2025 Research Portfolio

P246 – Electricity Markets

Program Description/Overview

Electricity systems are planned and operated in a way to maximize economic efficiency and reduce costs while maintaining reliability and resilience. Around the world, electricity markets are used with a varying set of products, auctions, and procedures to do so. The Electricity Market Operation and Design Research Program aims to address challenges of achieving a reliable, resilient, and affordable supply of electricity through technical market solutions including effective market design and advanced market clearing software. The program does this through (1) facilitating a collaborative forum that includes market operators from around the world as well as key transmission and generating entities, (2) acting as a comprehensive source of information for how state-of-the-art markets are designed, operated, and evolving, and (3) by providing new insights, methods, concepts, and market software enhancements that can continue to make power systems more efficient and reliable, especially as energy systems evolve through clean energy transitions and other large-scale impacts.

Electricity markets, including Regional Transmission Organization (RTO) and Independent System Operator (ISO) operated wholesale markets, energy imbalance markets, power exchanges, and bilateral programs exist around the world. As these markets grow in complexity and transition along with transition to changing resource mix, research and analysis is essential to support how economic efficiency and reliability can be achieved as new challenges arise. Research focuses on energy markets, ancillary service markets, capacity markets and resource adequacy mechanisms, financial transmission rights, and other features such as emissions. Research areas include market design surveillance, emerging technology integration, reliability assurance, price formation, sector coupling, and future market scenarios.

Research Value

The research program is a central forum for all activities related to electricity markets and their evolution. This program will deliver value to members in several ways:

- The ability to participate in a collaborative forum with peers to understand new features and initiatives being explored in market regions around the world
- Comprehensive information source of characteristics, features, and implemented market designs across electricity market regions.
- Ability to train new and transitioning staff on the basics and advanced features of electricity markets beyond a single region.
- Awareness of specific initiatives and the evolution of electricity markets around the world.
- Evaluation on which algorithms and designs that can lead to economic efficient and reliable solutions.
- Insights on specific characteristics and how they can be implemented in market clearing software that can help decision making in stakeholder forums and elsewhere.
- Assessments of how future systems and scenarios may impact revenue adequacy, reliability, and technology adoptions.

Approach

The research program focuses on key challenges and approaches that are high priority in each year. The current state of the art of electricity market design is provided regularly in the annual reference guide so the research team and members are kept aware of the most recent initiatives and updates. On other specific high priority topics, the approach is to monitor, develop, and test new designs and software enhancements. This is done in practice by 1) monitoring what proposals the ISOs and RTOs have put forth and characterizing differences to participants, 2) developing enhanced methods or software algorithms that are being proposed or that are proposed by the research team and advisors, and 3) testing these methods/algorithms out on varying scenarios to see advantages of alternative designs using metrics of reliability and economic efficiency.

Accomplishments

The following are some of the many valuable accomplishments that have been achieved through this program and its predecessor:

- Comprehensive **Market Design Reference Guide** that has gone through six iterations of improvements and updates.
- A set of proposed options for **managing state-of-charge** for storage resources within market clearing software that has been adopted by several market regions, and their implications.
- A detailed qualitative and quantitative comparison of 1Resource Integrated Hybrid and 2Resource Colocated Hybrid **Participation Models** for modeling of **combined co-located facilities of storage and renewables**.
- A comprehensive **training program** for new and advanced market design topics.
- Efficient mechanisms for **competitive ancillary service auctions** and demonstration of specific modeling features that can impact the utilization of multiple ancillary service products.
- Facilitating multiple collaboratives through supplemental efforts including the ISO/RTO Market Design Technical Forum and the FERC Order 2222 Collaborative.
- Guidelines on the benefits of **modeling natural gas networks** for electric operation and the different ways of doing so.
- Foundational assessments to the outcomes of wholesale electricity prices under systems fully supplied by zero-fuel-cost resources and opportunity-cost resources.
- Several impactful and timely **Industry Insights** and **Perspectives** from events and member requests.
- Successful **engagements with industry** including the FERC, state regulators, independent market monitors, traders, market software vendors, consumers, and technology trade groups.

Key Activities

The Electricity Market Operations and Design Program is new in 2024. The following activities will be pursued as part of the new program:

- Completing new versions of the Annual Market Design Reference Guide including initiating the two-volume approach.
- Initiating new advisory structure and meeting calendars for the new program.
- Monthly webcasts alternating between advisors' sessions and technical sessions including invited outside speakers.
- Continuation of research around energy storage state-of-charge management, computational improvements, and real-time energy storage participation options that provide reliable and efficient system solutions.
- Continuation of DER Aggregation integration research, including coordination aspects for DER Aggregation participation in electricity markets, computational enhancements, and incorporation of impacts of distribution system losses into market clearing decisions.
- Evaluation of reliability enhancements through market solutions such as regulation service, primary frequency response ancillary service markets, voltage control service, operating reserve demand curve, formulation enhancements, and advanced scheduling techniques.
- Evaluate and introduce concepts for achieving resource adequacy and resilience through electricity market solutions including improvements to accreditation techniques for capacity resources.
- Explore the integration of other technologies into market design and market clearing. Examples such as combined cycle generating turbines with mode transitions, power flow control technologies, HVDC controllable lines, hydrogen electrolyzers, long duration energy storage, and other technologies.
- Continuation of assessments into future market prices under systems supplied by zero-fuel-cost and opportunity-cost- resources and examine how storage, price responsive demand, and shortage conditions can impact these future prices.
- Provide Industry Insights and Perspectives on emerging topics and new proposals and studies coming out from the industry.
- Continue engagement with FERC, responding to NOI and NOPRs when appropriate on technical topics where research results can provide value to decision making.

Annual Market Design Reference Guide and Global Market Surveillance

Objective

It is important for market operators and stakeholders to have a comprehensive understanding of the evolution of electricity markets around the world. The annual market design reference guide is a comprehensive document with substantial amount of information on the current state of the art for electricity markets as well as the new initiatives that are being discussed and studied in each market region in North America.

Approach

The guide covers the following material:

Volume 1:

- Theory and introductions to electricity markets
- Acronym List
- Statistics on market size, resources, and financial volume
- Market Participant types and stakeholder prioritization
- Energy Markets, two-settlement, and price formation
- Ancillary Service Markets and cost-based ancillary services
- Financial transmission rights
- Capacity markets and resource adequacy
- Market Participation Models
- Cross-border exchange procedures

Volume 2: Initiatives and Annual

- Year in Review
- International overview
- FERC and National Updates
- Separate sections for each of the U.S. ISOs/RTOs
- Two sections for extended markets in the West
- Section on Southeast Energy Exchange Market
- Two sections for Canadian ISOs/RTOs
- Research activities

Research Value

The guide and access to collaborators and the EPRI researchers provides for a tremendous source of information. This information can provide significant cost savings and education that can enable additional cost savings and reliability improvements through knowledge of efficient features that can be adopted.

Anticipated Deliverables

Deliverable	Date
North American Electricity Market Design Reference Guide Volume 1 and 2: 2023 Version	May 2024
North American Electricity Market Design Reference Guide Volume 1: 2024 Version	Dec. 2024

Product ID	Title	Description	Published Date
3002029714	Wholesale Electricity Market Design in North America: 2023 Review Volume I and II	Detailed review of electricity market designs including U.S. and Canadian markets and history of design initiatives up to and through 2023.	Jun. 2024
3002026942	Wholesale Electricity Market Design in North America: 2023 Review Volume I	Detailed review of electricity market designs including U.S. and Canadian markets with implementations through 2023.	Mar. 2024
3002024553	Wholesale Electricity Market Design in North America: 2022 Review	Detailed review of electricity market designs including U.S. and Canadian markets and history of design initiatives up to and through 2022.	Apr. 2023
3002021813	Wholesale Electricity Market Design in North America: 2021 Review	Detailed review of electricity market designs including U.S. and Canadian markets and history of design initiatives up to and through 2021.	Apr. 2022

Advanced Electricity Markets and Market Clearing Software

Objective

As new technologies become part of the system or as new capabilities present themselves, market designs can enable these technologies in ways that can continue to lead to efficient and reliable solutions. This also includes improvements to the market clearing software. EPRI research can introduce new concepts, prototype designs and market management system features that can later be implemented by vendors, or conduct simulations to demonstrate potential outcomes or metric comparisons across potential solutions.

Approach

The following topics are continuously evaluated as part of this effort:

- Advanced participation models for emerging technologies such as energy storage state of charge management, hybrid and co-located resources, combined cycle transition models, distributed energy resource aggregations, power flow controllers and controllable lines, and long duration energy storage.
- Reliability assurance through capacity accreditation, frequency control, and other market solutions such as new ancillary service auction designs or enhancements to existing designs. This also includes enhancements to market clearing software that can schedule ancillary services from resources more efficiently.
- Price formation including market design features that can lead to economically efficient, equitable, and incentive compatible alignment with needed responses to energy and grid service needs.
- Exploration of advanced models and market designs that couple electric sectors with other sectors including gas/electric representation, AC optimal power flow, transmission and distribution coordination, electrification, hydrogen electrolysis, and transportation coordination.
- Market designs under future scenarios including high zero fuel cost supply, distribution markets, and large levels of price responsive demand and retail alignment.

Research Value

EPRI Research can assist stakeholders and market operators understand the potential enhancements that can lead to reliable and economic efficient solutions, especially under energy transition. This can help these entities make informed decisions to improve reliability, reduce costs, and maintain equity.

Anticipated Deliverables

Deliverable	Date
Participation model for emerging technologies: Long Duration Energy Storage and Firm Emissions Free Resources	Dec. 2025
Ancillary Service Evolution: Future of Ancillary Service Needs and efficient ways to procure reserves	Dec. 2025
Distributed Energy Resource Aggregation Participation in Market Clearing: Wholesale and Retail Market Options and Coordination	Dec. 2025
Resource Capacity Accreditation on Evolving Market Regions	Dec. 2025
Wholesale Market Prices under Deep Decarbonization Scenarios: Are the prices always zero?	Dec. 2025

Past EPRI Research on Topic

Product ID	Title	Description	Published Date
3002024549	How do Energy Storage Resources Impact Wholesale Electricity Prices in Future Systems with 100% Zero Fuel Cost (ZFC) Resources?	To investigate outcomes of zero fuel cost scenarios, this study reviews how prices are determined when electric storage resources are setting the price.	Dec. 2022
3002024565	The Value of Gas Network Modeling on Electricity System Operations	Quantitatively model and assess the accuracy of sophisticated hydraulic gas network modeling when studying electric operation during extreme weather.	Dec. 2022
3002025037	Implementing Flexibility Products and Extended Operating Reserve Demand Curves to Achieve Sufficient Flexibility	Two primary mechanisms being implemented to promote operational flexibility are compared and evaluated for improvements.	Dec. 2022
3002021814	Hybrid Storage Resource Participation Model Investigation Update	Study focused on hybrid resources and the impacts of different participation models for those resources.	Dec. 2021
3002021810	Exploring Resilience and Common-Mode Outages in Resource Adequacy and Planning	The report focuses on the specific ways in which common-cause outages and extreme events can be integrated into existing resource adequacy metrics, assessments, and resource planning.	Dec. 2021
3002021819	Electricity Market Design and Outcomes Approaching 100% Zero-Fuel Cost (ZFC) Resources	First study examining the impacts of a market that is dominated by resources that have zero fuel cost.	Dec. 2021
3002028648	Evaluation of Storage plus Renewable Hybrid Resource Integration	Key insights into the potential outcomes regarding reliability and economic efficiency for	Apr. 2021

Product ID	Title	Description	Published Date
	into Scheduling Operation: Conceptual Comprehensions	hybrid and co-located resource participation models.	
3002028649	Evaluating Challenges of Stand-alone Electric Storage Resources and Integration into Electricity Market Clearing: Implications of Software Design on SOC Management	Evaluates challenges related to integrating stand- alone electric storage into electricity market clearing software including different mechanisms for state-of-charge management.	Dec. 2020

Annual Market Design Reference Guide and Global Market Surveillance

Objective

The power system is a dynamic industry with new issues and new activities occurring all the time. This is especially true with system operation and planning and electricity market interactions. As new issues or features are raised, it is important to hear independent unbiased views as well as unique perspectives that show the gaps and research needs that may be yet unexplored. A similar need for studies and proposals that are released where it may be difficult to get an unbiased perspective on what the implications of the findings are.

Approach

The EPRI team will provide a set of Industry Insights and Perspectives that are based on unplanned topics so that the program can be flexible toward the high priority activities and proposals that are introduced throughout the year. Industry Insights are unique takes or clear and concise explanations of complex topics including summary of the issue or event when applicable. Perspectives are an EPRI independent review on a proposal, paper, or study by another entity to provide an unbiased view for advisors.

Research Value

As the industry is fast paced dynamic environment with complex new challenges facing stakeholders regularly, insights such as these can help save time and provide thorough education to help decision making.

Anticipated Deliverables

Deliverable	Date
Industry Insights – Insights on emerging topics or activities that provides a unique take or provides clear explanations of complex topics	Dec. 2025
Perspectives – Independent reviews of studies or proposals that are released by other entities for a unique perspective that is tied to research	Dec. 2025

Past EPRI Research on Topic

Product ID	Title	Description	Published Date
3002025827	EPRI Perspective: Can we Afford a Single Clearing Price Electricity Market?	A review of the debate on the merits and features of using uniform marginal-cost prices in electricity markets	Dec. 2022
3002025440	Electricity Market Suspension: Stopping the Market When It No Longer Functions: Investigation and Lessons Learned from the Australian National Electricity Market Suspension Experience	A review of how and why electricity markets may be suspended, and the mechanisms for how they are restarted. Also a detailed review of the market suspension that occurred in Australia's National Electricity Market in 2022.	Oct. 2022
3002024561	Ambient Adjusted and Dynamic Line Ratings on Transmission Facilities	Detailed review of FERC Order 881 that required the use of ambient adjusted line ratings as well as the inquiry on advanced dynamic line ratings.	Sept. 2022
3002021815	Carbon pricing in electricity markets	A review of some of the key technical challenges associated with integrating carbon pricing directly in electricity market clearing	Dec. 2021