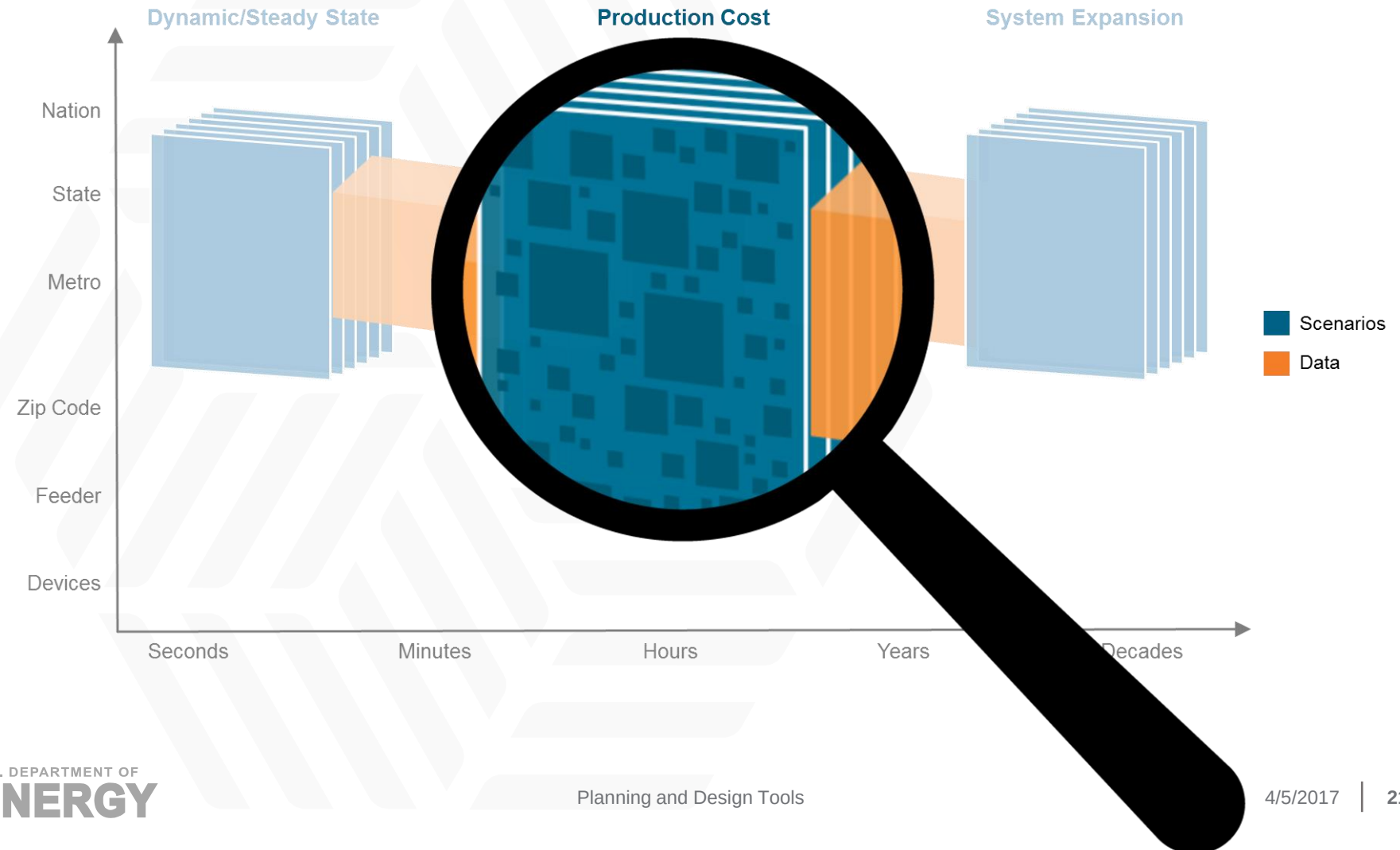


Adding Resolution



Increasing robustness