Research Opportunities Around the Evolution of ISO/RTO Wholesale Electricity Markets

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Yinong Sun, Energy Systems Modeler and Analyst, NREL
Todd Levin, PI, Energy Systems Engineer, Argonne National Laboratory
Andrew Mills, Research Scientist, Lawrence Berkeley National Laboratory
Robin Broder Hytowitz, Grid Ops & Planning, EPRI
Benjamin Hobbs, O'Connor Sustainable Energy Institute, Johns Hopkins University
Bethany Frew, Co-PI, NREL

Moderator: Erik Ela, Grid Ops & Planning, EPRI

Supporting RTO/ISO Market Regions through Research and Development

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U.S. Department of Energy

Topic Selection

- Background research and literature review
- Facilitate discussion among ISO/RTOs
- Identify key challenges

Project Execution

- Apply tools/models/methods to conduct technical analysis
- Close coordination and engagement with ISO/RTOs throughout execution

Research Dissemination

- Workshops with RTOs and stakeholders disseminating results
- Pathway to enhanced knowledge, tools, and methods within RTO/ISO regions

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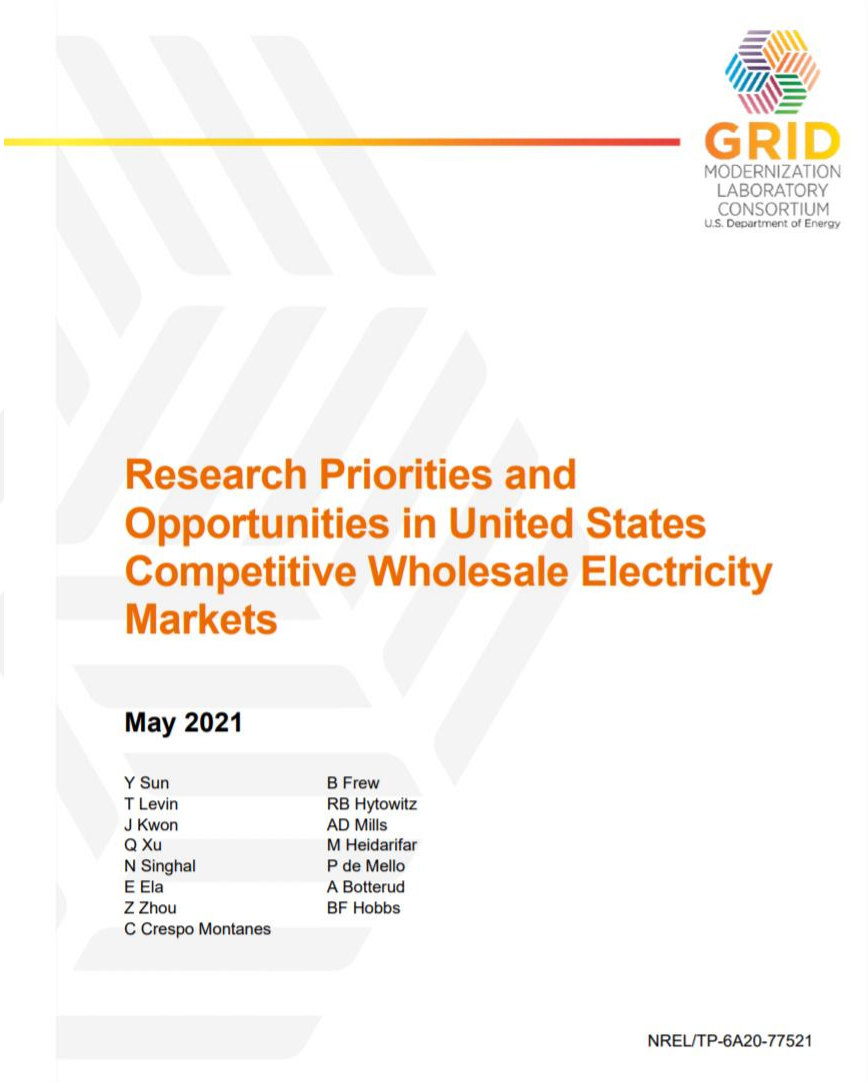
Overview

- Introduction to Report: Objective and Prioritization Results
- Topical Overviews: What is being done? What gaps still exist?
  - Resource Adequacy and System Resilience
  - Reliability Services and Operational Flexibility
  - Electricity Price Formation
  - Emerging Technology Integration
  - Transmission and Distribution Coordination; Wholesale and Retail Interactions
  - Transmission expansion planning and Financial Transmission Rights
- Q&A

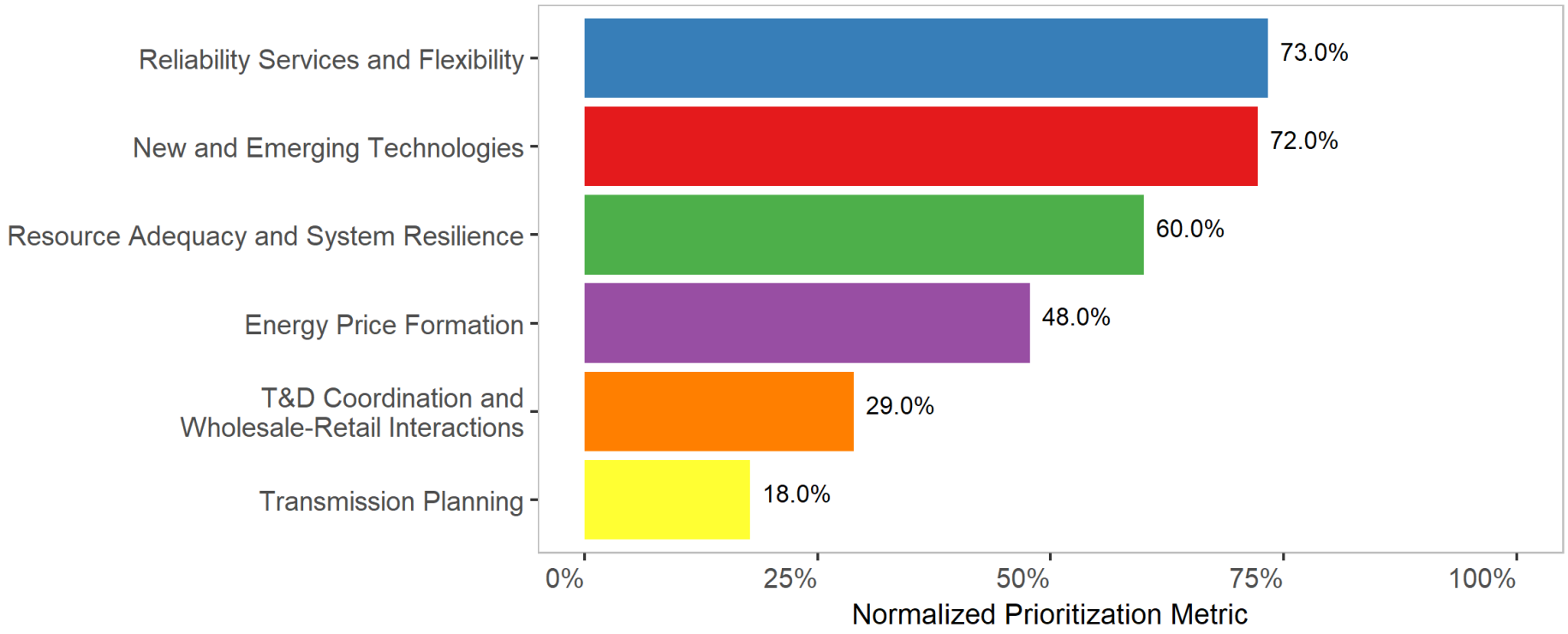
Literature Review and Market Survey



- First product of the GMLC project that aims to provide technical and analytical assistance to the seven U.S. ISO/RTOs
- Presents a research agenda for challenges and research opportunities in the 2–10-year horizon
- Summarizes the outcomes from an April 2020 ISO/RTO workshop on identifying and prioritizing market design related challenges
- Extensive review of ISO/RTO publications, industry reports, and the academic literature

https://www.nrel.gov/docs/fy21osti/77521.pdf

Prioritization Ranking of Aggregate Topic Areas Provided by The ISO/RTOs



- Six topic areas (bars shown above), which correspond to sections of the report
- Each section summarizes: 1) current market practice, 2) recent market initiatives, and 3) specific research questions and findings from literature

Priority Ranking of Market Challenges in Six Market Design Areas

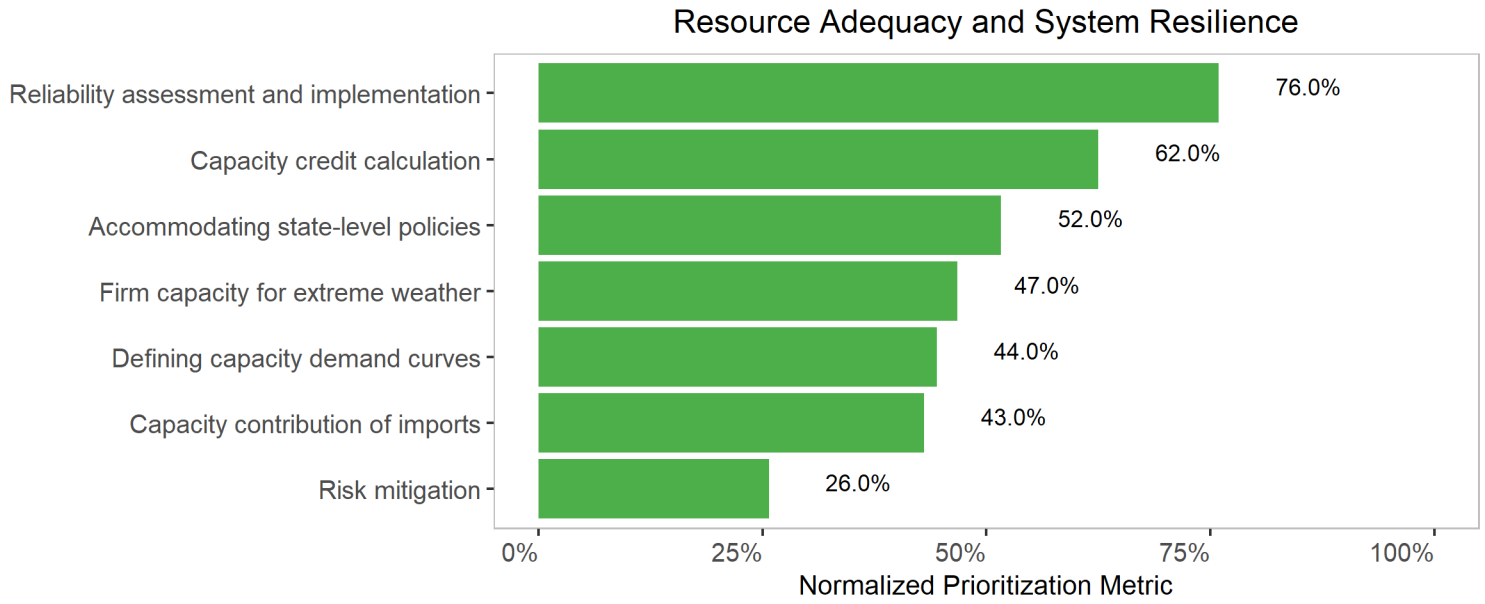
PRIORITY

PRIORITY

	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	

- Overlaps exist between the challenges within the six high-level topic areas, highlighting the fundamentally interconnected nature of different market products and design elements

Resource Adequacy and System Resilience: Stakeholder Prioritization



- Changing resource mix requires updates in quantifying reliability requirement and technologies' contribution
- Differentiated design of capacity requirements can better reflect the temporal-, locational-, and service-specific needs
- Fuel security, energy adequacy, and operational considerations become more important
- More frequent extreme weather events call for additional considerations to ensure resource adequacy and resilience

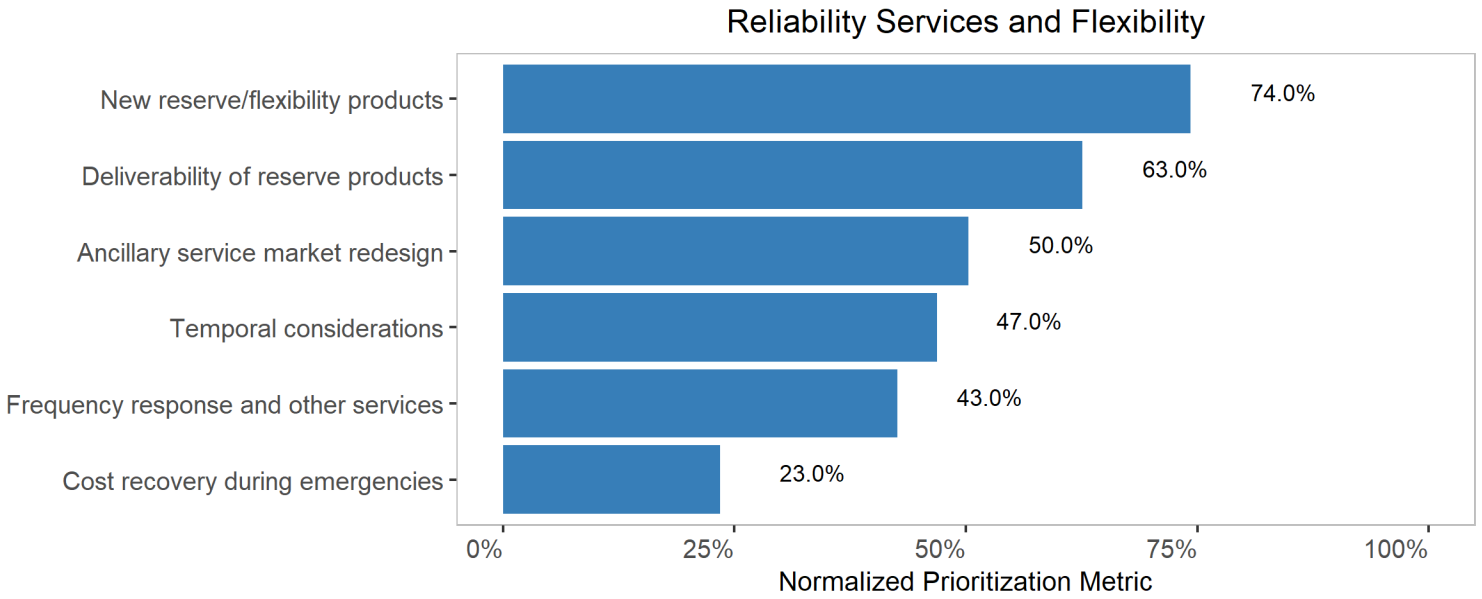
Resource Adequacy and System Resilience: Current Practice and Proposed Changes

ISO/RTO	Recent and Proposed Market Changes
PJM	• Exploring ***fuel and resource security*** through its Fuel Security Senior Task Force • Implement ***changes to its Minimum Offer Price Rule*** (MOPR) to accommodate state-subsidized resources into the capacity market
NYISO	• Comprehensive mitigation review to evaluate its ***buyer-side mitigation rules*** and ways to accommodate state policies • Revising capacity market rules • Conducted a ***fuel security*** analysis
ISO-NE	• Exploring longer-term market-based approaches to align ***multi-day energy needs*** with market price signals through the Energy Security Improvements Key Project to ensure fuel security • Implemented the Competitive Auctions with Sponsored Resources (CASPR) to efficiently ***accommodate state policies*** in its forward capacity market cost.
MISO	• Identifies the need to improve reliability requirements to reflect ***reliability needs across all hours of the year***, and to better ***accredit resource contributions*** towards resource adequacy in its Resource Availability and Need issue tracking task.
SPP	• Identifies security resilience, regional resource needs, and grid resilience initiatives as priorities in its strategic plan initiatives • Proposes to adopt ELCC methodology to determine ***accreditation of wind and solar resources***
CAISO	• Proposes multiple changes through ***Resource Adequacy Enhancements Initiative***: e.g., including full consideration of forced outage rates in reliability requirements, to develop a new flexible resource adequacy framework, to update rules for resource adequacy import provisions, and to improve resource deliverability through updated must-offer obligations
ERCOT	• ORDC updates and refinements to incentivize investments and achieve reliability targets (more in Energy Price Formation) • Monitoring drought-related risks affecting cooling water for thermal generation resources.

Resource Adequacy and System Resilience: Research Questions and Opportunities

Challenge	Research Questions and Opportunities
Enhance reliability assessment and implementation	• ***Revise engineering-based reliability assessment methods*** and develop ***more granular temporal and spatial reliability requirements*** • Incorporate ***economic-based reliability assessment*** for comparison.
Capacity rating and capacity credit calculation method	• Approaches to ***probabilistic-based methods to calculate capacity credits*** for VRE technologies • Revise capacity accreditation rules and ***develop rules to quantify emerging technology capacity contribution***
Accommodate state-level policies in capacity markets	• Explore ways to ***accommodate state-subsidized resources*** in capacity markets • Understand the potential impacts of different proposals on technology development and consumer cost
Shape and parameters of capacity demand curve	• Evaluate the market impacts of underlying ***parameters that define the shape of demand curves*** with current design • Explore **new demand curve designs**
Import resources capacity contribution and performance evaluation	• Revise ***qualification rules for import resources adequacy resources*** in planning • Revise import resources ***must-offer obligations*** to ensure firm energy delivery during operation
Market mechanism to procure firm capacity for extreme weather	• Explore whether new markets and/or updated market rules are needed to ***incentivize fuel supply arrangement months ahead of delivery*** • Incorporate ***fuel security and energy sufficiency*** into reliability considerations
Participant risk mitigation in capacity markets and bilateral contracts	• Explore how market design can be improved to mitigate asymmetric effects of different technologies' risk profiles • Provide ***technology-agnostic incentives for investment***

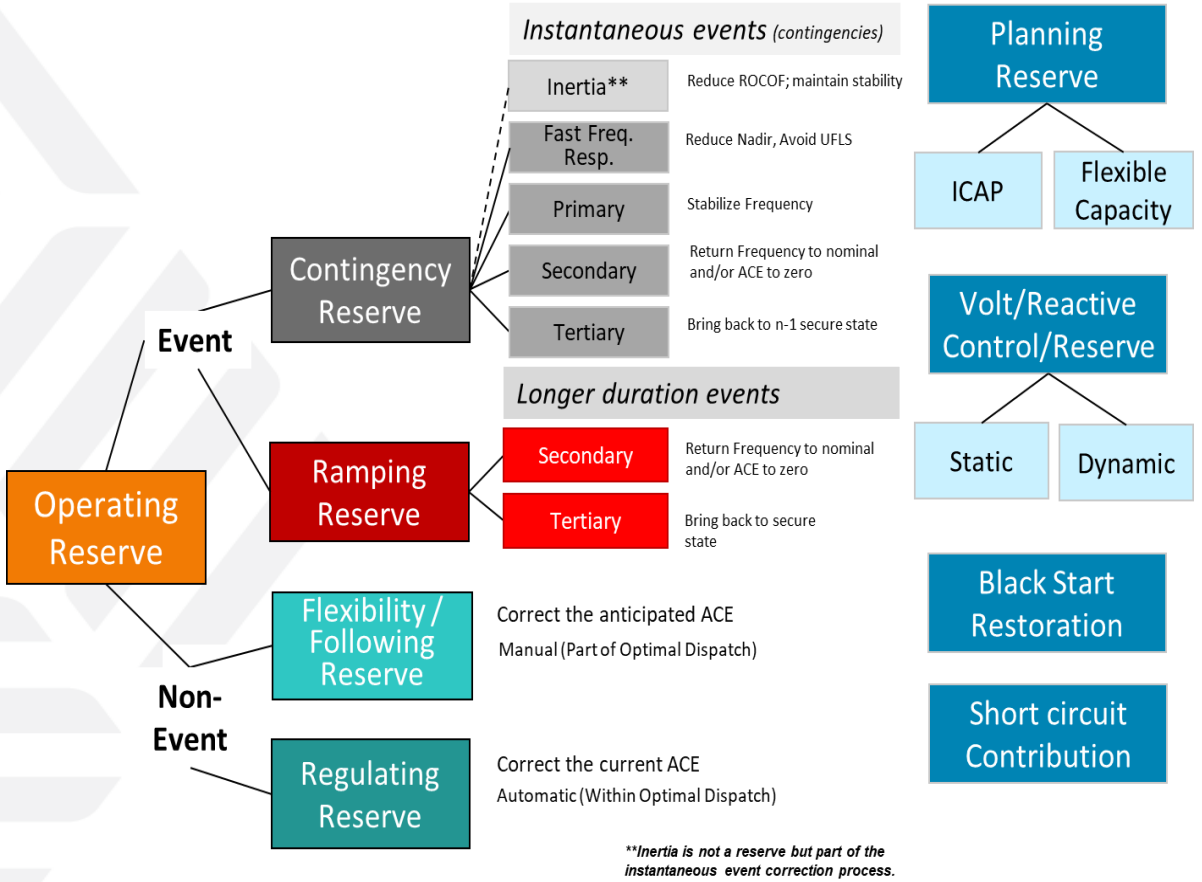
Essential Reliability Services and Operational Flexibility: Stakeholder Prioritization



- Given the **changing resource mix** and increase in **common-cause and extreme events**, many are considering changes to their essential reliability services and ancillary service products
- Many ISOs/RTOs are incorporating new products or services that help manage flexibility
  - Many needs for flexibility in different **timescales**, including DA to RT, inter-hour, intra-hour, multi-day, seasonally
  - Depends on the needs of a **specific system** and may include faster ramp rates, faster start-up/shutdown times, wider dispatchable range, and relaxed minimal commitment constraints
  - Need to consider how a new product should be **priced**, e.g., operating reserve demand curve (ORDC)

Essential Reliability Services and Operational Flexibility: Current Practice and Proposed Changes

	Recent and Proposed Market Changes
PJM	• Proposal to make **services consistent between DA and RT** • Changing **penalty prices** of reserves, including an **ORDC**
NYISO	• **Increasing flexibility** because of contingencies affecting transmission assets • Finer **geographic granularity** for operating reserve in load pockets
ISO-NE	• New **DA reserve services**: generation contingency reserve, replacement energy reserve, and energy imbalance reserve • While rejected by FERC, proposal for a rolling multiday-ahead market horizon
MISO	• Implemented a "fast-first" approach to **Automatic Generation Control** regulation deployment • Implementation of a **short-term reliability reserve product**, which allows both online and offline resources to offer capacity for availability in 30 minutes
SPP	• **Ramp product**, focused on RT impacts with a 20-minute horizon • **Uncertainty product**, accounting for forecast uncertainty over a longer term
CAISO	• **Imbalance reserves**, biddable product addressing DA to RT uncertainty • **Reliable capacity**, integrating parts of RUC into the DA market
ERCOT	• Undergoing an **ancillary service market redesign** • New services include primary frequency response, fast frequency response service, and ERCOT contingency reserve service



Adapted from Ela et al., *An Enhanced Dynamic Reserve Method for Balancing Areas,* EPRI, Palo Alto, CA: 2017. 3002010941.

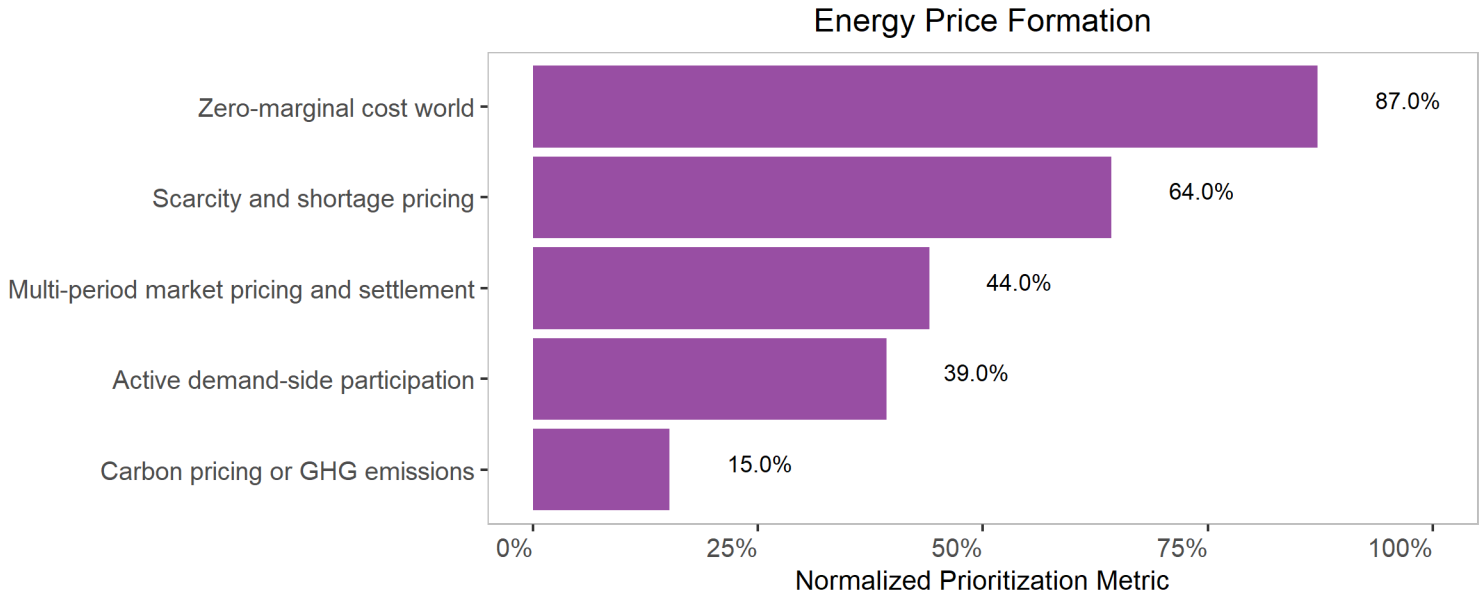
Essential Reliability Services and Operational Flexibility: Research Questions and Opportunities

Challenge	Research Questions and Opportunities
New reserve products	Are existing reserve products sufficient for the future resource mix? Are incentives and market products necessary for resources to provide these new market products?
Deliverability of reserve products	Are there particular products and services that should ensure the deliverability of reserve and to what level of granularity? Can this be done during the auction, or after?
Ancillary service market redesign	Should ancillary service markets as a whole be redesigned? Is there a need to reassess their functionality? Do the increased number and complexity of products interact in ways that meet system needs cost-effectively while preserving transparency, or are there ways in which that complexity interferes with market efficiency and reliability, including coordination of neighboring systems?
Temporal considerations (markets, commitments, or forecasts)	How would the multiday market be designed, and what are the benefits? What about horizons for RT markets or resolution changes (e.g., 15-minute DA markets)? What are the short- and long-term incentives for new market entry with multiday markets?
Frequency response and other services	Is the existing requirement and procurement method for PFR sufficient, and are other frequency response services or products needed? Should there also be alternative procurement mechanisms for other services such as inertia, voltage control, or short circuit current?

- Needs
  - Uncertainty due to forecast error
  - Increasing flexibility
  - Understanding risk
- Timeframes
  - Procurement
    - Short term (real-time market)
    - Medium term (day-ahead market)
    - Long term (capacity market or resource adequacy)
  - Eligibilty: 5-min deployable, 15-min, 1-hour, 24-hours

- Under consideration for several products at ISOs
- Difficulties with computational tractability
- Should more products be nodal?

Energy Price Formation: Stakeholder Prioritization



- **Getting the price right** has always been a key part of market design
- Many questions arise as the **resource mix changes** and **variable costs reduce** significantly
  - How does the right price in spot markets influence capacity markets, could we eventually eliminate the need for **capacity markets** with the right scarcity pricing together with carbon pricing?
  - How much does **operator action** influence pricing?
  - How much should pricing change due to increasing amounts of **stochastic information and resources** present in the power system?

Energy Price Formation: Current Practice and Proposed Changes

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ISO/RTO	Recent and Proposed Market Changes
PJM	• PJM is updating their fast-start pricing to include **separate pricing and dispatch runs** in DA and RT, amortized startup and no-load costs, and provide incentives to follow dispatch with lost opportunity costs • PJM has also been evaluating several **carbon-pricing** leakage mitigation mechanisms in its region
NYISO	• Following FERC orders, NYISO extended this pricing methodology to **all fast-start units**, starting in December 2020 • NYISO also has issued a proposal to include additional **carbon pricing** in its region
ISO-NE	• ISO-NE has implemented alternative modeling for fast-start resources • To provide further incentives in the short-term, ISO-NE implemented **Net Commitment-Period Compensation** rules
MISO	• MISO was **early** to implement alternative pricing for fast-start units and continues to make **improvements to the calculation method** behind its ELMP formulation
SPP	• SPP had no alternative pricing and proposed new methods in response to a FERC order that creates a separate pricing run and sets fast-start eligibility requirements
CAISO	• Although CAISO offers a COG resource category with associated pricing, no resources have opted to use this voluntary categorization.
ERCOT	• The operator offers fast-start resources the ability to set prices based on the inclusion of commitment costs

Energy Price Formation: Research Questions and Opportunities

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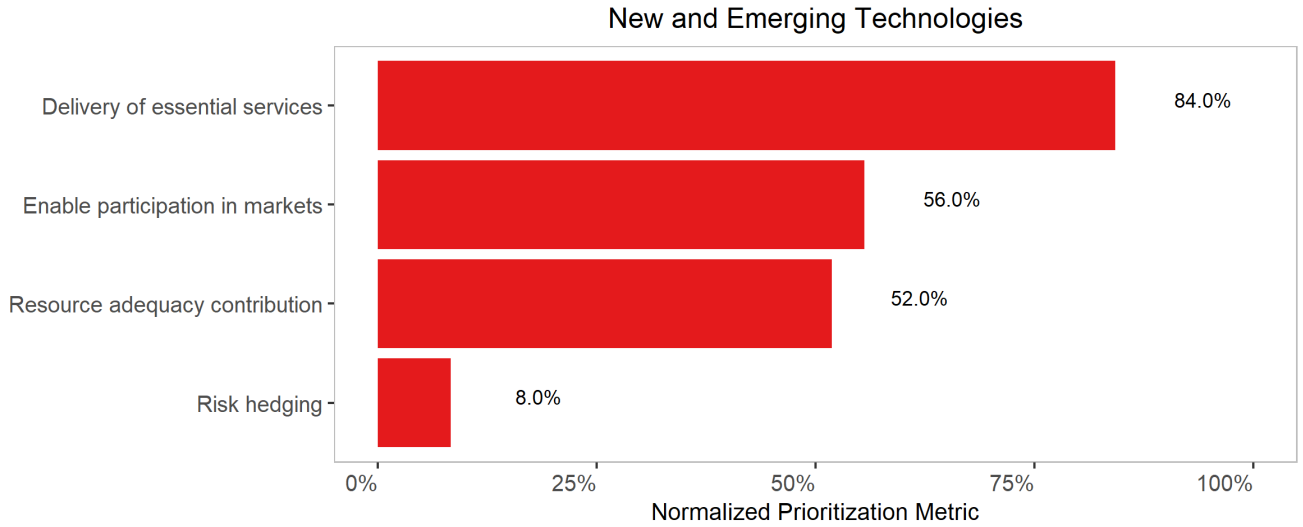
Challenge	Research Questions and Opportunities
Zero-marginal-cost world	• How will or should the **markets change** in an increasingly zero-marginal-cost world? • Are current pricing mechanisms **sufficient**? • Will we need unit commitment?
Scarcity and shortage pricing	• With varied resources mixes, is scarcity and shortage pricing designed and set **appropriately**? What is the correct offer cap? • How should **demand curves** be calculated?
Multi-period market pricing and settlement	• Is **multi-period pricing** and settlement possible, and do the benefits outweigh the complexities? • What should **settlements** look like?
Active demand-side participation	• How will markets change with active demand-side participation, including impacts of **Order 2222**? • Will operators **trust** demand to follow dispatch signals?
Carbon pricing or greenhouse gas emissions	• How can wholesale markets **efficiently** incorporate carbon pricing or emission-reducing incentives into prices? • How can ISOs/RTOs handle **seams**? What are the best methods to manage **multi-state** ISOs/RTOs?

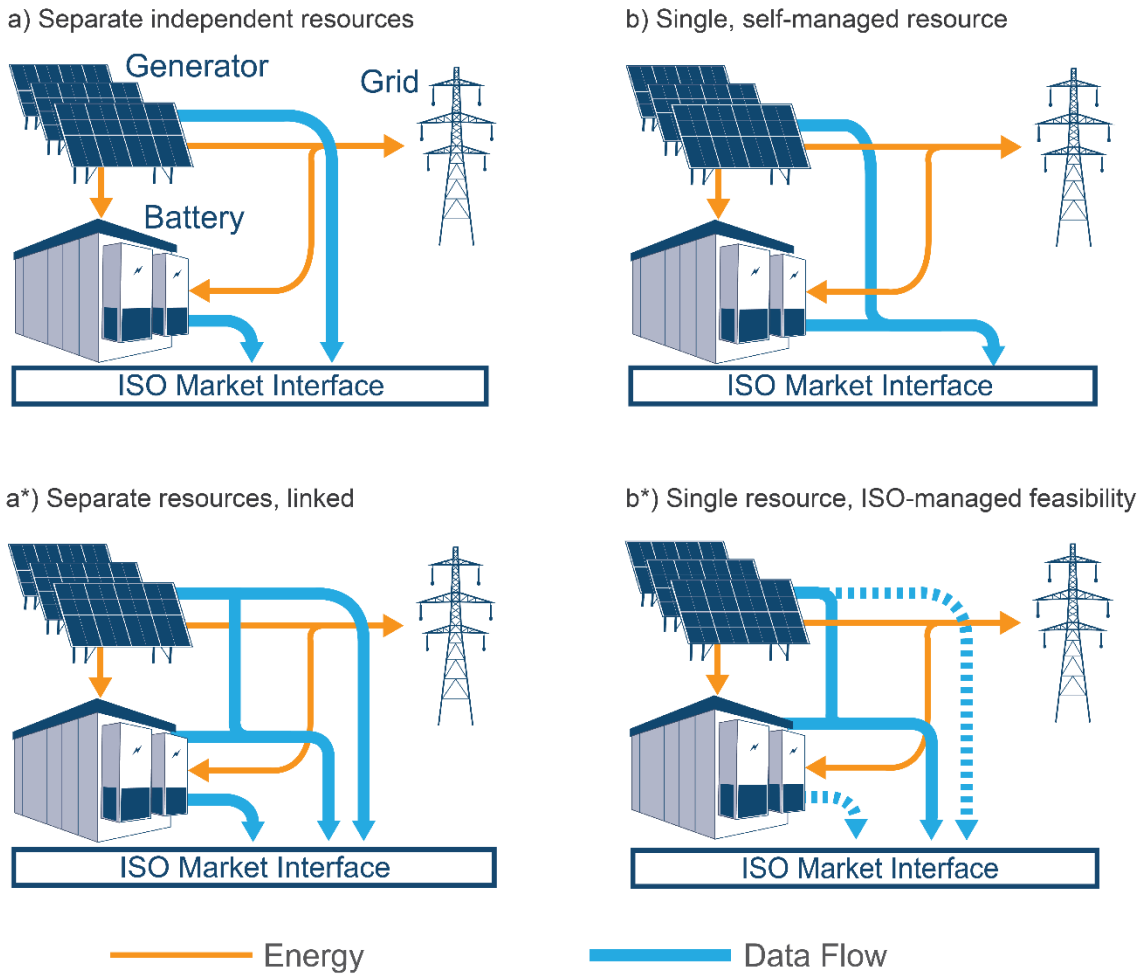
New and Emerging Technologies: Stakeholder Prioritization



- Seeing greater participation from the demand side, increase in nonsynchronous generation, new types of VRE like offshore wind, and renewable hybrid resources
- How can ISOs/RTOs ensure market designs continue to operate economically efficient markets and maintain reliability during a time with a rapidly changing resource mix?
  - Requires **delivering sufficient ERS** to maintain secure operations,
  - Developing **participation models** for new resources,
  - Ensuring **resource adequacy** with weather-dependent and energy-limited resources,
  - Enabling market participants to use **forward contracting** to minimize financial risks

New and Emerging Technologies: Current Practice and Proposed Changes

	Recent and Proposed Market Changes
PJM	• Improve **representation of complex resources** (e.g., combined-cycle units) in market-clearing software
NYISO	• Rules and procedures to **accommodate hybrid resources**: "co-located" and "aggregation" model • Provision of **grid services from renewables** with adequate controls
ISO-NE	• **Price-responsive demand** project to integrate DR into market comparable to other resources
MISO	• **Hybrid Resource Participation** Model: contribution to resource adequacy, sizing interconnection capacity, and treatment in market operations
SPP	• New approaches to **treat wind generation on par with other conventional resources**: requirements for cost-based offers in constrained areas?
CAISO	• **Hybrid Resources Initiative** allows for different configuration and technology combinations
ERCOT	• **Mapping DERs** to transmission loads, provide a locational marginal price rather than zonal load price, improve representation of DER capabilities in planning models • Battery Energy Storage initiative to **facilitate integration of storage**

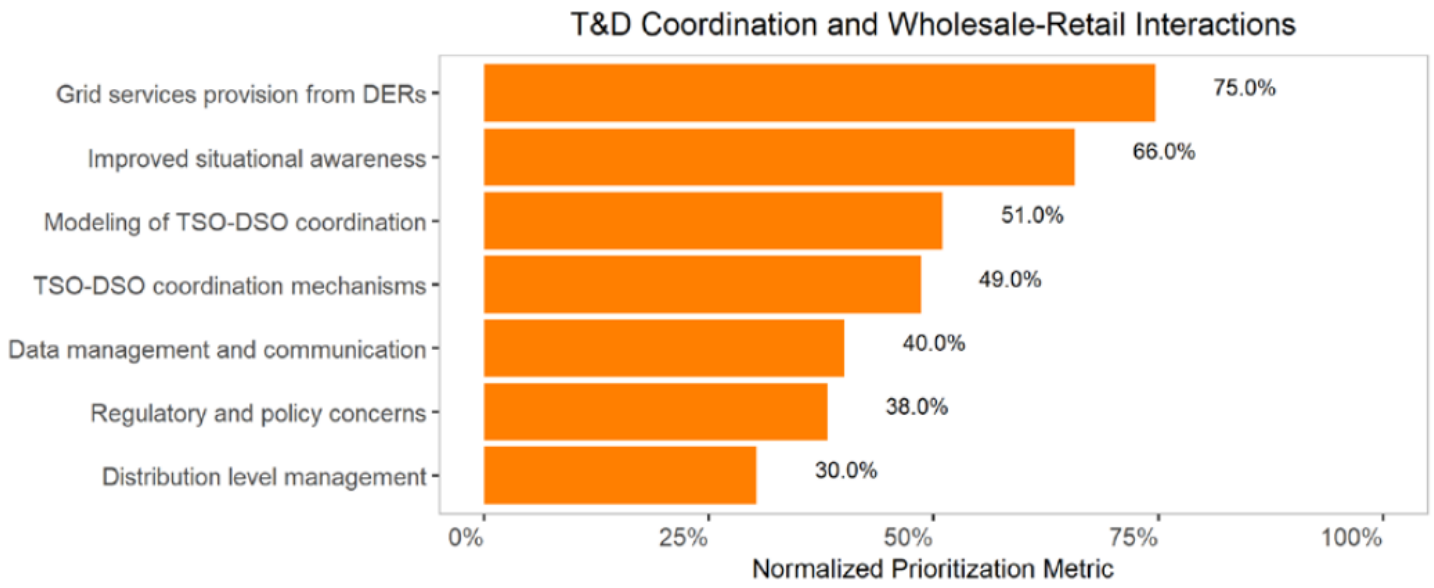


Adapted from Gorman et al., 2020. "Motivations and Options for Deploying Hybrid Generator-plus-Battery Projects within the Bulk Power System." *The Electricity Journal* 33 (5) https://doi.org/10.1016/j.tej.2020.106739

New and Emerging Technologies: Research Questions and Opportunities

Challenge	Research Questions and Opportunities
Delivery of Essential Services	• **Define essential reliability services** for an evolving grid • **Demonstrate and recognize capabilities** of emerging technologies to provide those services • Where practical, **develop pricing mechanisms and signals** to competitively procure services
Enable Participation in Markets	• **Develop participation models** that balance participant flexibility with system operator requirements • Design markets and software to capture characteristics of emerging technologies and enable provision of reliability services, especially **multi-period optimization and state-of-charge management**
Resource Adequacy Contribution	• Evaluate changes to resource adequacy contribution of variable and energy-limited resources with changes in the mix of resources, including **potential synergies between technologies** • Create **efficient investment signals** by reflecting changing contributions in forward capacity markets
Forward Contracting and Risk Hedging	• Generators and loads rely on forward contracts to reduce risks, all ISO/RTOs markets include a form of FTRs to **help market participants hedge risks** associated with locational price variation • Alter design to **enhance hedging effectiveness** for renewable generation

Transmission–Distribution Coordination and Wholesale-Retail Interactions: Stakeholder Prioritization



- Grid is transitioning from tradition one-way interaction to bidirectional interactions
  - Rooftop solar, energy storage, demand response etc.
- Consumers are increasingly becoming market participants
- Traditional wholesale markets are not designed to coordinate with many small, bidirectional resources
- New participation models are needed to unlock value of services that these resources can provide

Transmission–Distribution Coordination and Wholesale-Retail Interactions: Current Practice and Proposed Changes

ISO/RTO	Recent and Proposed Market Changes
PJM	• 2018 W-DER proposal sets role of a DSO in DER interconnection and operational coordination process. • Enables ***aggregated participation*** (<0.1 MW) in C/E/AS markets.
NYISO	• DER Roadmap initiative has developed a series of market enhancements since 2017 with several objectives: • (1) ***integrating DERs into C/E/AS markets***, (2) aligning with state policies, (3) enhancing measurement and verification, (4) aligning compensation with performance, (5) dual wholesale/retail participation, and (6) coordination with system planning, interconnection, and forecasting.
ISO-NE	• Several considered initiatives to help ***participation in C/E/AS markets***. • Several initiatives related to forecasting DERs (short- and long-term), including load impacts are underway.
MISO	• Series of workshops in 2019 began framing key challenges, DER 300 workshop focused on T&D interface. • Published a DER framing and discussion document in 2020. • The Five-Year Plan of MISO states that the planning and modeling processes will account for DER growth.
SPP	• Near term objective to enhance visibility into the distribution system. • Long-term objective to enhance control through ***market participation*** across jurisdictional layers.
CAISO	• Began investigating the needs for T&D coordination in a high-DER future in 2016. • Then ***enabled aggregation*** of DERs connected to distribution systems.
ERCOT	• Developed approach for mapping registered DER units to appropriate transmission system loads in 2018. • Enables larger DERs to receive localized (nodal) price signals, helps ERCOT manage congestion on the grid. • ***Lowered the limit for DER participation in E/AS*** markets to 1 MW.

Transmission–Distribution Coordination and Wholesale-Retail Interactions: Research Questions and Opportunities

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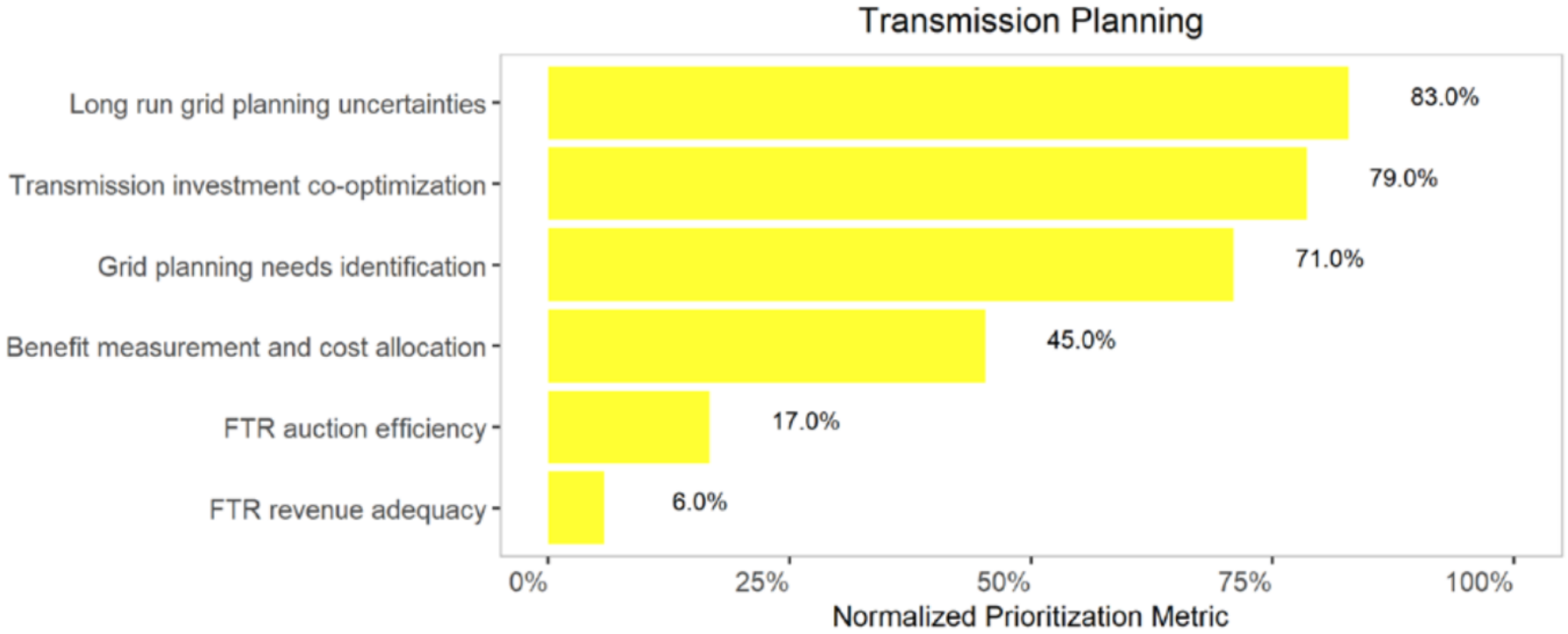
Challenge	Research Questions and Opportunities
Market design and control methods for the provision of grid services from DERs	• Wholesale market participation models for DERs that ***capture their unique physical and operating characteristics*** • Implementation of ***new market products*** (e.g., reactive power, voltage support) • ***Compensation methods aligned with performance*** • Dual participation of DERs in ***retail and wholesale*** markets • ***Hierarchical control strategies*** for aggregated DER resources providing multiple services
Improved situational awareness	• ***Advanced short-term forecasting*** *of DERs* with high accuracy • Assessment and monitoring DERs connected at the distribution level ***to unlock full range of services***
Modeling and assessment of ISO–DSO coordination approaches	• Modeling of various ISO–DSO coordination schemes • Assessment of different approaches (e.g., ***cost-benefit analysis***, feasibility and/or ***reliability assessment***)
Develop novel ISO–DSO coordination mechanisms	• Review of ***potential ISO–DSO coordination mechanisms*** • Develop ***new concepts*** for ISO–DSO coordination
Data management and communication	• Metering, telemetry, and verification requirements and methods • **Communication and data management** protocol for information exchange between entities
Regulatory and policy concerns	• ***Coordination between multiple governing entities*** to overcome jurisdictional issues
Distribution level markets and management	• Review and modeling of DSO management systems that interact with ISO/RTOs • ***Market prices with full consideration of network constraints*** (e.g., distribution level LMPs) • Settlement methods of DERs located at the distribution level

Transmission Expansion Planning & Financial Transmission Rights: Stakeholder Prioritization



- VERs → Transmission and FTRs are likely to be increasingly valuable as flow patterns become more variable & less predictable
- TEP & FTR are both key to network management, but have distinct purposes, market practices, & challenges
- Their links are important: e.g., FTR revenue insufficiency → greater incentive to manage outages better, expand capacity

Transmission Expansion Planning & Financial Transmission Rights: Challenges in Current Practice

Problem	Practice and Considered Changes
TEP Uncertainty	• Evidence from modeling that considering uncertainty can either **increase or decrease investment** (diversification vs preserve option by postponement), **and increase net benefits** of plans • CAISO, SPP, MISO lead in formal consideration (load growth, resource costs/availability, policy, VERs, retirements, exports)
Proactive/ Co-optimized TEP	• **Chicken/Egg:** Although transmission has longer lead times, **anticipative planning/co-optimization rare** • Thus, **TEP emphasizes savings in production costs rather than capital costs**, understating transmission value • SPP, MISO use GEP tool prior to TEP. CAISO TEAM method attempted to anticipate how gen investment follows transmission.
TEP Goals	• Need-oriented: Focus on reliability, policy, and economic needs, often with distinct planning processes • **Lack of integration can lead to inefficiencies**
TEP Cost Allocation	• **Benefit uncertainties** contribute to incomplete implementation of beneficiary pays (NYISO & MISO multi-value planning furthest along) • **Weaken cooperation incentives**
TEP Project vs System Focus	• E.g., **reactive evaluation of proposals**, rather than comprehensive system planning • Spillover benefits & costs to other balancing authorities not systematically considered, so cross BA projects undervalued. • **2021 Federal infrastructure bill**
FTR Auction Efficiency	• A rising concern among stakeholders**: FTR allocation systems provide benefits to consumers** that reflect value of the rights? • Discussions in PJM, CAISO about how to modify ISO-backing of FTRs
FTR Revenue Adequacy	• **Chronic problem** addressed in diverse ways across ISOs • How does shortfall allocation affect market efficiency, and **incentives for better outage management**?

Transmission Expansion Planning & Financial Transmission Rights: Research Questions and Opportunities

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Problem	Research Questions and Opportunities
TEP Uncertainty	• **Uncertainty-based optimization to quantify option & diversity value** of near-term transmission investments under profound uncertainty • How to **rank the importance of uncertain factors** that affect TEP?
Proactive/ Co-optimized TEP	• Can we develop practical large-scale co-optimization models to **estimate combined investment-production cost savings** from changing generation/storage expansion as a result of transmission investments? • How to reflect **realities of resource investment processes** in co-optimization?
TEP Goals	• How to **identify beneficial transmission projects** that are missed by traditional needs identification processes? • **Quantify reliability benefits in $** terms and include in economic studies
TEP Cost Allocation	• Methods to identify and allocate cost of "local" transmission lines when they provide **regional benefits** • **Adapt cost-allocation to uncertain & changing circumstances** to increase assurance that all parties benefit • How to allocate **costs of reinforcements that are primarily to serve export markets**, or policy objectives for other regions?
TEP Project vs System Focus	• How should the planning of transmission facilities that have systemwide benefits include **public input, and balance local and systemwide effects**?
FTR Auction Efficiency	• How should FTR auction efficiency be promoted to **assure consumers that they are better off with ISO-operated FTR markets** than without FTRs?
FTR Revenue Adequacy	• How to **minimize** revenue inadequacy? • **Which FTR shortfall allocation methods distort market efficiency the least**, and maximize the hedging value of ISO FTR systems?

Questions