Geographic Decomposition of Production Cost Models

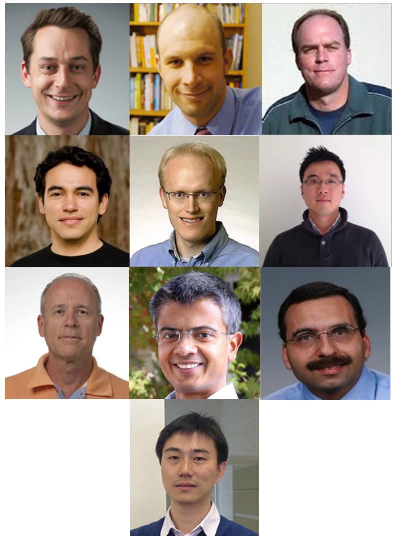
Josh Novacheck, Clayton Barrows, Aaron Bloom, Brendan McBennett

06/27/2017

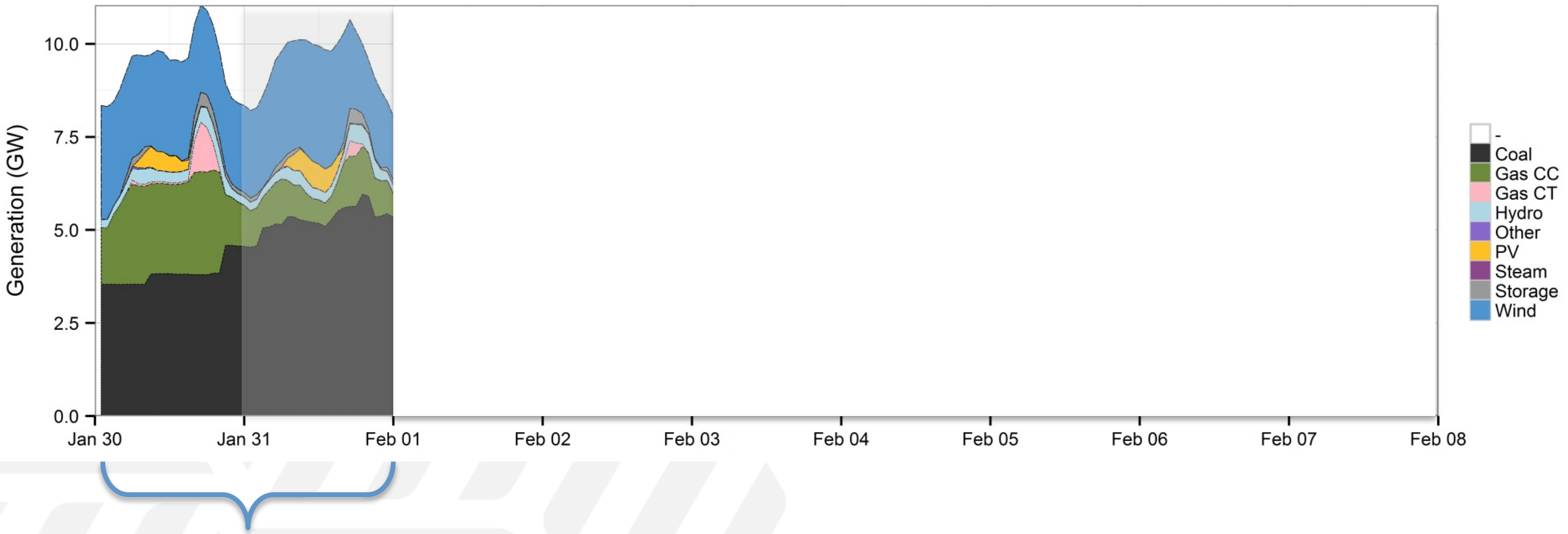
FERC Technical Conference: Increasing Real-Time and Day-Ahead Market Efficiency through Improved Software
Washington, DC

GMLC: Multi-Scale Production Cost Models

- GMLC: Grid Modernization Laboratory Consortium
  - An aggressive five-year grid modernization strategy for the Department of Energy
- Design and planning tools sub-area includes Multi-Scale Production Cost Models
  - Develop multi-scale production cost models with faster mathematical solvers
- PCM Goal:
  - Substantially increase the ability of production cost models (PCM) to simulate power systems in more detail faster and more robustly.
  - Both Deterministic and Stochastic
- Talks at Technical Conference:
  - Session T1-B: Optimization Driven Scenario Grouping for Stochastic Unit Commitment (LLNL)
  - Session T3-A: Geographic Decomposition of Production Cost Models (NREL)
  - Session T3-A: Temporal Decomposition of the Production Cost Modeling in Power Systems (ANL)

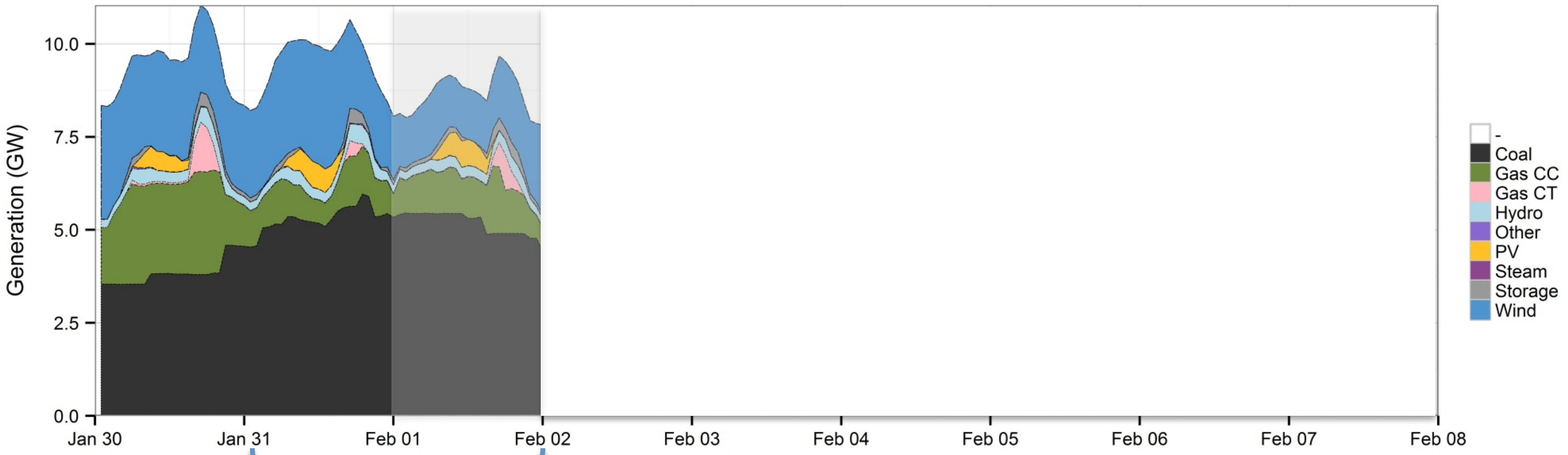


Unit Commitment and Economic Dispatch



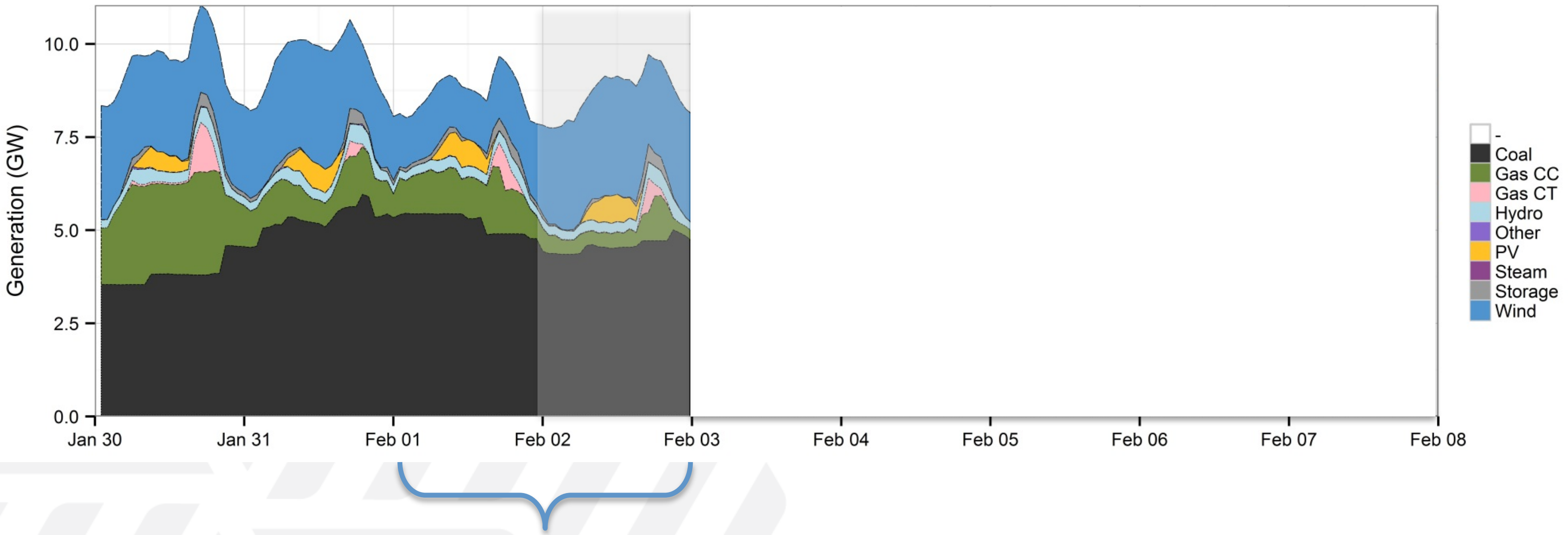
optimization horizon:
48 hours

Unit Commitment and Economic Dispatch



rolling forward in
24 hour increments

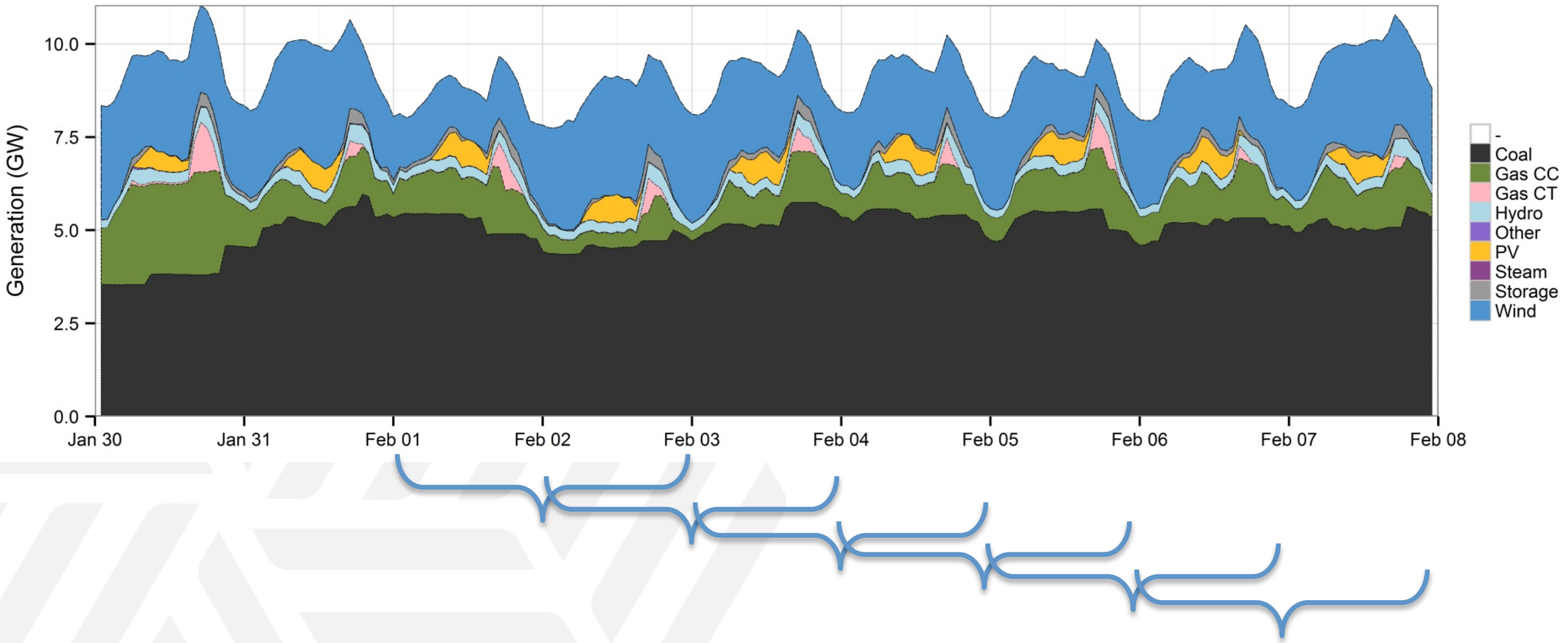
Unit Commitment and Economic Dispatch



The state of the system at time t=0 is dependent on:

1. Generator commitment status: on/off
2. If "on": hours of continuous operation; current ramp rate
3. If "off": hours since last operation (minimum shut down duration)

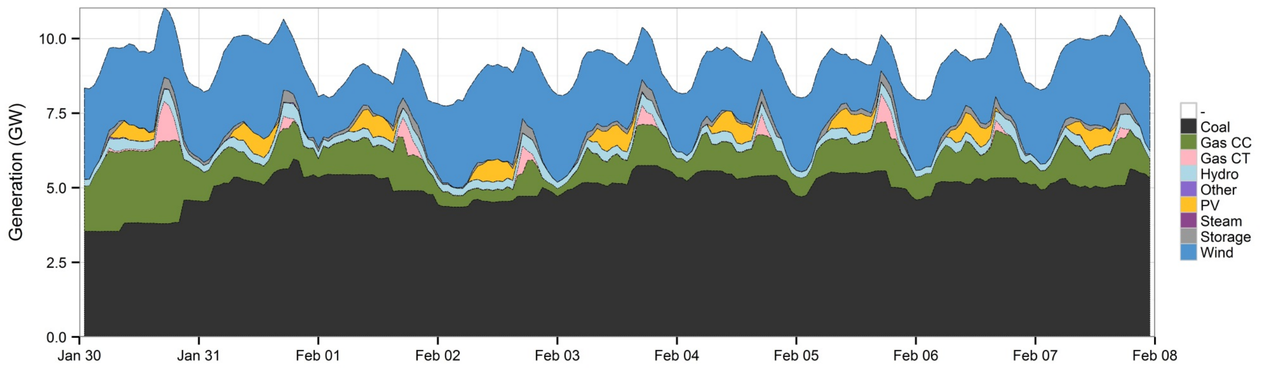
Unit Commitment and Economic Dispatch

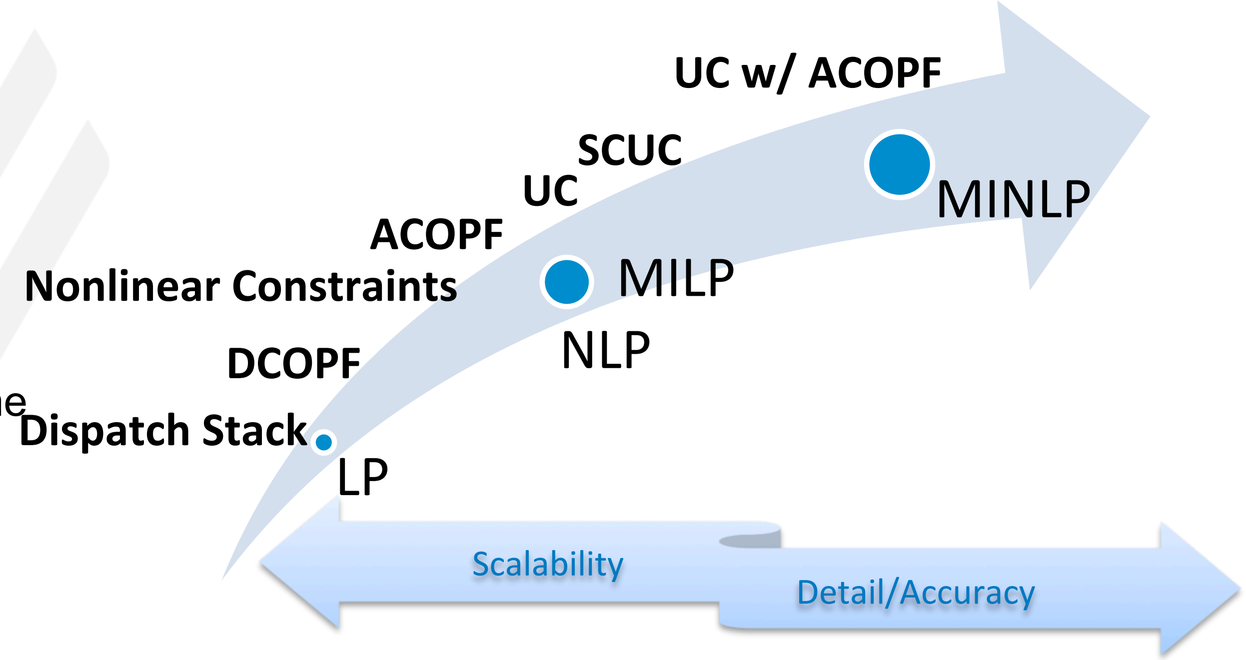


Individual MIP computation times can exceed multiple days.
Annual solutions can easily become impractically long.

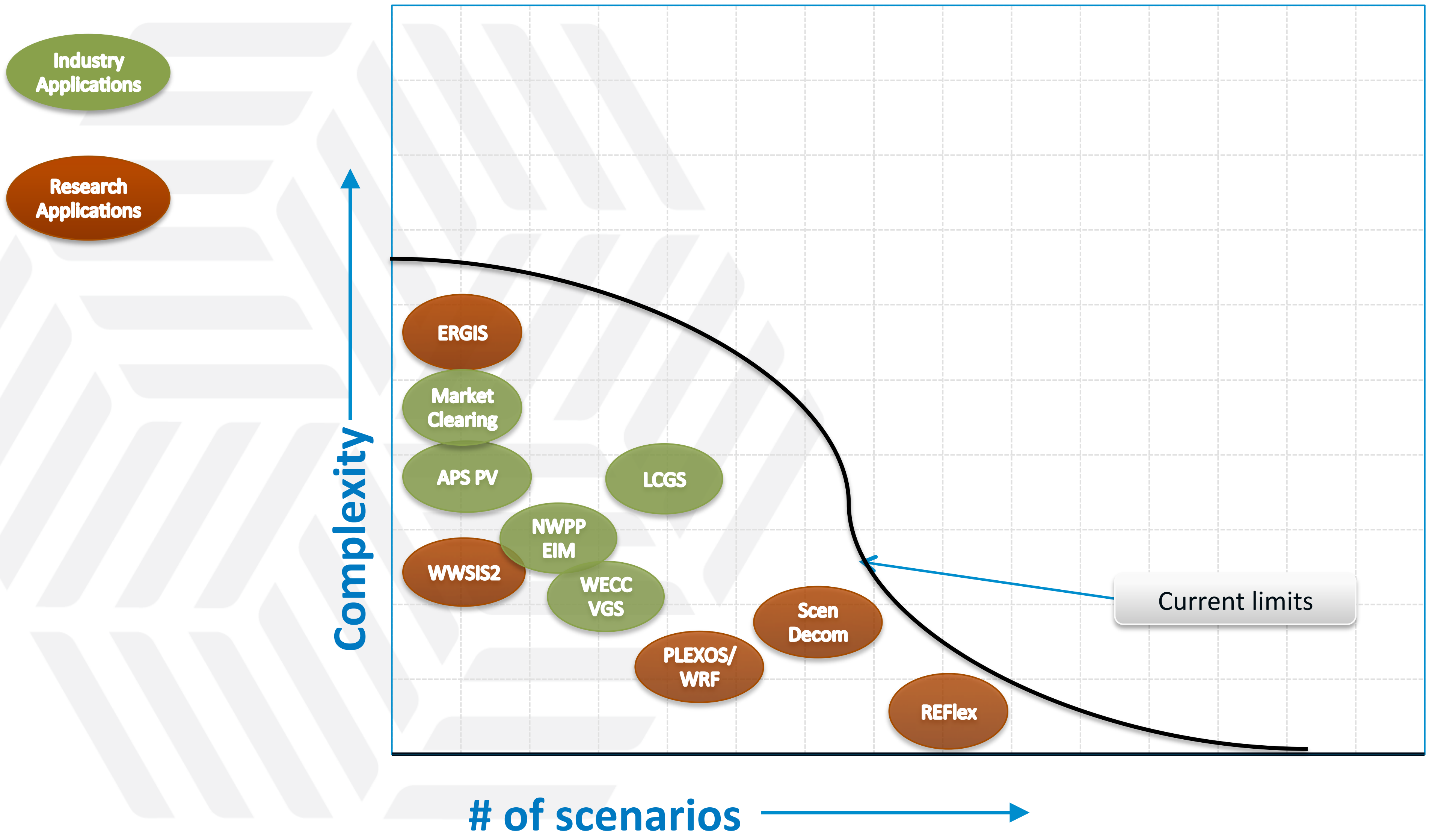
Production Cost Modeling

- Understand the impacts of hypothetical situations
  - Neglect capital costs
  - Typically simulated as least cost optimization models
- What's important:
  - Accuracy
    - Resolution/scope
    - Physics approximations
    - Economic/market approximations
  - Speed
    - Study scope determined by computational time required for a single scenario

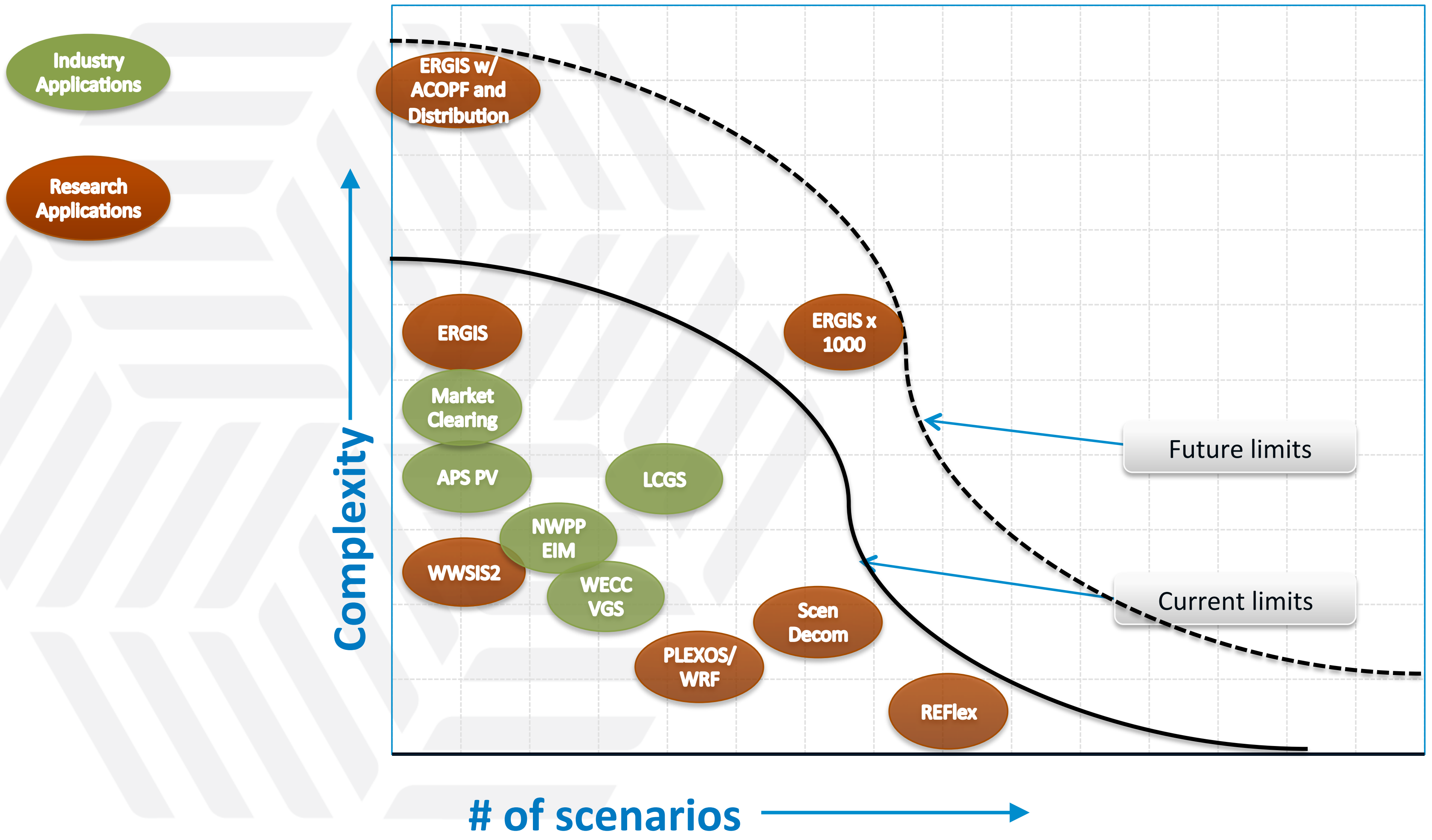




Boundaries of PCM

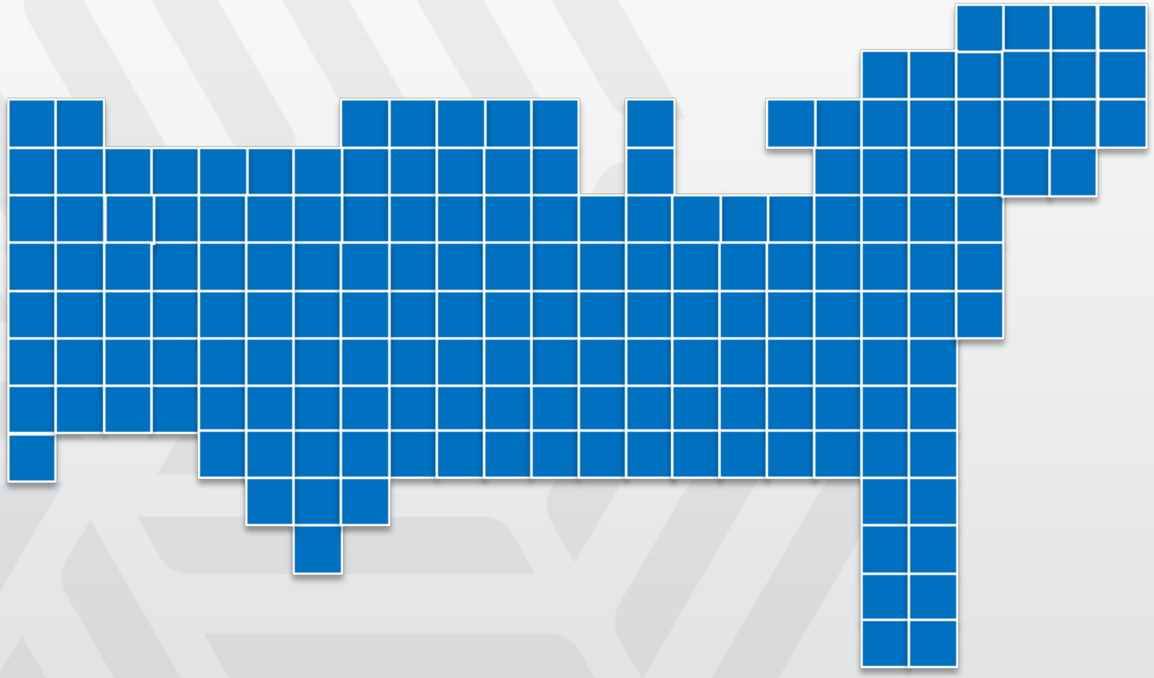


Boundaries of PCM



Traditional Approach: One optimization for the entire system

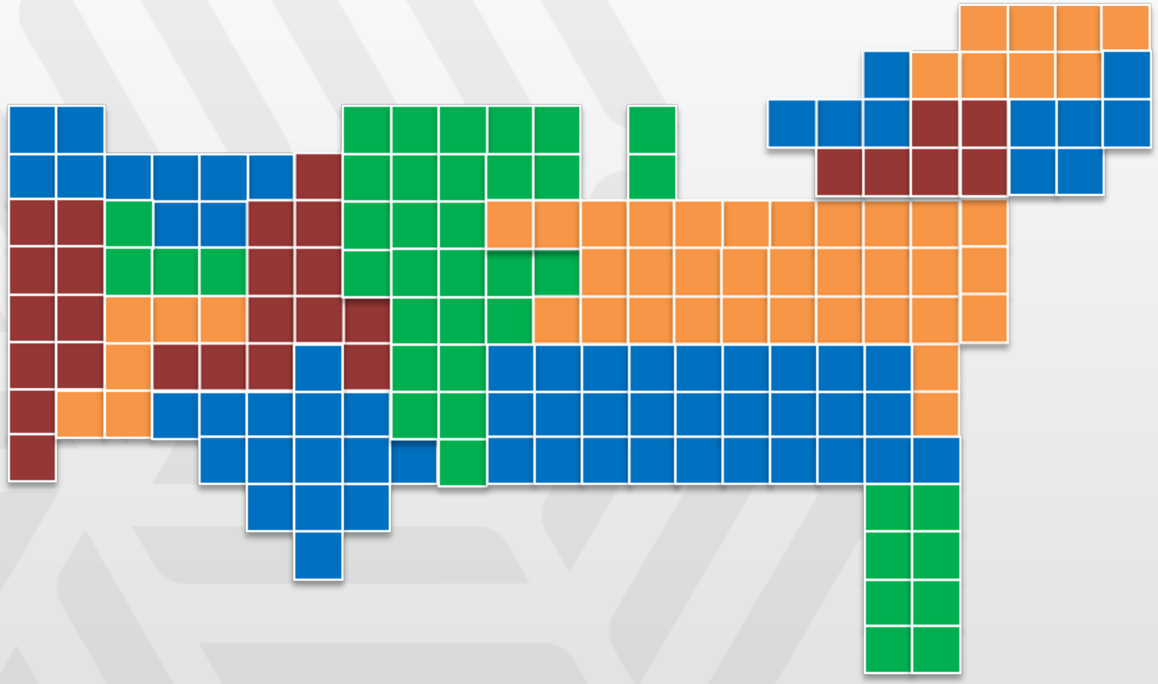
Examples:
- Eastern Renewable Generation Integration Study
- California Low Carbon Grid Study
- Western Wind and Solar Phase II



= 10 GW

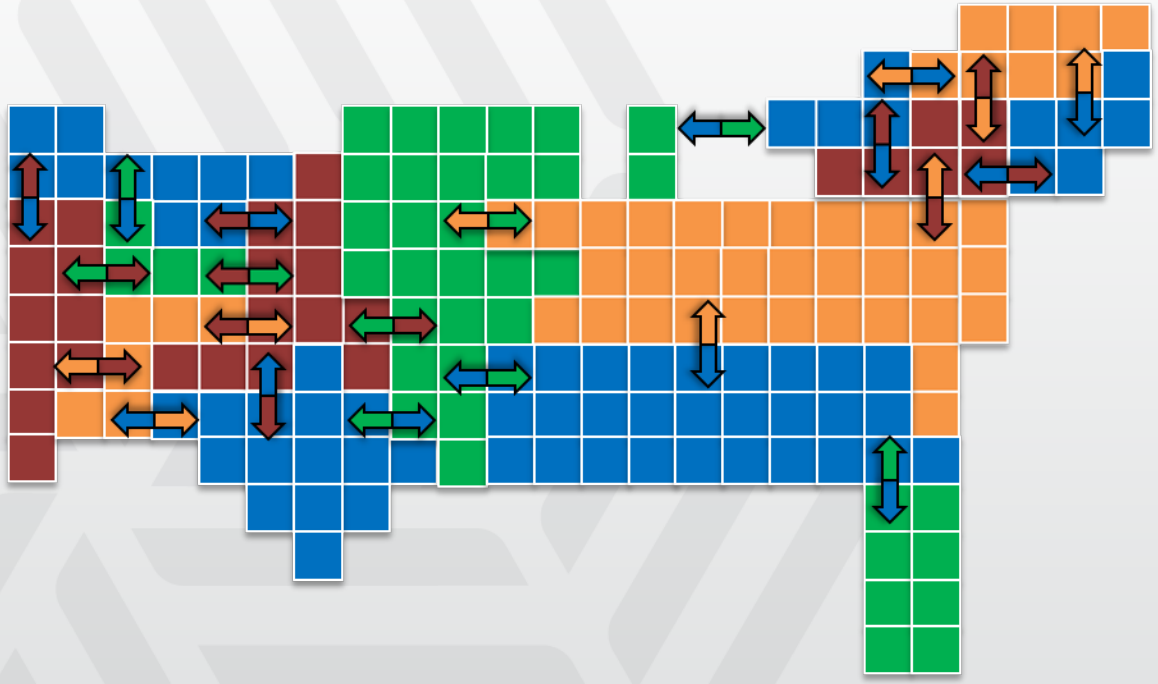
- Drawback 1: Single objective function, when in reality there are multiple
- Drawback 2: Intractable solve time on detailed models

New Approach: Geographic Decomposition



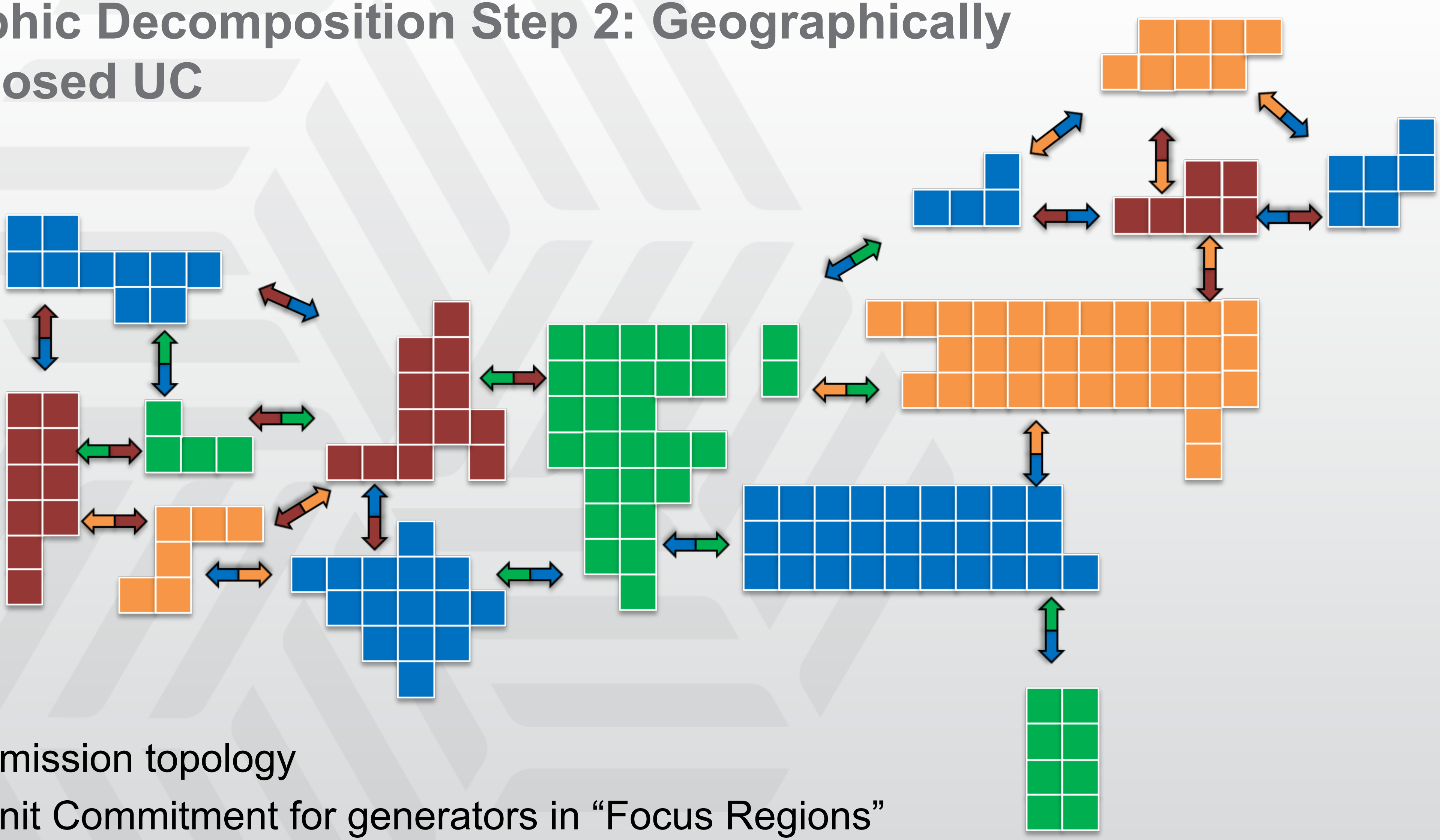
- Benefit 1: Separate optimization for each region
- Benefit 2: Reduced total solve time
- Benefit 3: More accurate representation of regional flexibility and constraints

Geographic Decomposition Step 1: Transmission Flow Forecast



- Continental model is run at hourly Day-Ahead time step
- Linear commitment dramatically reduces solve time
  - Other simplifications to be considered if needed (i.e. Min up/down times, start costs, etc.)
- Objective is to determine forecasted power flow throughout the network

Geographic Decomposition Step 2: Geographically Decomposed UC

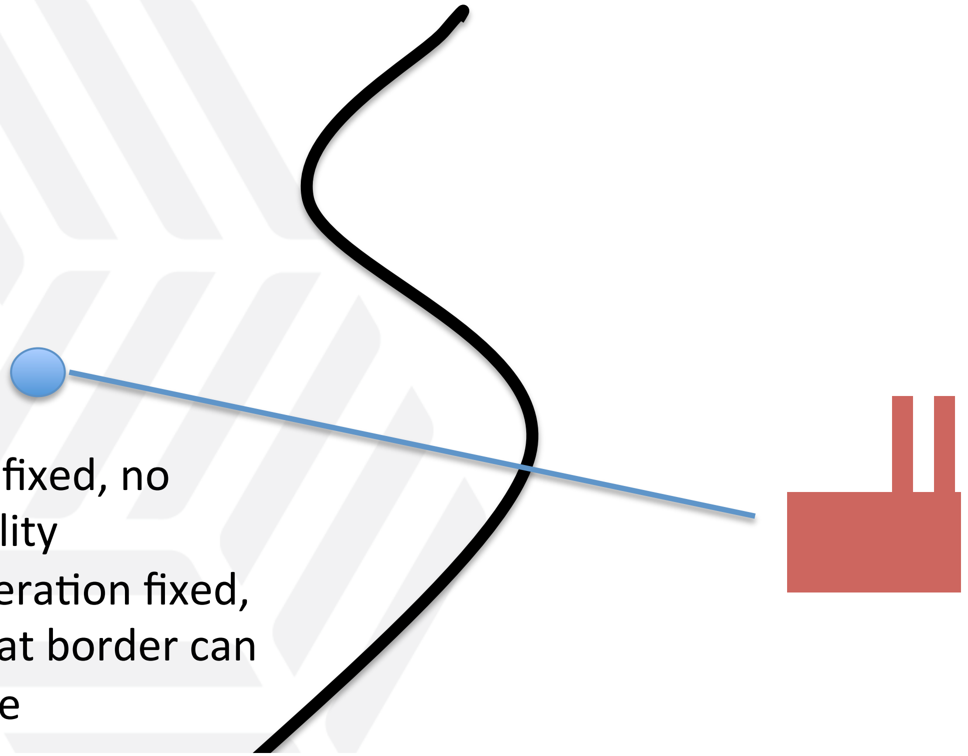


- Full transmission topology
- Integer Unit Commitment for generators in "Focus Regions"
  - Able to add more detailed assumptions (i.e. enforce lower voltage line thermal limits, smaller MIP gap)

Non-Focus Regions

- Fix flows on interregional lines between Focus and Non-Focus Region
  - Changes inequality constraint to an equality
  - Does not remove any decision variables
    - Non-Focus generators must be dispatched to meet fixed flow constraints
- Fix generation of Non-Focus generators
  - Remove binary decision variables
  - Flow on lines may be inconsistent with flow in Step 1
    - Net interchange between regions is fixed
- Set target prices
  - Requires the creation/siting of pseudo-generators/loads in non-focus regions and results in inaccurate transmission flow patterns
  - Soft constraints can skew prices
  - Flow on lines may be inconsistent with flow in Step 1
    - Net interchange between regions may also change

Fixed Generation Flows

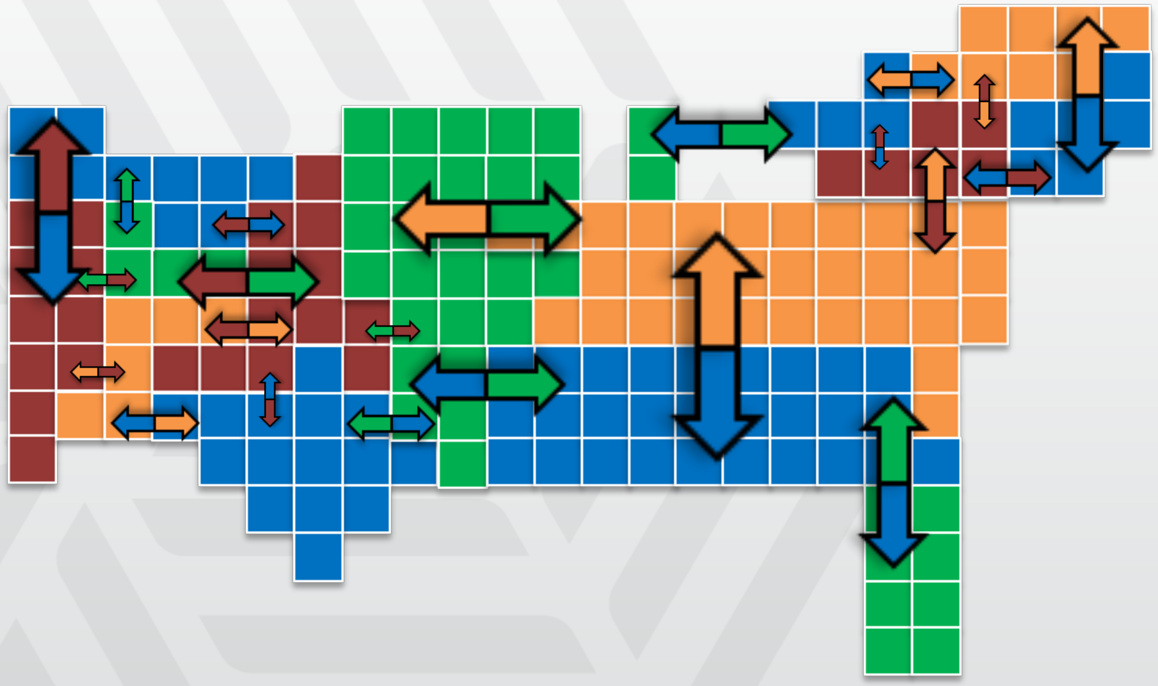


- If line fixed, no flexibility
- If generation fixed, flows at border can change

- Dispatched at 25% in Flow Forecast
- Min Stable of 60%
- Near border with parallel lines

TOTAL INTERCHANGE IS FIXED BETWEEN REGIONS

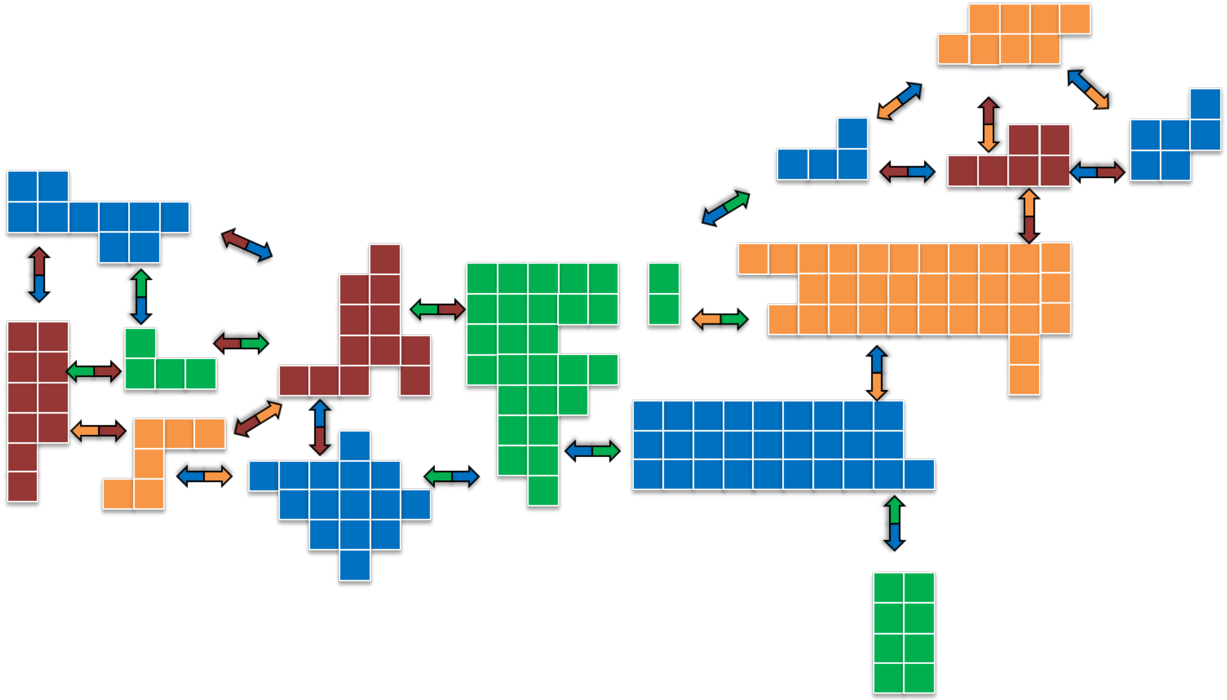
Geographic Decomposition: Step 3 Combined Real-Time



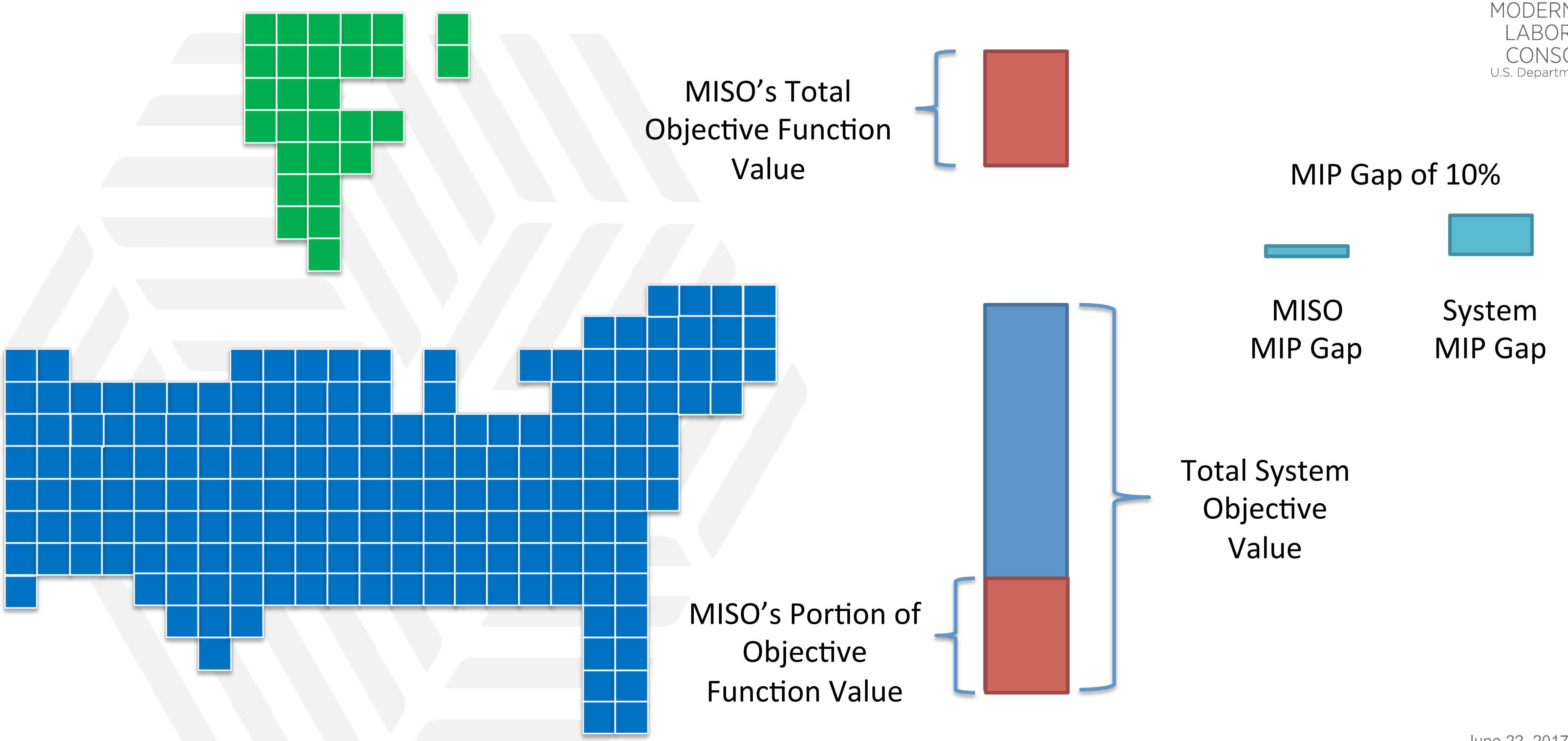
- RT dispatch as single geography again
- Unit commitment decisions from integer decisions in Step 2
- Flows change based on refined UC decisions and forecast errors (i.e. Load, Wind, Solar)
- Ensures flows are physically consistent

Discussion of Step 2: Geographically Decomposed UC

- Fewer integer decisions
  - Each region only considers unit commitment for their own region
- MIP Gap
  - Each region has unique MIP Gap
  - Measure small changes
- Add detail to simulation
  - Enforce more line limits
  - Reduce MIP gap
- Hurdle rates
  - Main method for modeling market friction in Traditional Approach
  - We can still model friction with Hurdle Rates within decomposed regions

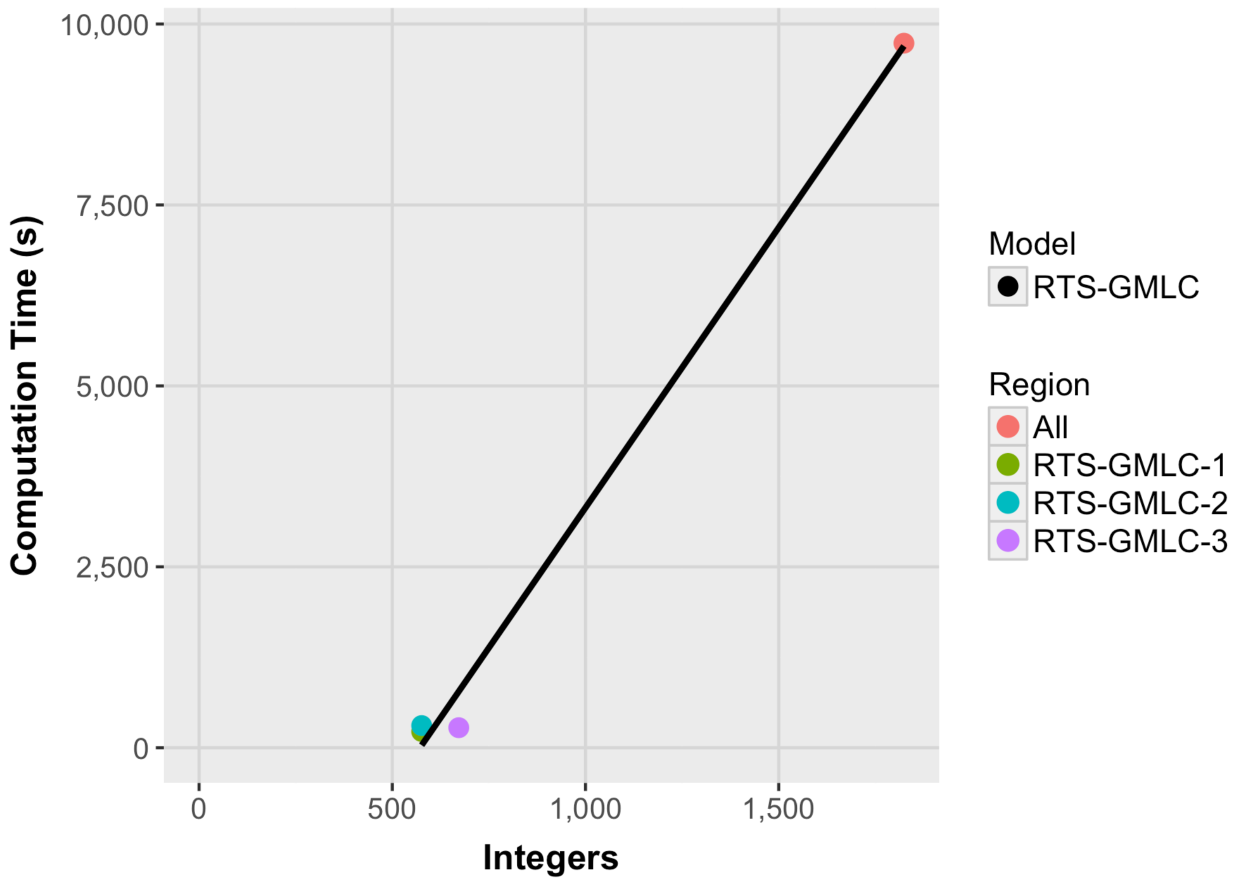


MIP Optimization Tolerance (Gap)

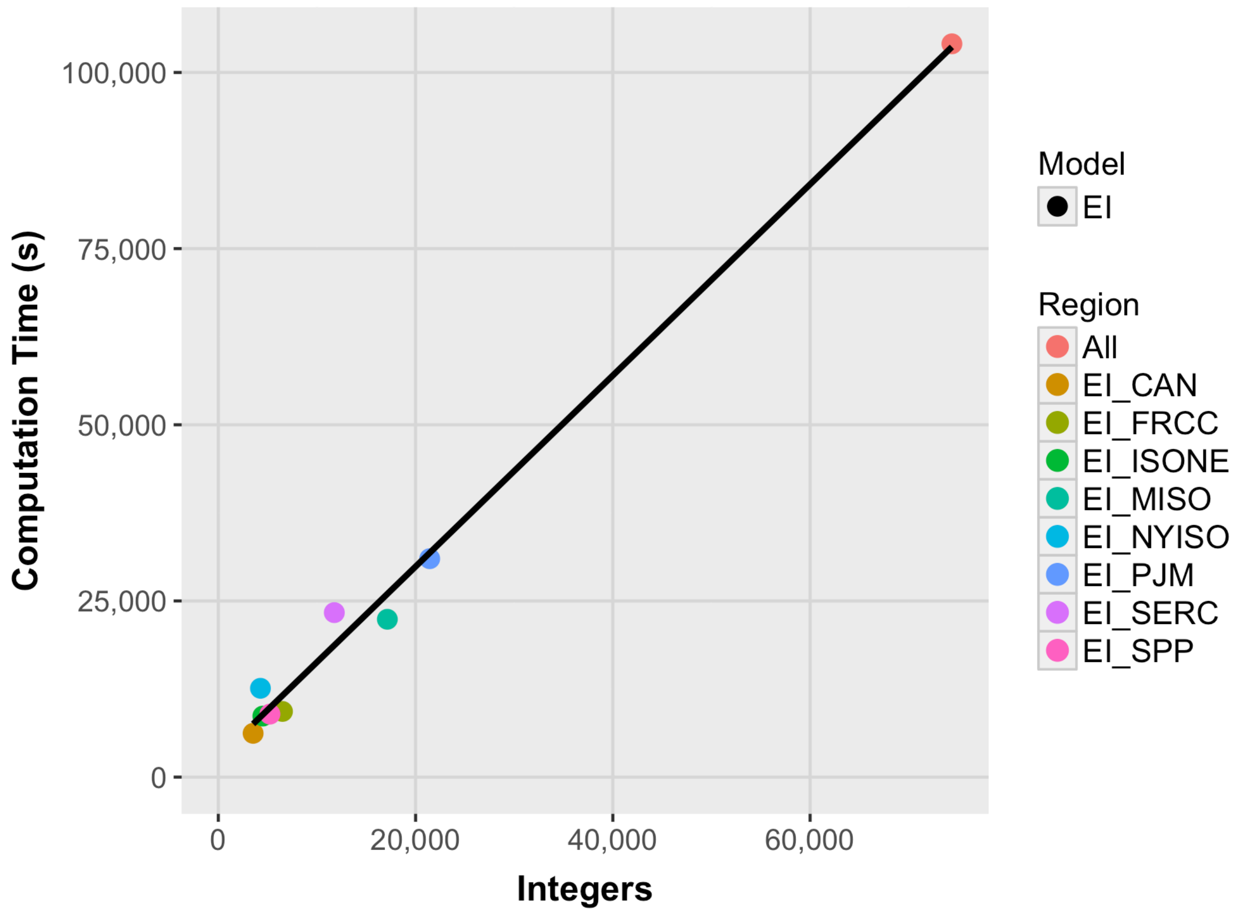


Integer variable reduction

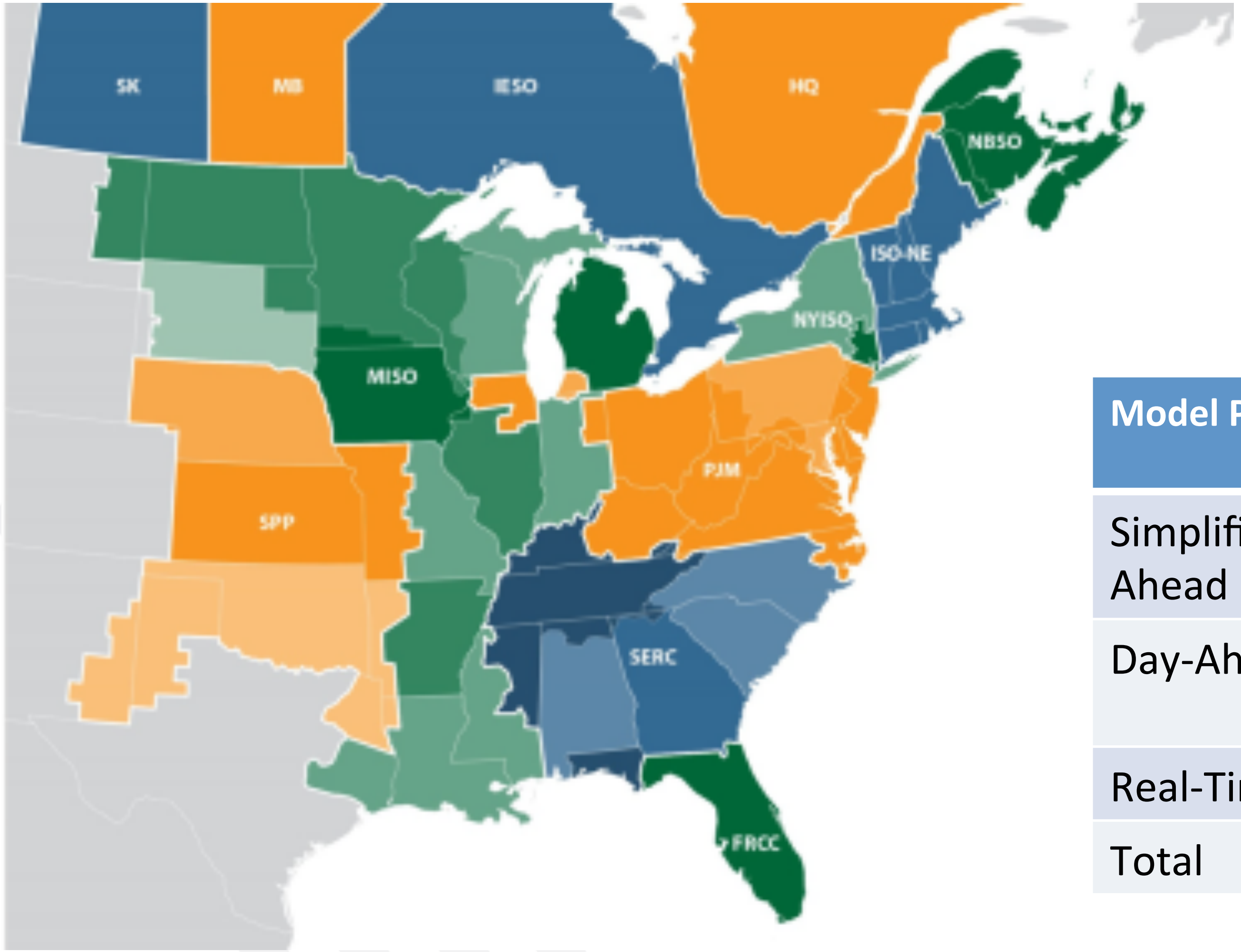
RTS-GMLC



REFutures East



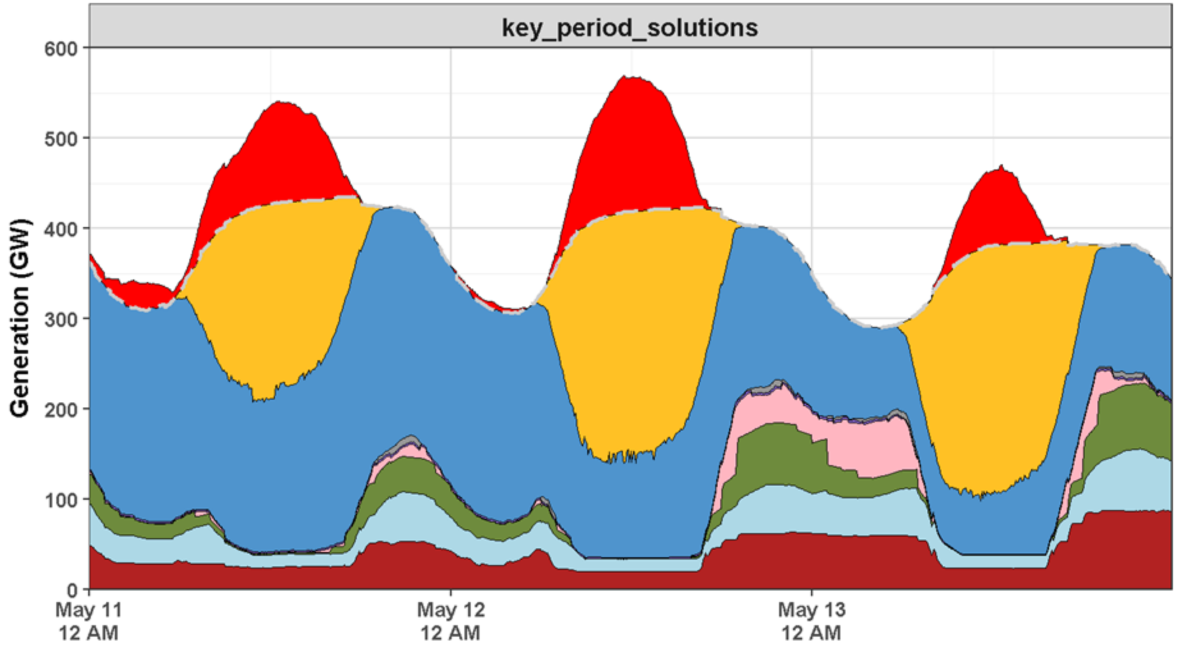
Testing in REFutures East

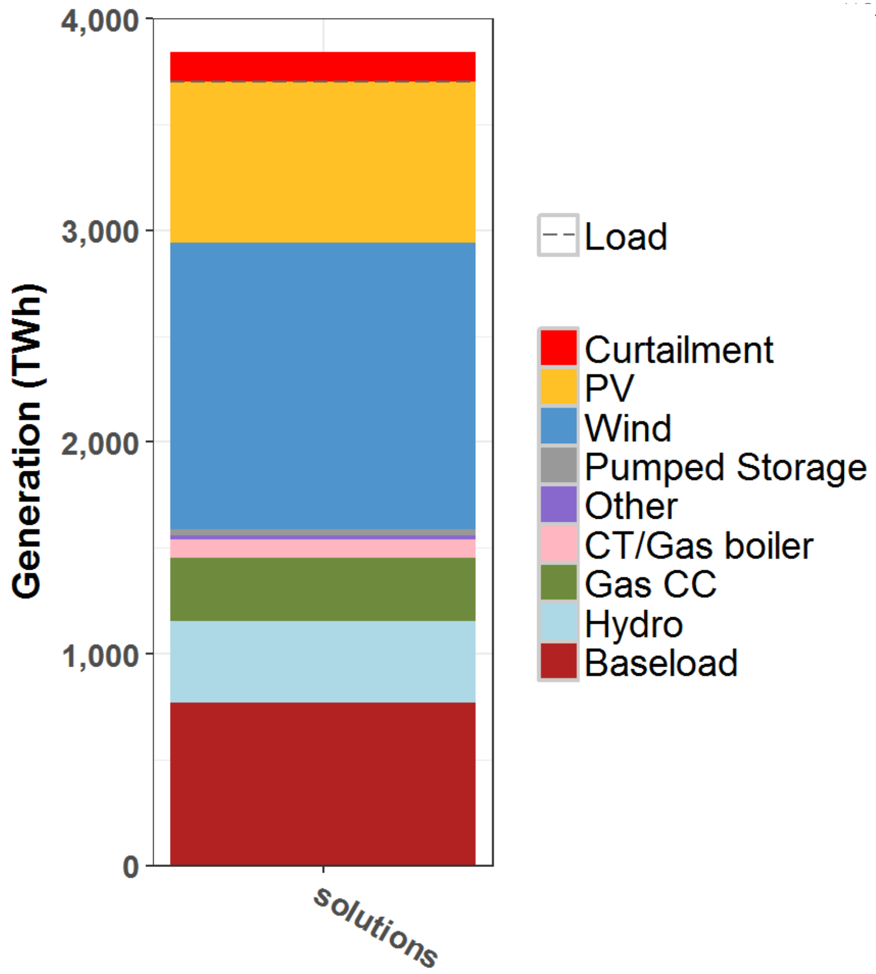


- Project to analyze 70-75% VG in the East
- Regional transmission representation (i.e. simplified ERGIS)

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

REFutures Base Case Results

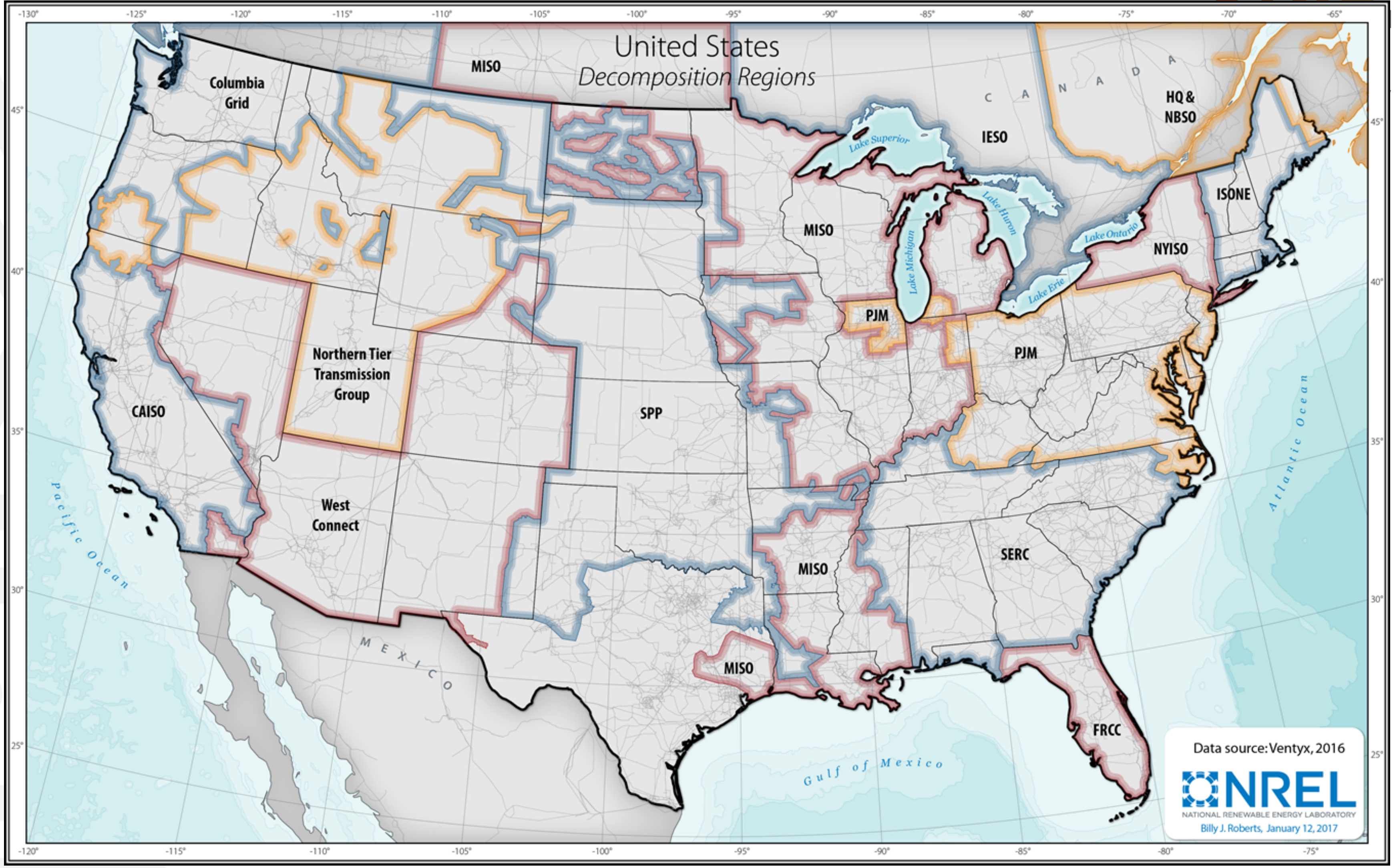




Geographic Decomposition for the Interconnections Seam Study

Model Phase	Solve Time
Transmission Flow Forecast	24-30 hrs/week
Decomposed UC	20 hrs/week
Real-Time	10 hours/week
Total	54-60 hours/ week

ERGIS required ~3 weeks to solve a 7 day simulation



Thank you!

- Conclusions/paths forward
  - Speedup ~proportional to integer variable reduction
  - Representing multiple operators
    - Additional analysis/tuning required
  - Additional speedup opportunities
    - Further decompose regions
- Contact:
  - Joshua.Novacheck@NREL.gov