Modeling Renewable Energy in US-REGEN

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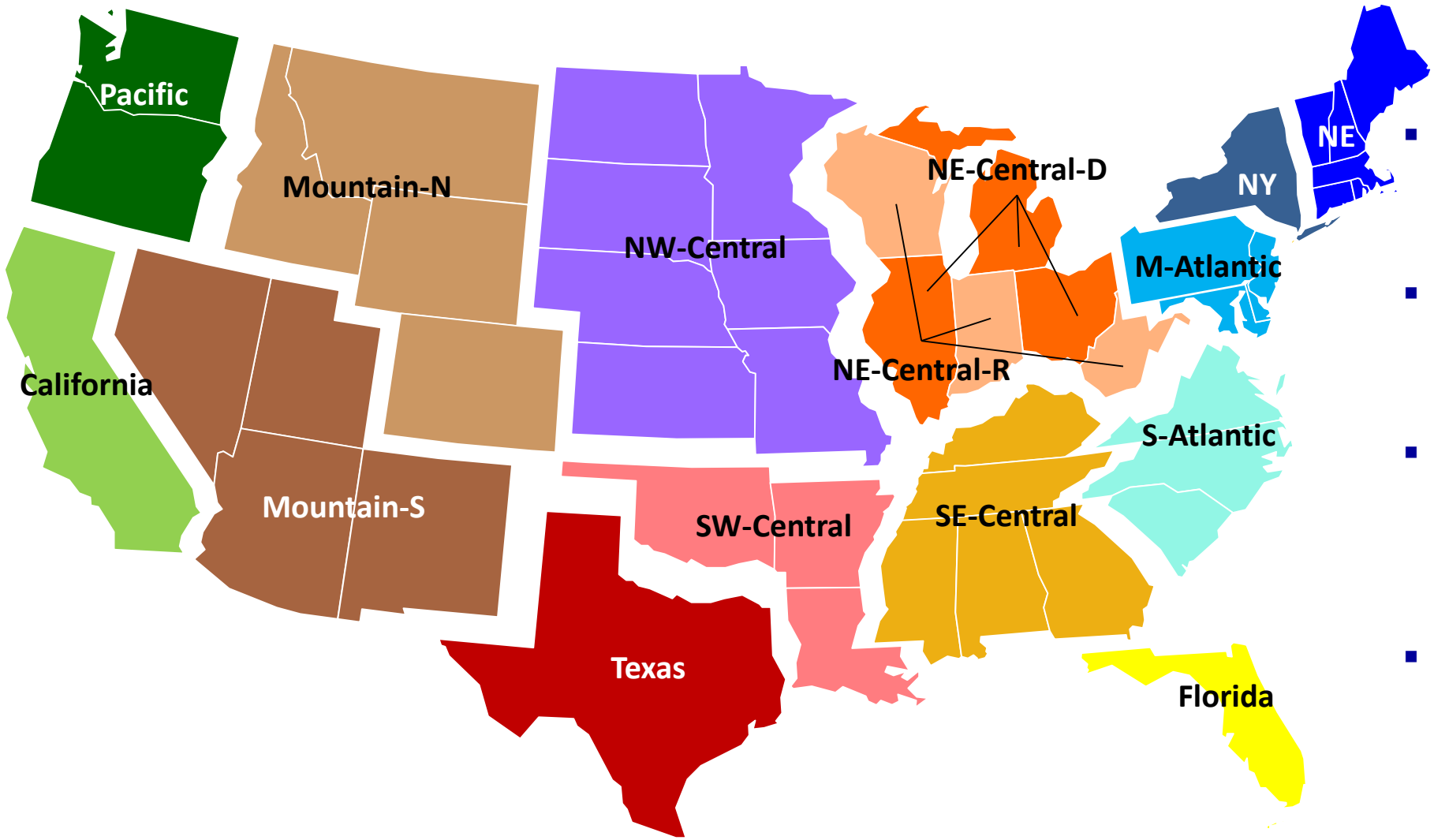
Challenges for modeling variable renewable energy (VRE)

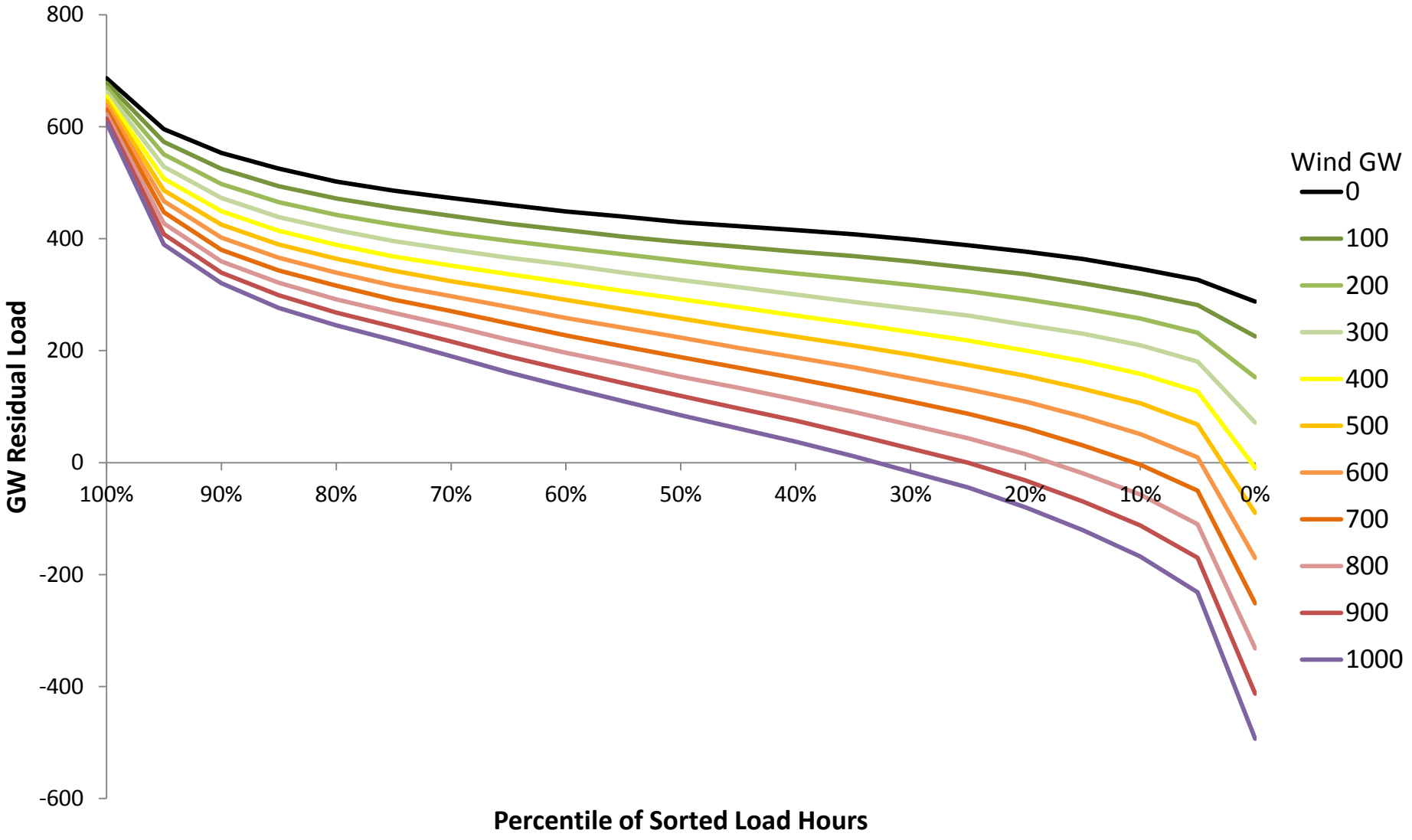
- Wind and solar are at the center of most scenarios for decarbonization of electric generation
- Decreasing returns to scale driven by intermittency in particular is key for understanding the potential contribution of VRE relative to other options
- Yet traditional capacity planning models are not equipped to handle their spatial and temporal variation
- One major methodological challenge is solving for capacity investments over an extended time horizon while also maintaining sufficient spatial and intra-annual resolution
- US-REGEN uses the representative hour method for dynamic simulations to 2050, but complements with static simulations of a single year using 8760

US-REGEN Model Design



- Capacity Expansion economic model for policy and regulation analysis to 2050
- Endogenous dispatch and investment in generation and transmission capacity
- Regional detail and representative hour approach to capture intra-annual variation of load/wind/solar
- Informed by EPRI data and expertise, used extensively for Clean Power Plan and longer-term decarbonization analysis

Residual load duration curve shifts with increasing VRE



- Begin with hourly data for load and wind/solar at regional level
- This illustration shows joint distribution between US total load and US average wind output
- Timing of contribution relative to load is the key factor driving capacity needs and economic value of VRE investments
- Any aggregation of intra-annual distribution must preserve the residual load duration curve

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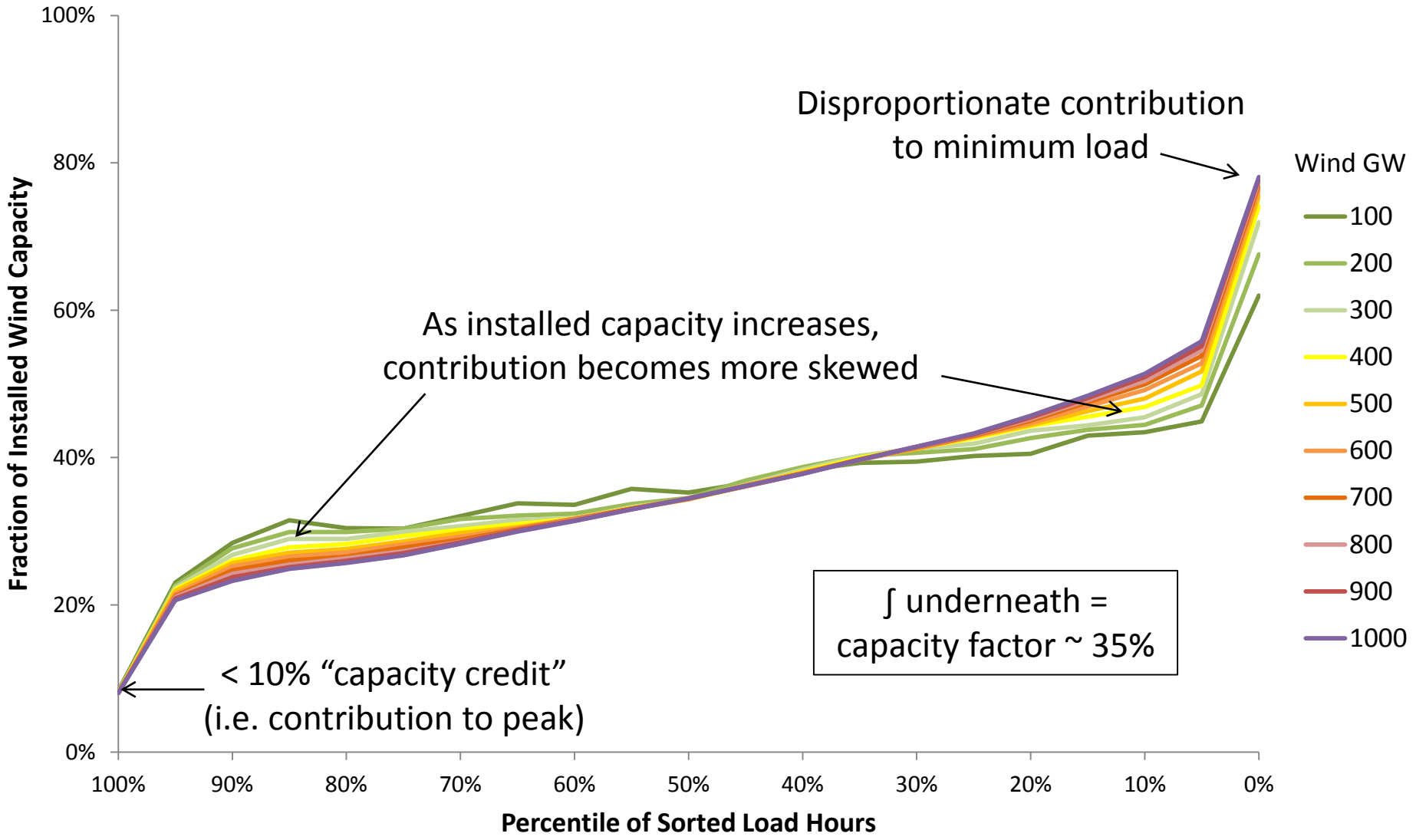

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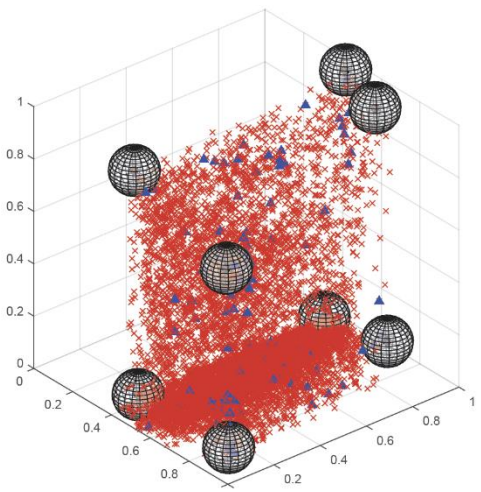
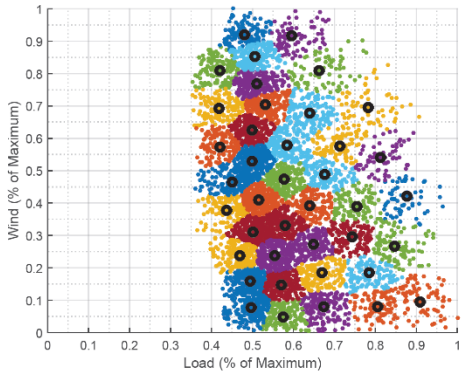
Overview of US-REGEN “representative hours” method

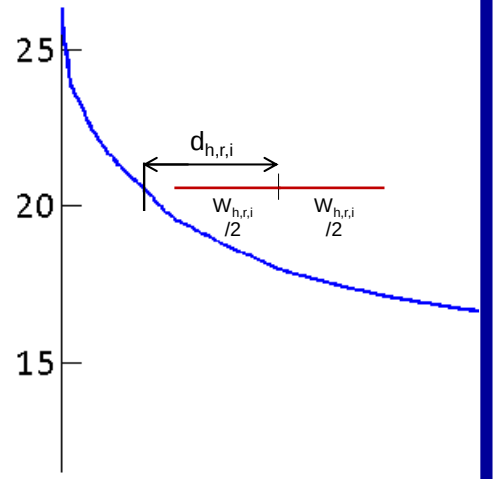
1 Select “extreme” hours



2 Select “cluster” hours



3 Hour weighting

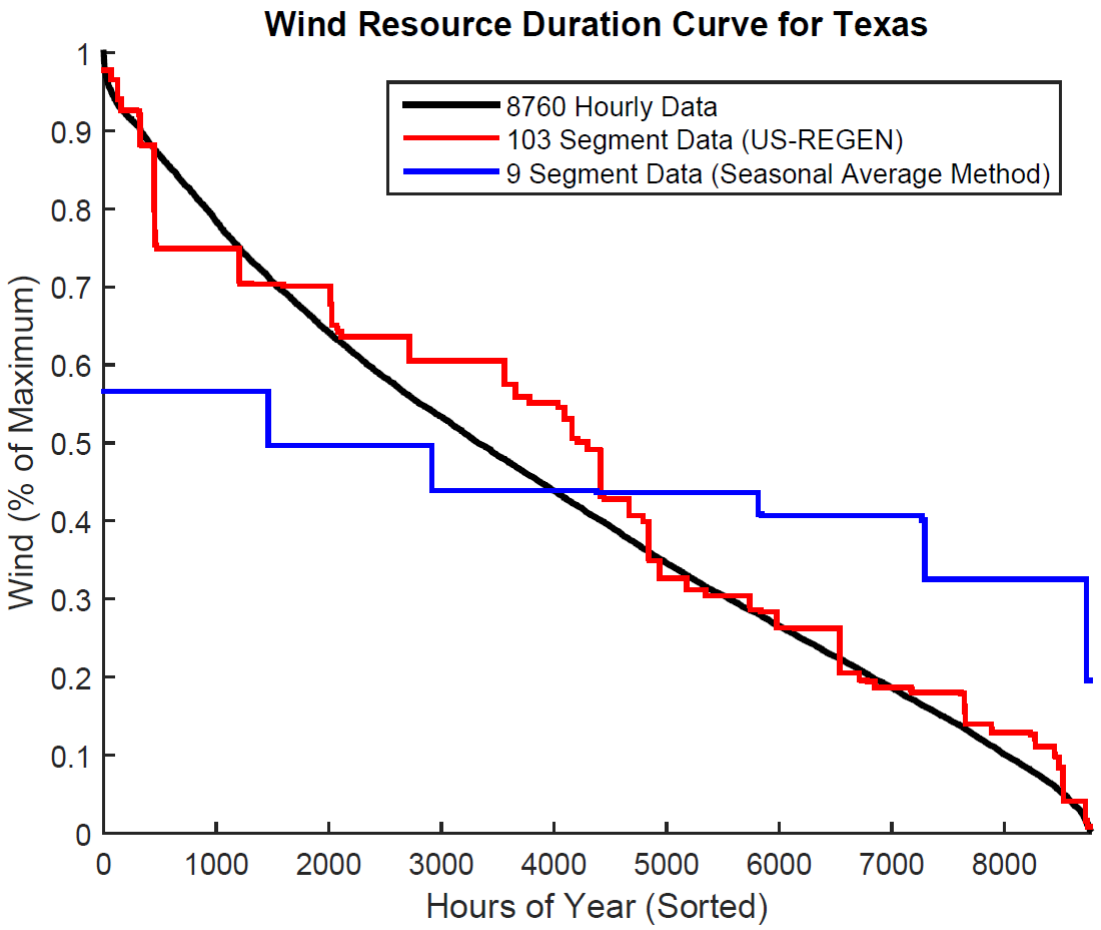


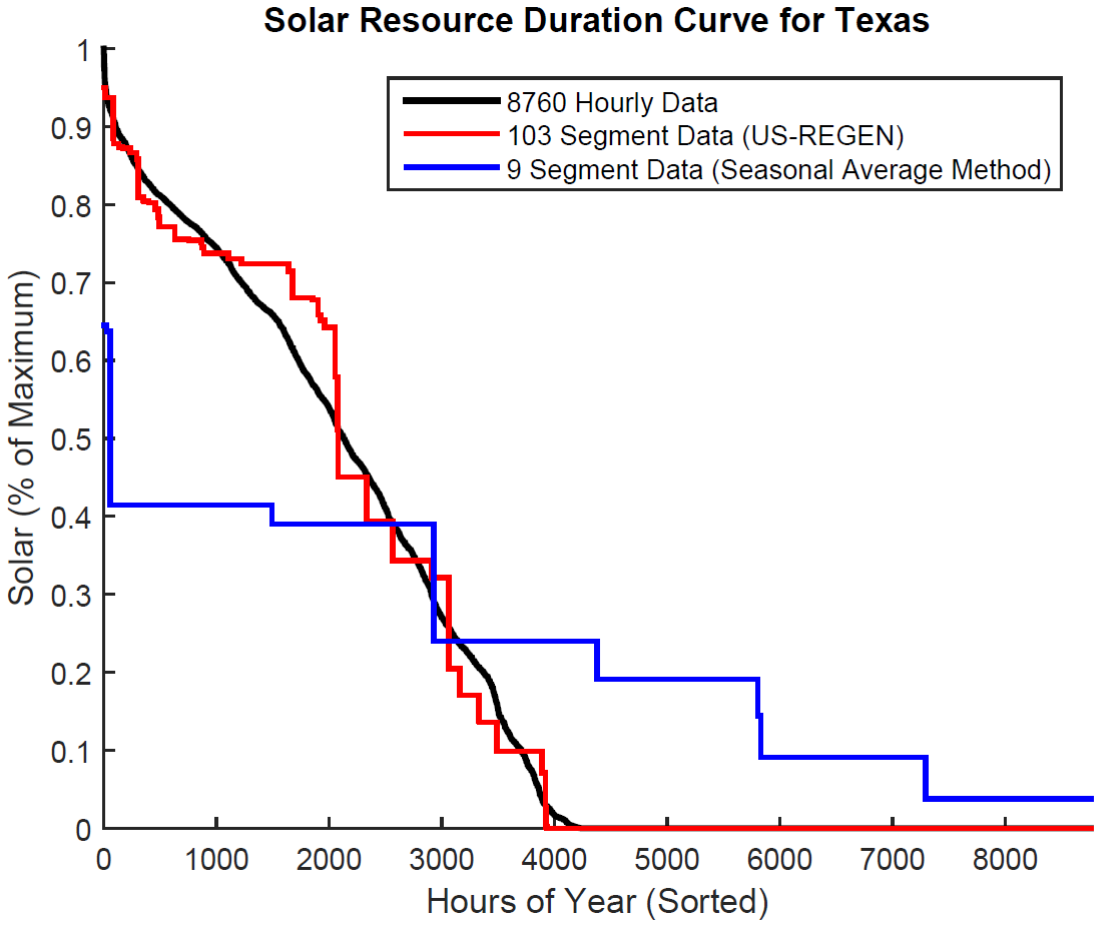
Goal: To strategically select annual hours that capture key distributional requirements for load, wind, and solar time series across several interconnected model regions

Contrast with a simpler alternative method

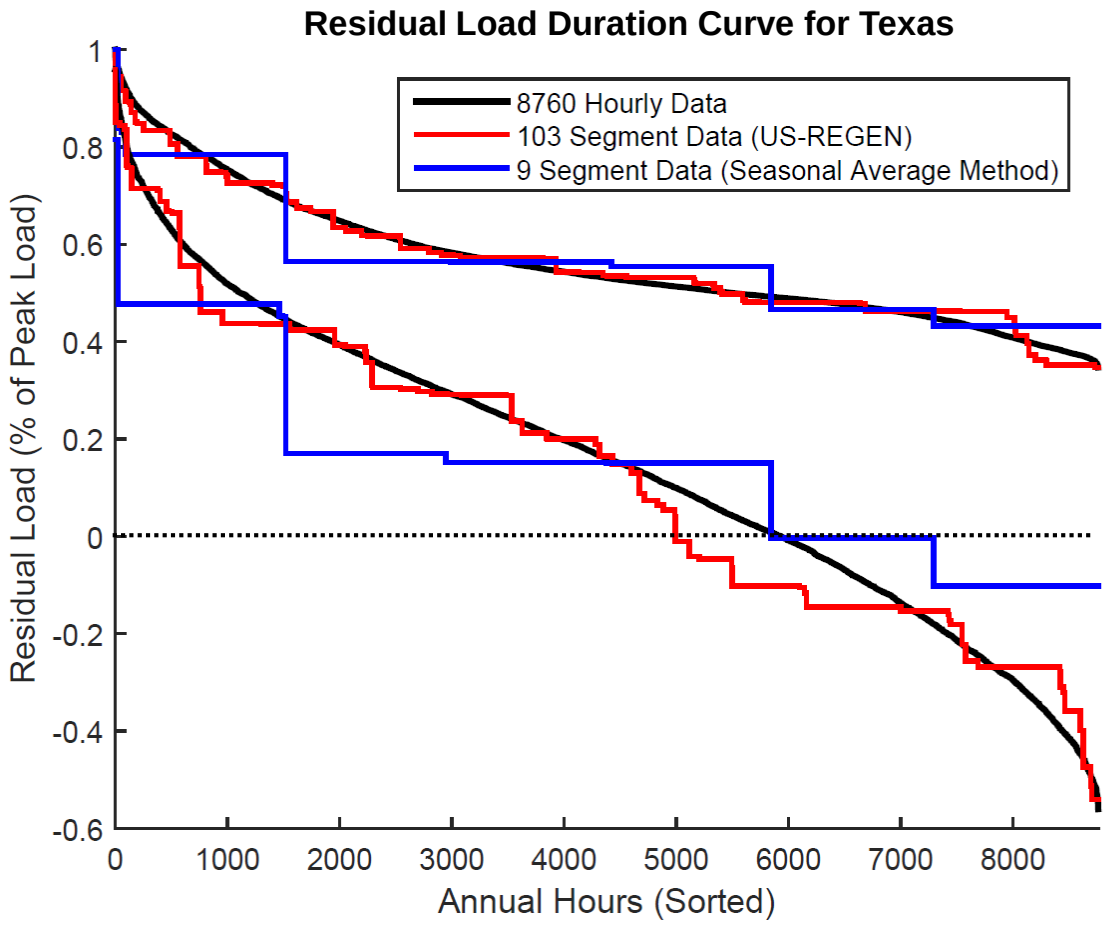
- Traditional approach: Simple representation of load duration curve with small number of segments
  - Reasonable approximation in conventional power system with dispatchable assets
  - However, this approach has trouble capturing wind/solar variability
- Many models attempt to capture load curve and assign wind/solar coefficients based on average resource availability during corresponding load period
- Shortcoming of “seasonal average” approach is that it insufficiently describes both individual distributions of resource availability and joint distribution

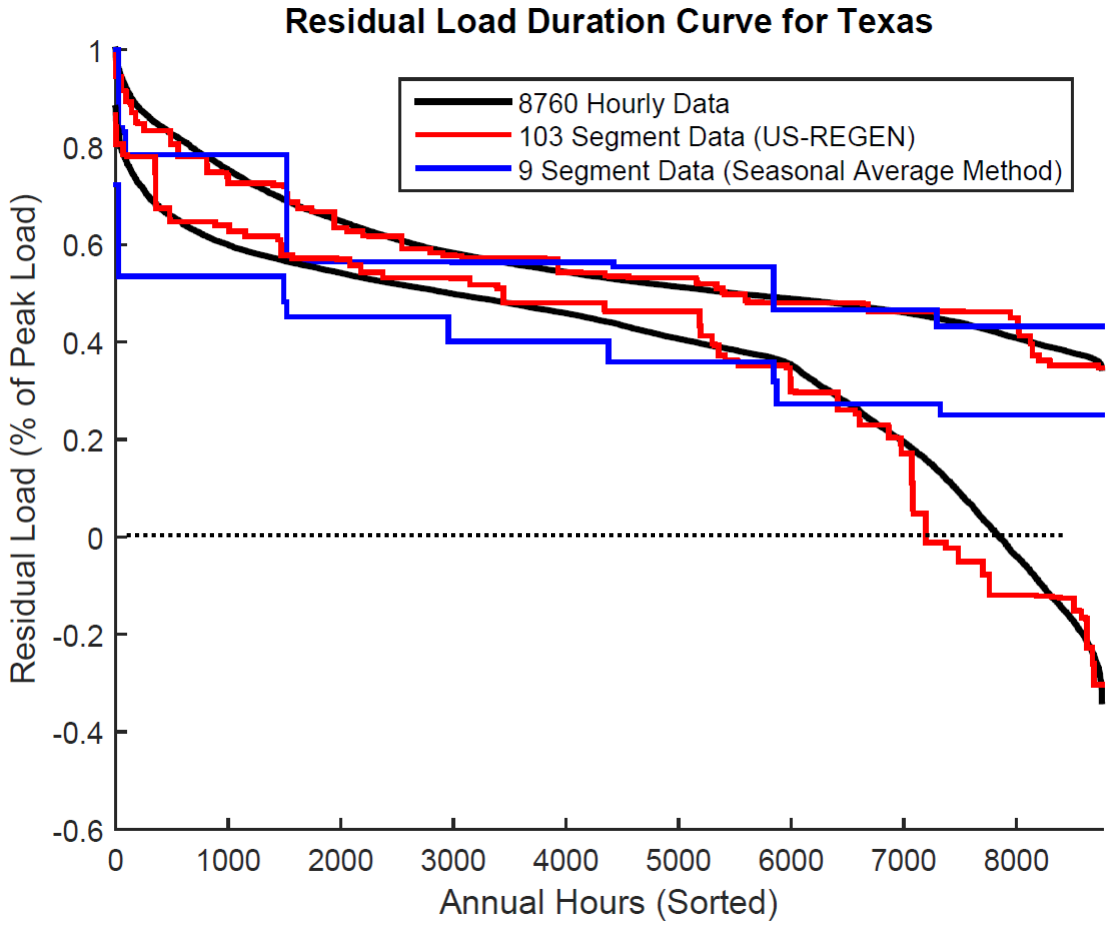
Representative hours preserve resource distributions



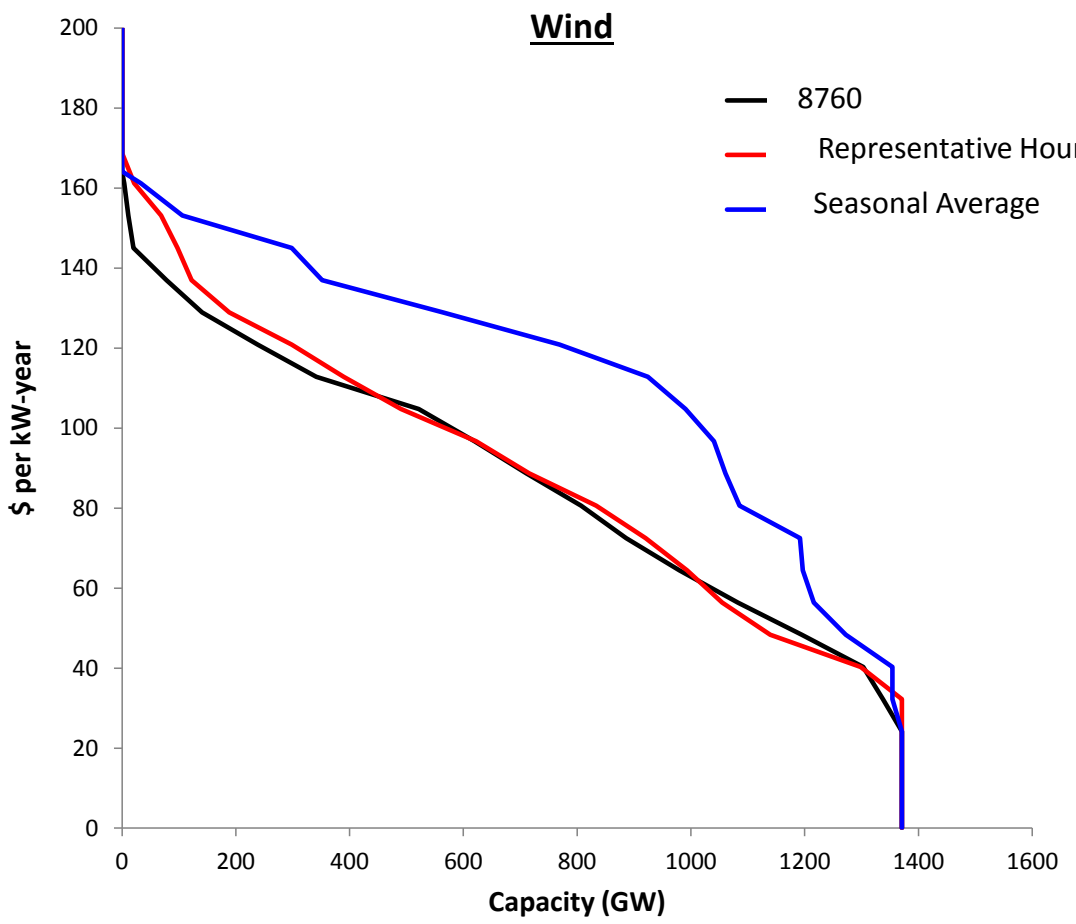


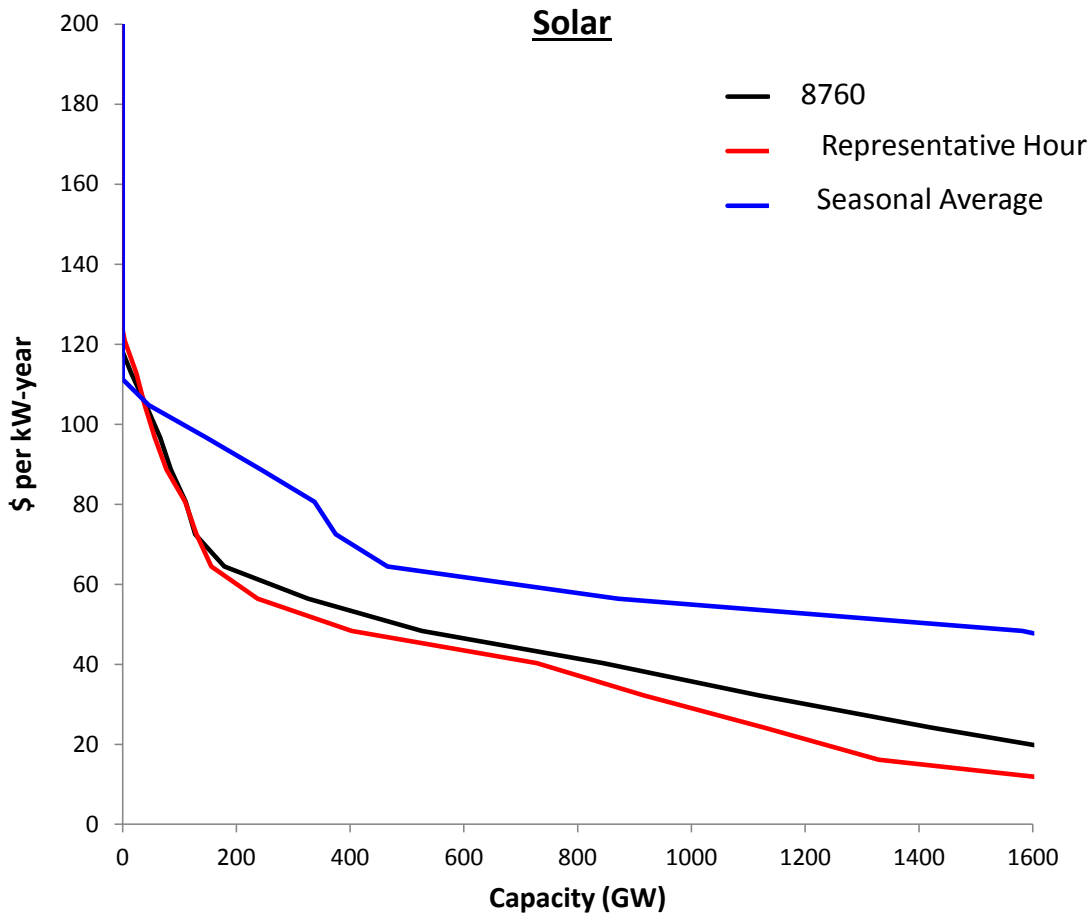
Representative hours preserve residual load curves





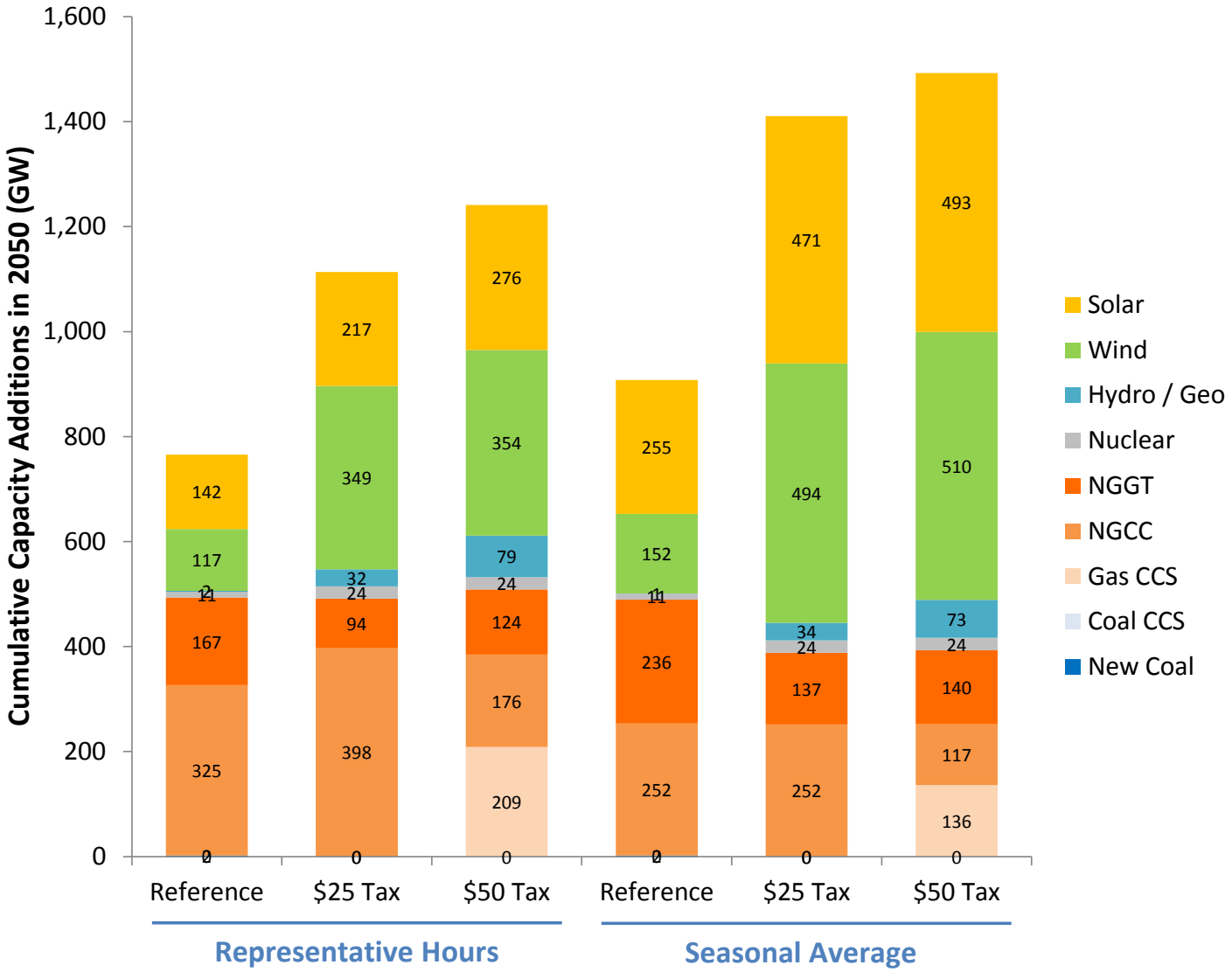
Representative hours preserve marginal value





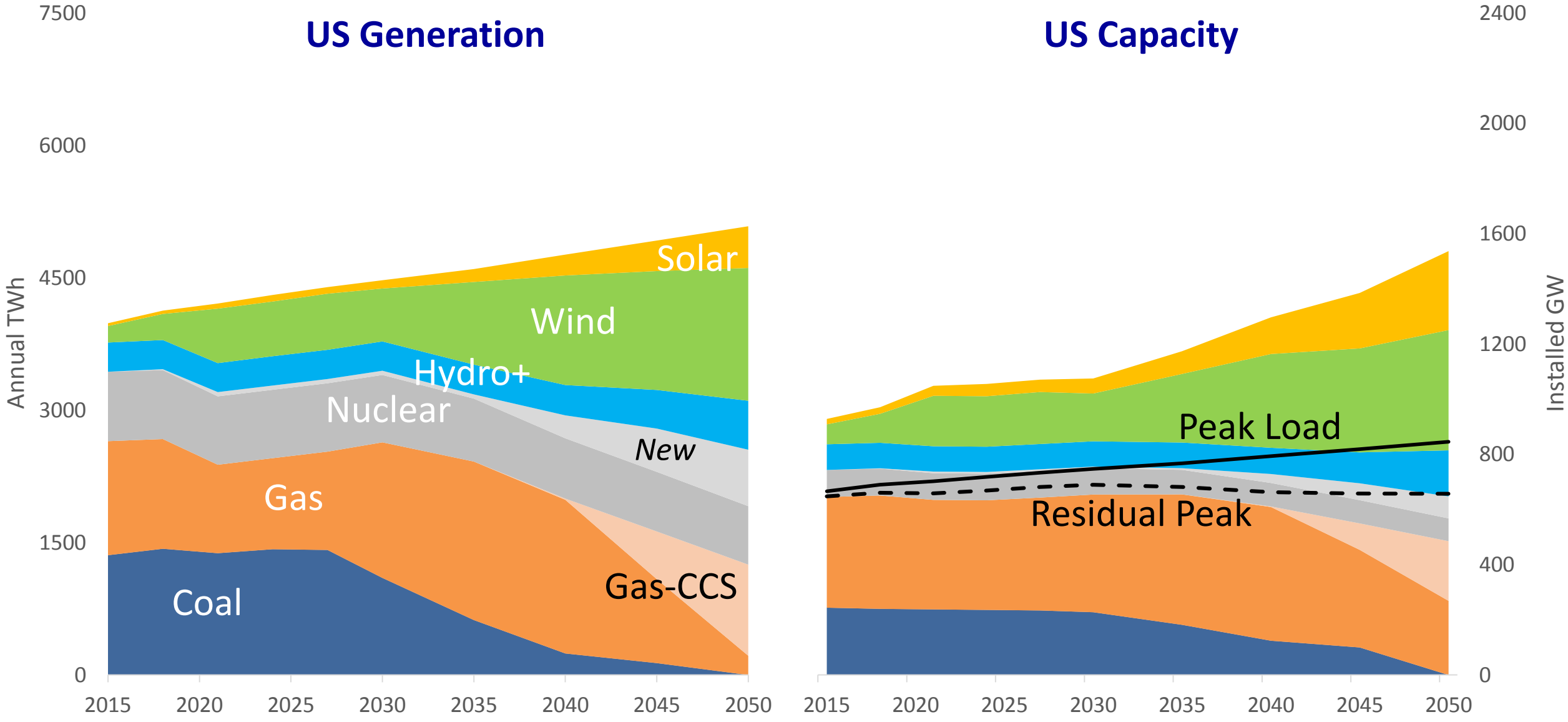
Based on analysis of capacity rental and dispatch in a static version of US-REGEN

Implications for dynamic simulation: Capacity build to 2050



- Comparison between reference scenario and two stylized policy cases with a $25 and $50/tCO2 tax
- Renewable deployment increases with more stringent CO2 policy, but less penetration with representative hours than with seasonal average
- Representative hours also indicate larger role of for supporting capacity

Another example: Deep Decarbonization Scenario



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What's not discussed in the above but also important

- Incorporating storage investments into dynamic planning model
- Potential flexibility constraints on thermal capacity
  - Hourly ramping requirements
  - Unit commitment constraints
- Potential operational constraints related to inertia and frequency control during moments of high instantaneous VRE penetration
- Integration with an evolving demand-side with smarter devices, more electrification, and potential responsiveness

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