

# RESEARCH PRIORITIES AND OPPORTUNITIES IN UNITED STATES COMPETITIVE WHOLESALE ELECTRICITY MARKETS

## *MARKET DESIGN UNDER DEEP DECARBONIZATION*

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# BACKGROUND

- U.S. electricity systems are decarbonizing
  - Due to cost reductions and social objectives
- Decarbonized systems have several key characteristics including:
  - Resources with zero-fuel cost
  - Resource with variable and uncertain, weather-dependent generation
  - Resources with opportunity costs
  - Increasing participation from distributed resources
- These have implications for efficient competitive wholesale market design
  - Ensuring that markets provide appropriate short and long-term incentives valued resources
- Challenges will emerge as we approach 100% carbon-free systems
  - Not exclusive to 100% decarbonized systems
- There is a growing body of literature related to these issues
  - Many high-level questions remain

# QUESTIONS FOR CONSIDERATION

- Are current market frameworks largely sufficient for a decarbonized future?
  - If so, what incremental modifications are needed?
  - Which should be prioritized for early implementation?
- Are larger fundamental shifts required?
  - What might these look like?
  - How would they be implemented in practice?
- In either case, substantial research is still needed

# APPROACH

- Seven technical areas
  - Provide a broad overview of:
    - Market challenges
    - Potential solutions
    - Associated research needs

Reliability  
and Flexibility

Emerging  
Technologies

Resource  
Adequacy

Price  
Formation

T&D  
Coordination

Transmission  
Planning

Governance  
and Policy

- Building upon a previous report\* that:
  - Provided more technical depth on market challenges in these same areas
  - Did not have a particular focus on decarbonization
  - Did not explicitly consider governance and policy

\*Sun et al. 2021. **Research Priorities and Opportunities in United States Competitive Wholesale Electricity Markets.** (No. NREL/TP-6A20-77521). <https://www.nrel.gov/docs/fy21osti/77521.pdf>

# RESEARCH CHALLENGES (2021)

	Challenge 1	Challenge 2	Challenge 3	Challenge 4	Challenge 5	Challenge 6	Challenge 7
Reliability and Flexibility	New reserve/flexibility products	Deliverability of reserve products	Ancillary service market redesign	Temporal considerations	Frequency response and other services	Cost recovery during emergencies	
Emerging Technologies	Reliability services with growing VRE	Emerging resource market participation	Resource adequacy contribution of emerging resources	Risk hedging through forward contracts			
Resource Adequacy	Reliability assessment and implementation	Capacity credit calculation	Accommodating state-level policies into capacity markets	Defining capacity demand curves	Capacity contribution of imports	Firm capacity for extreme weather	Risk mitigation in capacity markets and bilateral contracts
Price Formation	Zero-marginal cost world	Scarcity and shortage pricing	Multi-period market pricing and settlement	Active demand-side participation	Carbon pricing or GHG emissions		
T&D Coordination and Wholesale-Retail Interactions	Grid services provision from DERs	Improved situational awareness of DERs	Modeling of TSO-DSO coordination	TSO-DSO coordination mechanisms	Data management and communication	Regulatory and policy concerns	Distribution level management
Transmission Planning	Long run grid planning uncertainties	Transmission investment co-optimization	Grid planning needs identification	Benefit measurement and cost allocation	FTR auction efficiency	FTR revenue adequacy	

# RESEARCH CHALLENGES (2023)

	Challenge 1	Challenge 2	Challenge 3	Challenge 4	Challenge 5	Challenge 6
Reliability and Flexibility	Changing reliability needs and grid requirements	Economic procurement of reliability services	Reliable operations during extreme events	Deliverability of reserve products	Inelastic demand	
Emerging Technologies	New market participation models	Improved technology representation in scheduling/ dispatch	Adequate mechanisms for managing investment risk	Market power monitoring and mitigation	Equitable technology deployment	
Resource Adequacy	Economically efficient market design	Supply-side uncertainty and variability	Demand-side uncertainty	Spatial and temporal resolution	Climate and extreme weather	Infrastructure interdependencies
Price Formation	Improved scarcity pricing	Enhanced market clearing mechanisms	Uncertainty representation in price formation	Reflecting the value of clean energy and carbon remissions reductions in prices		
T&D Coordination	Coordinated transmission and distribution planning	Improved market participation models for DERs and DSRs	Communications, controls and dispatch software	Policy and regulatory structures for DER integration	Capturing reliability contributions from the distribution system	Improved tariff structures
Transmission Planning	Multi-regional coordination	Coordination with generation expansion planning	Slow interconnection processes	Need for robust and equitable cost allocation	Capturing value of non-wires solutions	Consideration of HVAC or HVDC lines
Governance and Policy	Tensions between state and federal policies	Investments driven by policies rather than prices	Lack of mandate for a clean, firm energy market product	Reliability concerns from load growth and firm resource retirements	Policy incentives do not account for resource adequacy or operational reliability	



# RESEARCH NEEDS



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# RESEARCH NEEDS

	Challenge 1	Challenge 2	Challenge 3	Challenge 4	Challenge 5	Challenge 6
Reliability and Flexibility	Changing reliability needs and grid requirements	Economic procurement of reliability services	Reliable operations during extreme events	Deliverability of reserve products	Inelastic demand	

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# Reliability and Flexibility

- Analyze services that are currently unpaid due to excess availability to understand if payments will be required in future systems to guarantee their provision
- Develop improved optimization and simulation tools that account for the full range of costs and benefits of reliability services in future systems
- Develop grid model inputs that link with weather data and climate projections to capture operational reliability impacts of extreme weather events
- Development of improved algorithms that account for reserve deliverability in scheduling, dispatch, market clearing

# RESEARCH NEEDS

	Challenge 1	Challenge 2	Challenge 3	Challenge 4	Challenge 5	Challenge 6
<b>Emerging Technologies</b>	New market participation models	Improved technology representation in scheduling/ dispatch	Adequate mechanisms for managing investment risk	Market power monitoring and mitigation	Equitable technology deployment	

# Emerging Technologies

- Design incentive compatible market participation models for all technologies.
- Develop computationally efficient tools for SOC management and capacity degradation in batteries.
- Develop new market power metrics that account for opportunity costs and behavior of energy limited resources.

# RESEARCH NEEDS

	Challenge 1	Challenge 2	Challenge 3	Challenge 4	Challenge 5	Challenge 6
<b>Resource Adequacy</b>	Economically efficient market design	Supply-side uncertainty and variability	Demand-side uncertainty	Spatial and temporal resolution	Climate and extreme weather	Infrastructure interdependencies

# Resource Adequacy

- Determine which market design frameworks and products best support resource adequate investments (and retirements) in systems dominated by resources with zero marginal costs
- Increased temporal granularity of thermal generator outages to account for hourly/daily/seasonal differences in expected outage rates
- Develop improved representation of low probability high impact events (such as extreme events) in reliability assessment and capacity expansion tools
- Analyze the impact of common mode failures across multiple infrastructures on electricity system reliability

# RESEARCH NEEDS

	Challenge 1	Challenge 2	Challenge 3	Challenge 4	Challenge 5	Challenge 6
<b>Price Formation</b>	Improved scarcity pricing	Enhanced market clearing mechanisms	Uncertainty representation in price formation	Reflecting the value of clean energy and carbon remissions reductions in prices		

# Price Formation

- Assess market power impacts of different scarcity pricing schemes
- Analyze the interplay between scarcity pricing and resource adequacy mechanisms
- Assess benefits of co-optimization and more frequent market clearing
- Analyze price formation interactions between clean energy incentives and carbon policy.



# RESEARCH NEEDS

	Challenge 1	Challenge 2	Challenge 3	Challenge 4	Challenge 5	Challenge 6
<b>T&amp;D Coordination</b>	Coordinated transmission and distribution planning	Improved market participation models for DERs and DSRs	Communications, controls and dispatch software	Policy and regulatory structures for DER integration	Capturing reliability contributions from the distribution system	Improved tariff structures

# T&D Coordination

- Identify the main regulatory and technological barriers that prevent ISOs/RTOs from coordinating transmission and distribution planning decisions
- Determine which new products (e.g., reactive power, voltage support) will be necessary to facilitate wholesale market participation of DERs
- Analyze cost-benefit tradeoffs of different market structures, considering central optimization by the ISO or local optimization by the DSO or any potential structure in between
- Develop optimization and simulation methodologies that consider DER contribution to T&D system reliability
- Analyze the impact of different customer tariff structures on wholesale electricity markets

# RESEARCH NEEDS

	Challenge 1	Challenge 2	Challenge 3	Challenge 4	Challenge 5	Challenge 6
<b>Transmission Planning</b>	Multi-regional coordination	Coordination with generation expansion planning	Slow interconnection processes	Need for robust and equitable cost allocation	Capturing value of non-wires solutions	Consideration of HVAC or HVDC lines

# Transmission Planning

- Developing new algorithms that iterate between TEP and GEP to reach consensus
- Analyze impact of interconnection process reform in which ISOs/RTOs perform a first-ready, first-served cluster study process
- Investigate the tradeoffs between required transmission expansions and non-wires alternatives for deep decarbonization
- Develop problem-specific software for off-shore wind transmission studies considering HVDC candidates and new technologies, e.g., multi-terminal voltage source converter-based HVDC

# RESEARCH NEEDS

	Challenge 1	Challenge 2	Challenge 3	Challenge 4	Challenge 5	Challenge 6
<b>Governance and Policy</b>	Tensions between state and federal policies	Investments driven by policies rather than prices	Lack of mandate for a clean, firm energy market product	Reliability concerns from load growth and firm resource retirements	Policy incentives do not account for resource adequacy or operational reliability	

# Governance and Policy

- Explore implications of switching from technology specific renewable energy credits to **clean energy attribute credits**, which can be produced from any net-zero generation resource.
- Evaluate whether markets can be **co-optimized to allow LSEs to meet reliability and clean energy** targets at a lower cost than procuring products separately.
- Determine who will contract with or otherwise procure **clean firm resources necessary to meet reliability targets**.
- Compare cost and reliability profile of **meeting clean energy demand in a centralized versus bilateral market** structure.

# CLOSING THOUGHTS

- Systems are evolving, markets may need to evolve as well
  - Fundamental economic principles should still be observed
- There is no single “correct” answer to any of these challenges
  - Many different possible approaches and pathways
  - Need to balance theory and implementation
  - Need to be flexible as systems and markets evolve
- What every path we take should consider:
  - Market objectives
  - Social objectives
  - Policy interactions
  - Realities of governance



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