

Advanced ISO Models for Storage and Hybrid Resources Operation

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Introduction

- Electric storage resources (ESRs) are key for decarbonizing power systems and must be efficiently integrated into ISO operations.
- ISOs have modified market scheduling frameworks to include ESRs, but new clearing algorithms and economic approaches are needed.
- Accurate ESR modeling is required to provide incentive-compatible price signals, meet physical constraints and ensure reliability.
- ESR modeling is also proxy for new problems in power systems.

Modeling efforts need to be:

- Fast. ISOs are already facing ESR-related challenges.
- Compatible. New modeling approaches have to be compatible with existing market clearing software platform used by ISOs.
- Compliant. Algorithm development is subjected to existing and future market rules, ISO policies and regulatory frameworks.

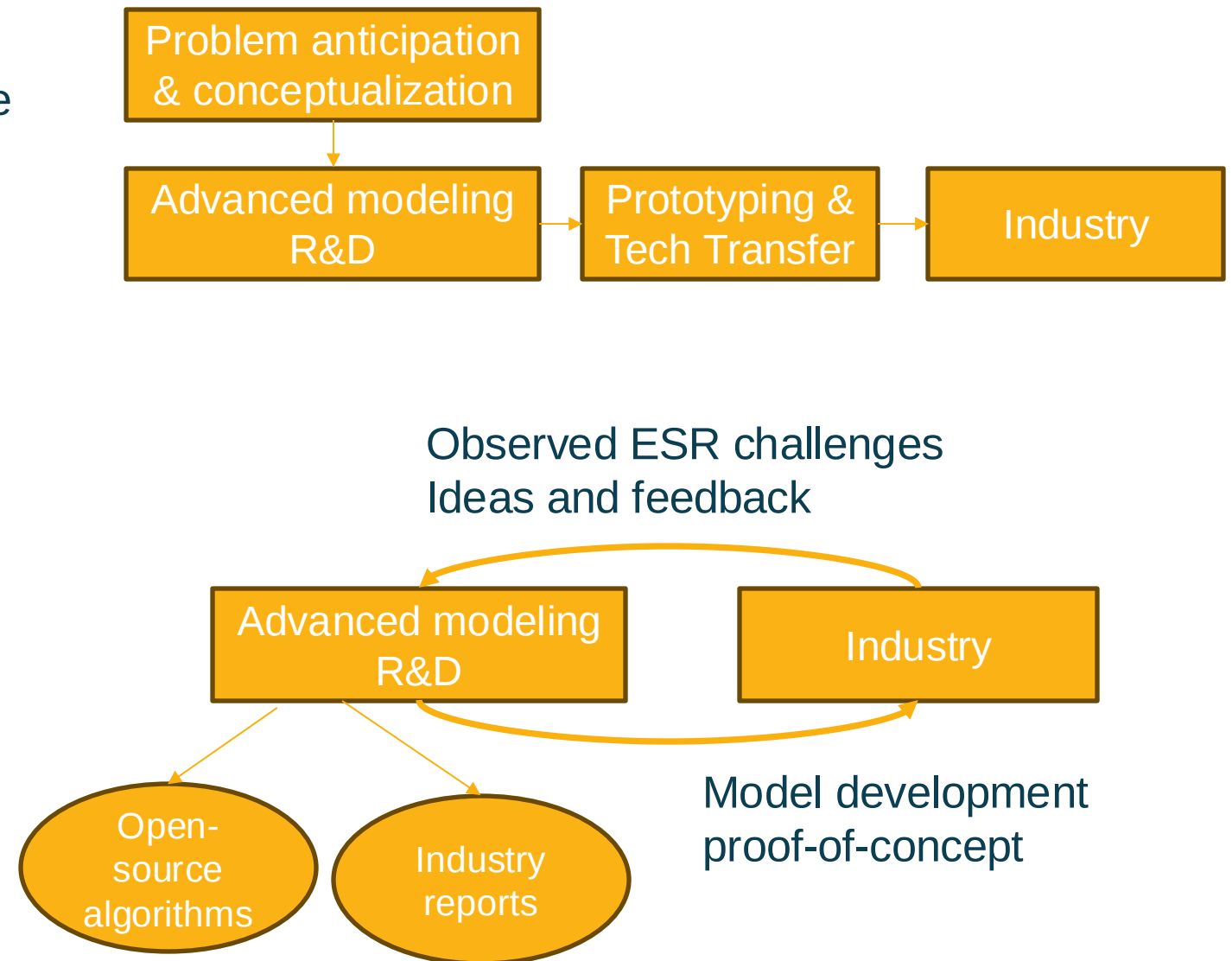
Review of Storage Participation in United States Electricity Market Regions

	Installed capacity (MW)	Queue capacity (GW)	Peak load in 2023 (MW)
CAISO	7,858	149	44,534
ERCOT	3,416	76	85,508
ISO-NE	332	19	24,043
MISO	82	37	124,229
NYISO	198	36	30,206
PJM	343	55	146,843
SPP	27	25	56,184

Source: Form EIA-860M, December 2023 Release

Innovation Approach

- Traditional innovation approaches require multiple steps bring models from early-stage research to the industry.
- Given the urgency of addressing ESR-related modeling gaps, current innovation pathways may take too long.
- ISOs are starting to face the challenges of representing storage and some of them already have ideas for potential solutions.
- There is an opportunity for rapid development, prototyping and testing of algorithms that can be open-sourced and then adopted by the ISO software vendors.



Industry Perspective

- Paper surveys, online surveys and in-depth interviews
- Engaged seventeen representatives from seven U.S. ISO/RTOs
- At least one from each ISO/RTO

Poll ID	Poll Type	Poll Question	Poll Option	Count	Total Votes	Results	Survey Name
38616408	Word cloud	A. Please provide your name, job title, and organization	Kenneth Ragsdale	1	3		ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616408	Word cloud	A. Please provide your name, job title, and organization	Nitika Mago, Manager Balancing Operations Planning	1	3		ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616408	Word cloud	A. Please provide your name, job title, and organization	Sai Moorthy, Principal, ERCOT	1	3		ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616409	Ranking	B. Please prioritize the four listed topical areas based on what you believe requires the most extensive R&D related to electric storage resources (ESRs), with 1 being the topical area that requires the most extensive R&D and 4 being the least.	Day-ahead market	2	3	1	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616409	Ranking	B. Please prioritize the four listed topical areas based on what you believe requires the most extensive R&D related to electric storage resources (ESRs), with 1 being the topical area that requires the most extensive R&D and 4 being the least.	Real-time market	3	3	3.67	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616409	Ranking	B. Please prioritize the four listed topical areas based on what you believe requires the most extensive R&D related to electric storage resources (ESRs), with 1 being the topical area that requires the most extensive R&D and 4 being the least.	Ancillary services market	3	3	3.33	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616409	Ranking	B. Please prioritize the four listed topical areas based on what you believe requires the most extensive R&D related to electric storage resources (ESRs), with 1 being the topical area that requires the most extensive R&D and 4 being the least.	Miscellaneous	2	3	1	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616443	Ranking	C. With respect to the day-ahead market (DAM) topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 5 being the least.	Development of computational and/or modeling improvements to simplify SoC management of ESRs by the ISO/RTO.	3	3	2.67	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616443	Ranking	C. With respect to the day-ahead market (DAM) topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 5 being the least.	Evaluation of ESR utilization and SoC management in reliability unit commitment (RUC) (or exceptional dispatch).	3	3	3.33	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616443	Ranking	C. With respect to the day-ahead market (DAM) topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 5 being the least.	Exploration into enhanced energy representation for appropriate SoC calculation within the market clearing software.	3	3	3	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616443	Ranking	C. With respect to the day-ahead market (DAM) topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 5 being the least.	Evaluation of an increased time granularity within the DAM to minimize potential discrepancies with the real-time market.	2	3	0.67	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616472	Ranking	D. With respect to the real-time market (RTM) topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 4 being the least.	Development of approaches to augment incentive compatibility of multi-interval RTSCED problems for ESRs through enhanced price formation and other market enhancements.	3	3	2.67	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616472	Ranking	D. With respect to the real-time market (RTM) topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 4 being the least.	Evaluation of the impact of different SoC management options for ESRs in the RTM.	1	3	1	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616472	Ranking	D. With respect to the real-time market (RTM) topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 4 being the least.	Development of ways to enhance the performance of ESRs in the RTM, particularly during critical resource adequacy events	1	3	0.33	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616673	Ranking	E. With respect to the ancillary services (A/S) market topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 4 being the least.	Evaluation of impact and feasibility of A/S on SoC management. Exploration of approximation of dynamic deployment factors (multipliers, attenuation factors) for different A/S.	3	3	3	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616673	Ranking	E. With respect to the ancillary services (A/S) market topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 4 being the least.	Exploration into enhanced energy representation (i.e., including energy usage under different A/S needs) for appropriate SOC calculation within the market clearing software.	3	3	2	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616673	Ranking	E. With respect to the ancillary services (A/S) market topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 4 being the least.	Exploration of the impacts of sustained duration performance requirements for A/S on the SoC of ESRs. This includes assessing and analyzing the price formation impacts of using a cascading reserve model compared to a reserve model that does not cascade reserves in the context of energy-limited resources.	2	3	0.67	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616740	Ranking	F. With respect to miscellaneous topics, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 7 being the least.	Adequate representation of ESR degradation within the market clearing software.	2	3	2.33	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616740	Ranking	F. With respect to miscellaneous topics, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 7 being the least.	Development of market participation models for long-duration energy storage, e.g., H2 technologies or other multi-day storage technologies.	2	3	3	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616740	Ranking	F. With respect to miscellaneous topics, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 7 being the least.	Development of market power mitigation approaches for storage-based resources, including estimation of opportunity costs.	1	3	1.33	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616740	Ranking	F. With respect to miscellaneous topics, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 7 being the least.	Addressing challenges with integrating Storage + X resources, where X is Hydro or Thermal, or Thermal Storage + Controllable Demand resources.	1	3	2	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616740	Ranking	F. With respect to miscellaneous topics, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 7 being the least.	Evaluation of storage as transmission assets (SATA) and transmission-only assets (SATOAs).	2	3	2.33	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616740	Ranking	F. With respect to miscellaneous topics, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 7 being the least.	Analysis of price formation in renewables-dominated power systems with energy storage participation.	2	3	3	ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)
38616813	Word cloud	7. Additional areas of interest that are NOT covered in the aforesaid sub-topics? Please identify specific examples of research and modeling gaps that are under consideration for future implementation at your organization below. This may include early conceptualization or initial ideation.	In a world with thousands of MWs/MWhs of batteries	1	1		ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)

ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources

A. Please provide your name, job title, and the name of your organization.

B. Please prioritize the four listed topical areas based on what you believe requires the most extensive R&D related to electric storage resources (ESRs), with 1 being the topical area that requires the most extensive R&D and 4 being the least.

Rank

C. With respect to the day-ahead market (DAM) topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 5 being the least.

Rank

D. With respect to the real-time market (RTM) topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 4 being the least.

Rank

E. With respect to the ancillary services (A/S) market topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 4 being the least.

Rank

F. With respect to miscellaneous topics, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 7 being the least.

Rank

Ranking poll

EPRI

ISO/RTO Survey on Navigating Modeling Frontiers for Electric Storage Resources (4/7)

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D. With respect to the real-time market (RTM) topical area, please rank below sub-topics in order of research relevance to your organization, with 1 being the most important and 3 being the least. (1/2)

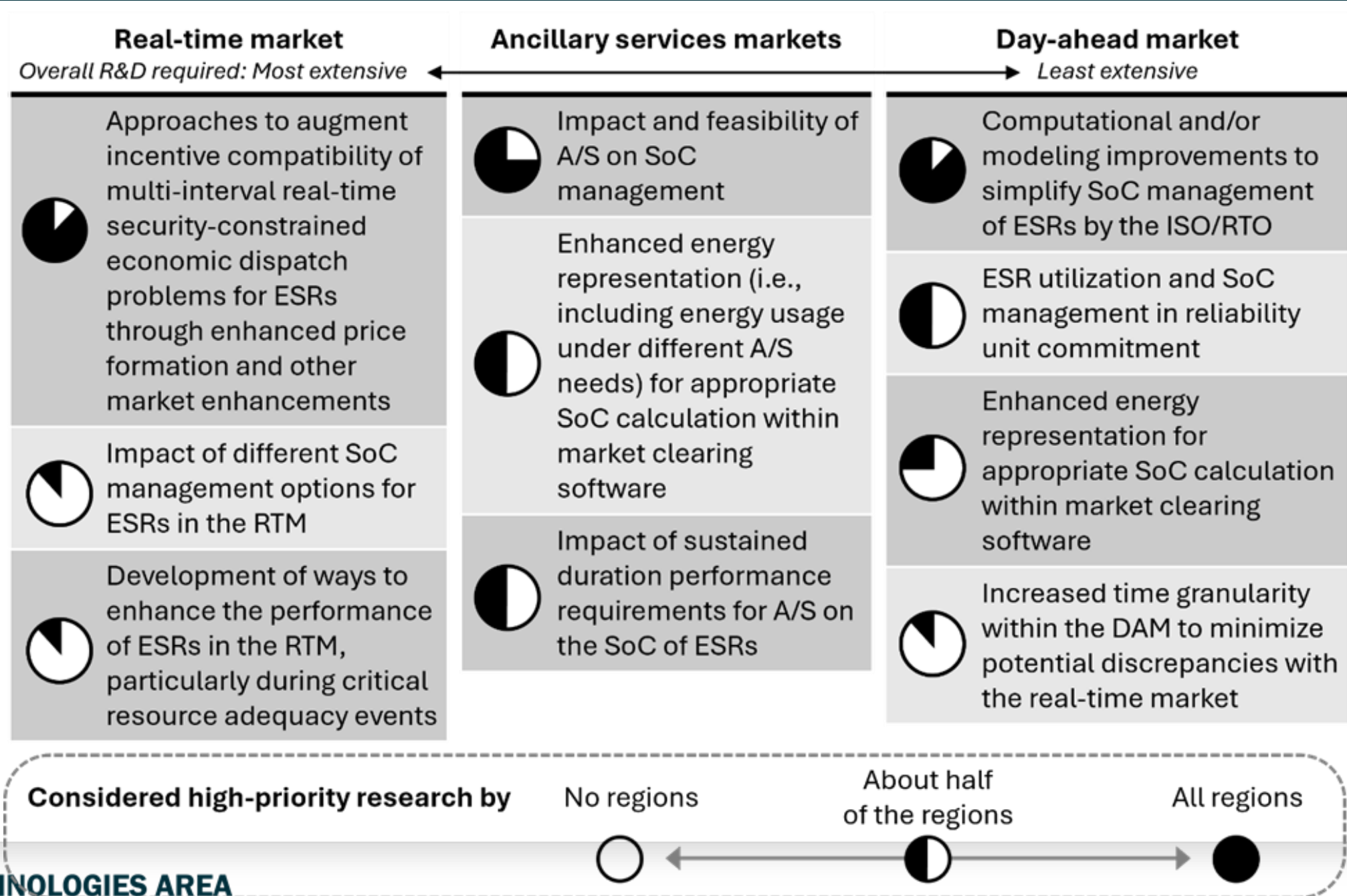
1. Development of approaches to augment incentive compatibility of multi-interval RTSCED problems for ESRs through enhanced price formation and other market enhancements, e.g., temporal LMPs, multi-interval settlements, energy capability product. 2.67
2. Evaluation of the impact of different SoC management options for ESRs in the RTM, e.g., fixed end-of-horizon target SoC level using day-ahead information, end-of-horizon \$/MWh value offer, extended RT horizon, self-managed SoC. 1.00

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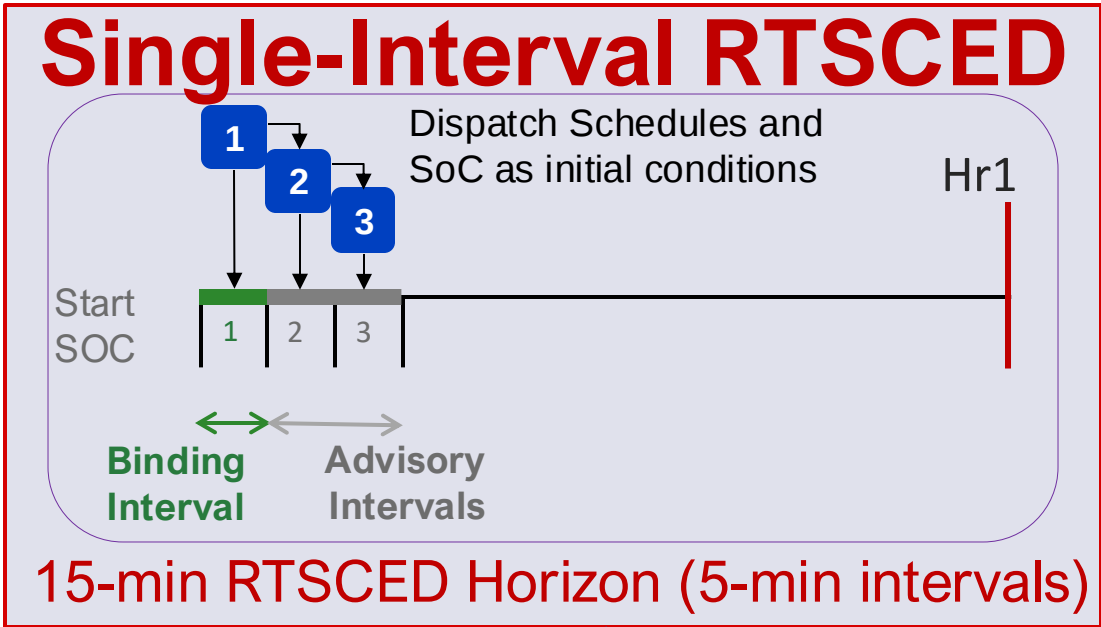
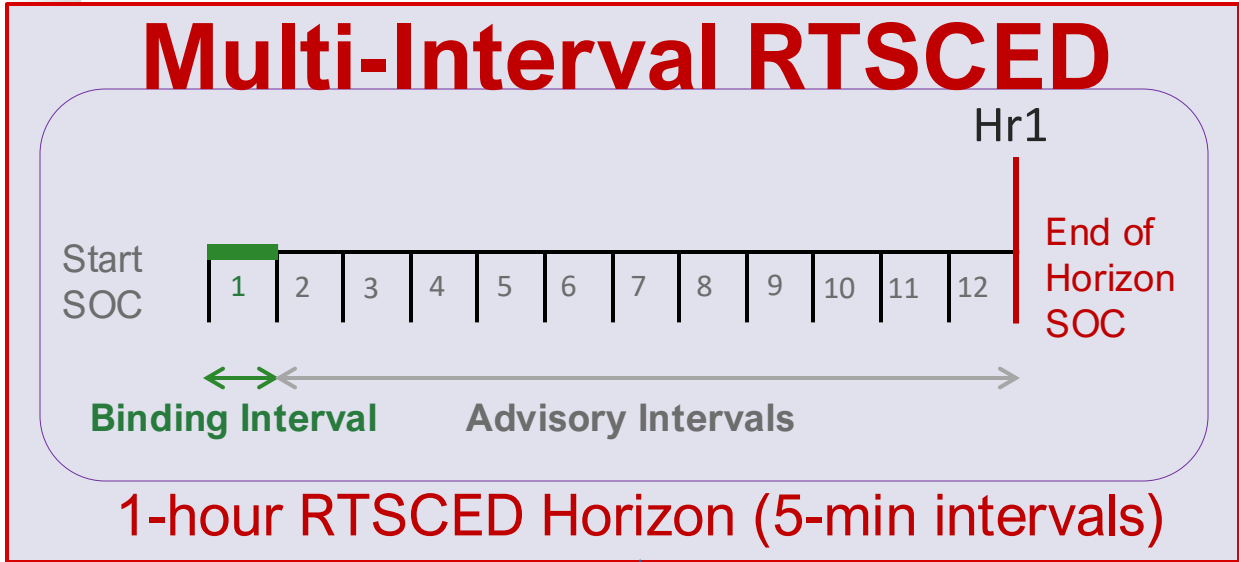


ENERGY TECHNOLOGIES AREA
BERKELEY LAB

Key storage-related modeling challenges facing market operators were identified and prioritized based on industry survey and ISO/RTO engagement



Real-time: Approaches to augment incentive compatibility of multi-interval RTSCED problems



Multi-interval optimization

- *Pros*: Enhance reliability; reduce infeasibilities, price spikes and production costs
- *Cons*: Computational complexity; misalignment of incentives

Single-interval optimization

- *Pros*: Simplicity
- *Cons*: Reduced reliability; increased price spikes, ramp and SoC infeasibilities and operating costs

U.S. ISO/RTO Real-time Market Characteristics

Real-time Scheduling Process	NYISO	PJM	SPP	ISO-NE	MISO	CAISO
Real-time SCED software option	Multi-interval	Single-interval	Single-interval	Single-interval	Single-interval	Multi-interval
Real-time ED optimization horizon	55-65 minutes	10 minutes	5 minutes	15 minutes	10 minutes	35-50 minutes
Real-time dispatch solve frequency and time step	5 minutes					

Note: Scheduling processes have unique characteristics including how frequently they are updated, the time resolution of the interval being evaluated, how far the look-ahead horizon goes forward, and what binding and/or advisory decisions are being made. The differences can be attributed to the characteristics of the resource mix being dispatched, and legacy software and business practices*.

Research Path

3 risks of misrepresenting ESR in RT:

1. Reliability risk due to under-commitment: Long-start generator commitments made day-ahead are based on assumptions of storage SOC.

- Storage RT operations may result in the **inability to supply demand**.

2. System operating cost risk: limited look-ahead window can produce **short-sighted decisions** early in the day that result in greater total production.

3. Pricing and incentive compatibility risks: The advisory nature of RTSCED look-ahead intervals can, at times, make it uneconomic for storage resources to **follow central dispatch decisions**.

Realistic modeling approaches...

- 1) RT without SOC targets (base case)
- with Manual Dispatch for security.
- 2) Individual SOC targets (RT enforcing SOC targets based on DA solution).
- 3) System SOC target: The system would have a total SOC target guiding the sum of SOC available across all ESRs.

Work starting in Year 2



Implement and compare these approaches in terms of computational burden, load-shedding events, need for manual exceptional dispatch, and economic efficiency.

Open-source the implementation so that CAISO's platform vendor can implement them.

Team and Year 1 Report



J. Kemp



A. Moreira



Grid Integration Group
Energy Storage & Distributed Resources Division

Navigating modeling frontiers for electric storage resources in wholesale electricity markets

Nikita Singhal¹, Alexandre Moreira, Julie Mulvaney Kemp, Erik Ela¹,
Miguel Heleno

¹Electric Power Research Institute

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Read our Report:

<https://eta-publications.lbl.gov/publications/navigating-modeling-frontiers>

Thank you