Integration of Electric Storage Resources

Value of ESRs in providing grid services

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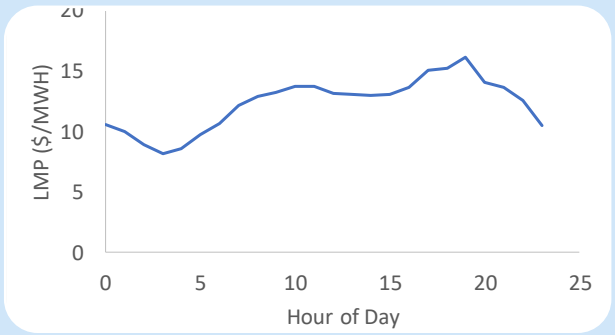
Electric Storage Resource (ESR) Services and Contributions

- Installed capacity to ensure adequacy
- Energy arbitrage
- Flexibility and rapid response
- Operating reserve & other reliability services
- T & D congestion management and deferral

Key Challenges to value of ESRs as a flexibility resource

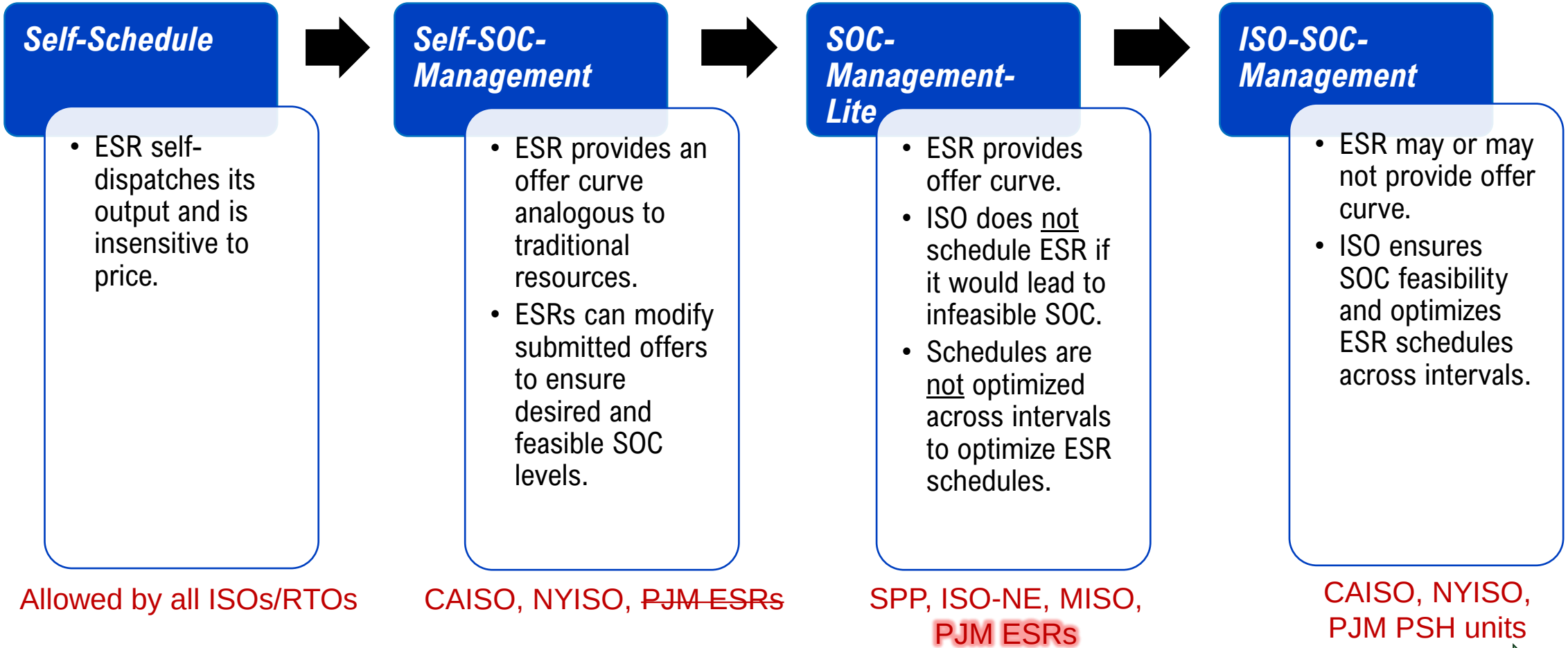


Flat Energy prices/costs limit arbitrage benefits

Key Challenges to value of ESRs as a flexibility resource

- State of charge management
- Limited by real-time scheduling horizons
- Degradation impacts and costs
- EMS/MMS software intricacies

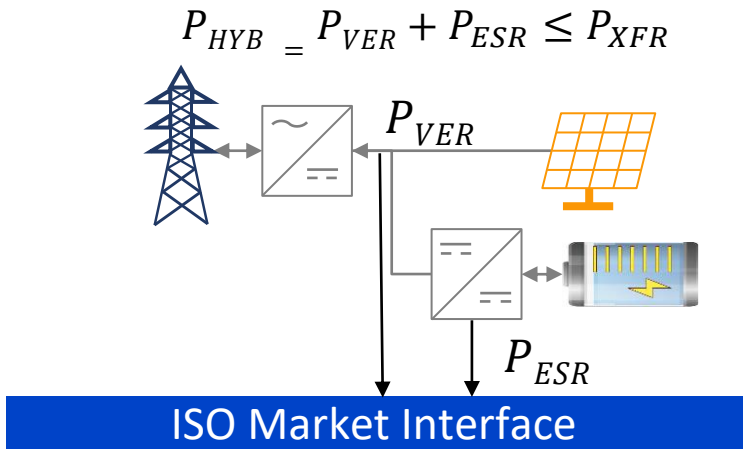
State of Charge Management: Options



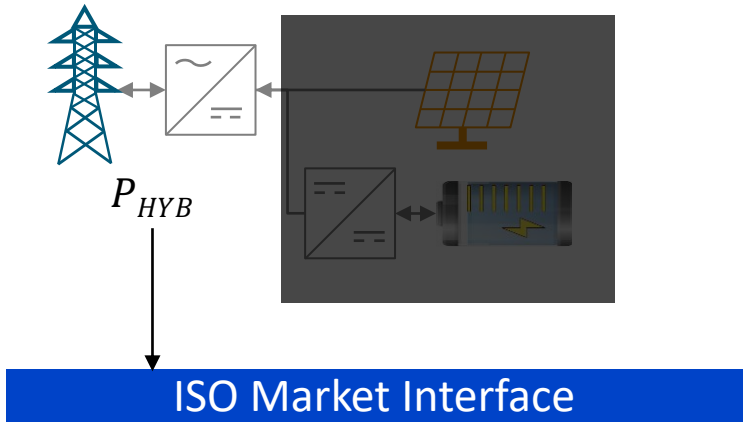
Hybrid Storage/VER Market Modeling Options

Option 1: Separate Independent Resources

Separately represent each resource, with minimal changes to existing market designs



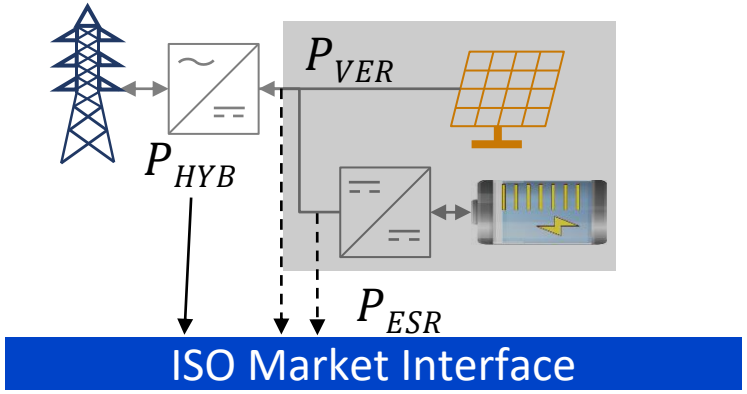
Option 2: Single Hybrid Resource, Self-Management



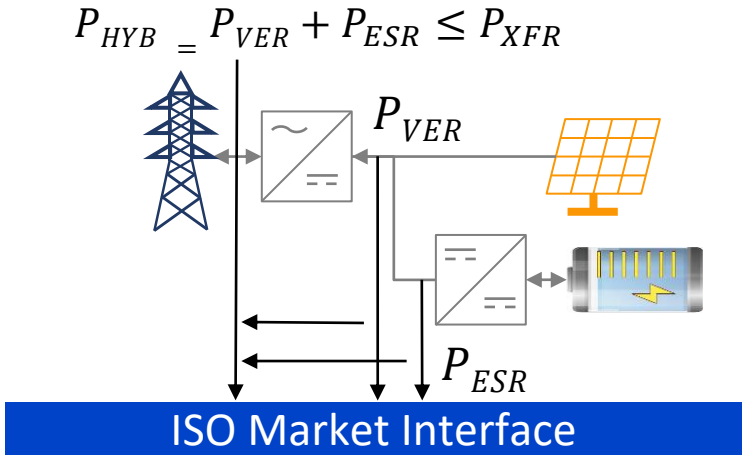
Single offers and operating parameters allows participant bidding strategy flexibility

Option 3: Single Hybrid Resource, ISO-Managed Feasibility

Add telemetry requirements to allow ISO to limit infeasible schedules



Option 4: Separate Resources, Linked



Add linking constraint to increase ability to operate resource in combined fashion

*figure illustrates dc-coupled strategy for demonstration purposes

Storage as a Capacity Resource

Increasing Penalties for Unavailability

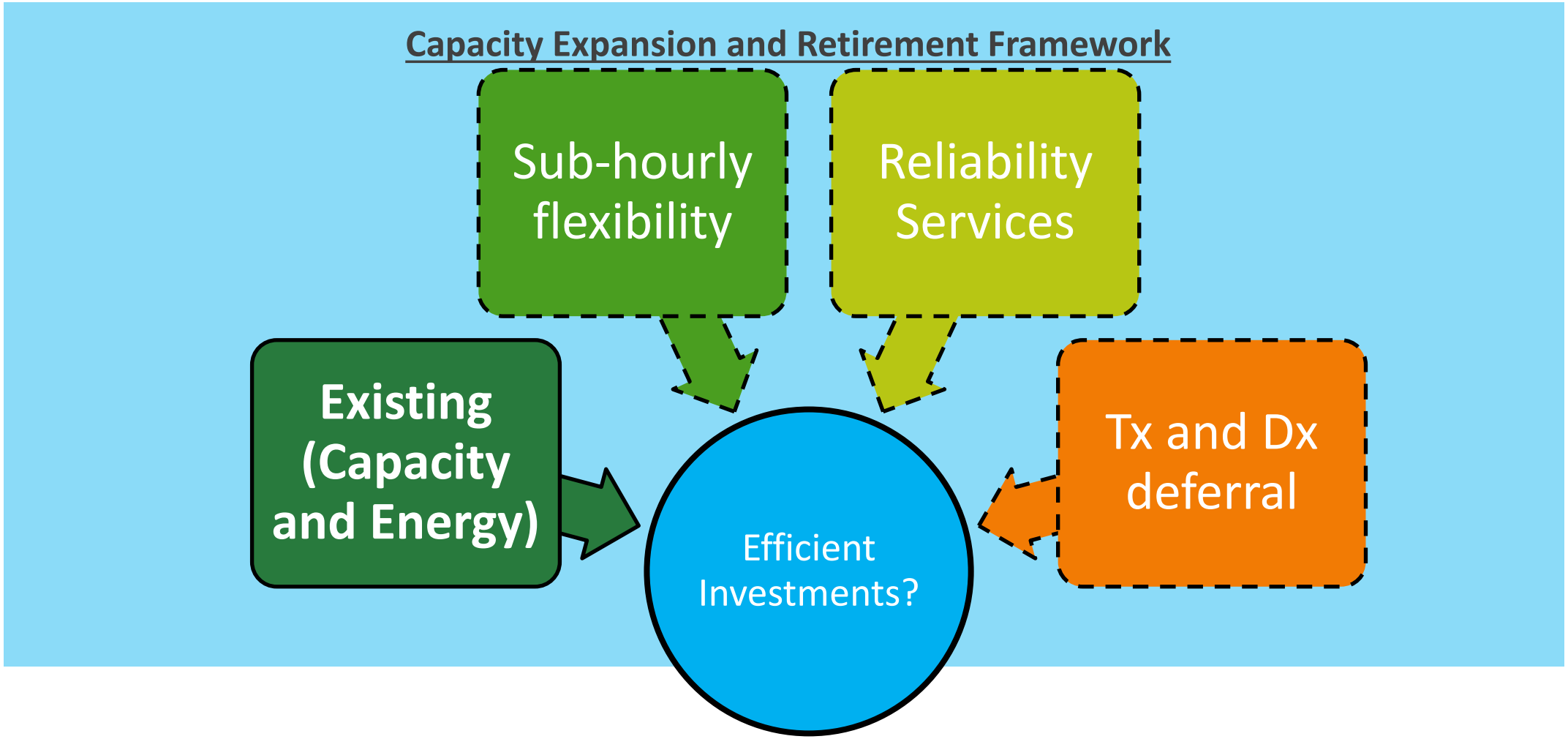
Increasing Duration

Duration	No Penalty	1000 $/ MWh Penalty	$5000 / MWh Penalty	$9000 / MWh Penalty
1 hr	32-42%	81-83%	89-91%	92%
2 hr	60-67%	89-95%	96%	98%
4 hr	81-92%	100%	100%	100%
6 hr	95-97%	100%	100%	100%
8 hr	95-100%	100%	100%	100%

Lannoye et al, *Energy Storage Capacity Value Estimation,* EPRI, Palo Alto, CA: 2019. 3002013491.

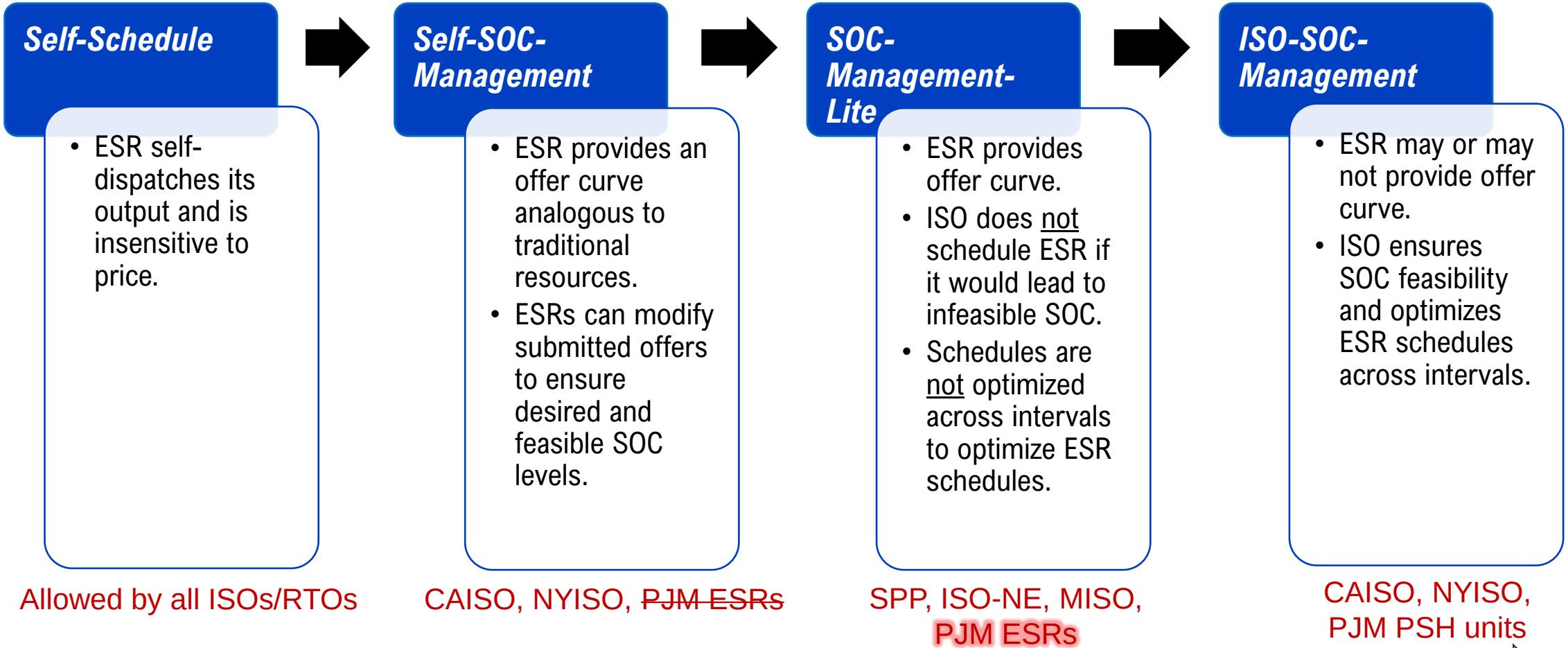
Value of storage for meeting peak also varies by system and storage penetration

Key Challenge: Emerging Technologies and Resource Investment Frameworks



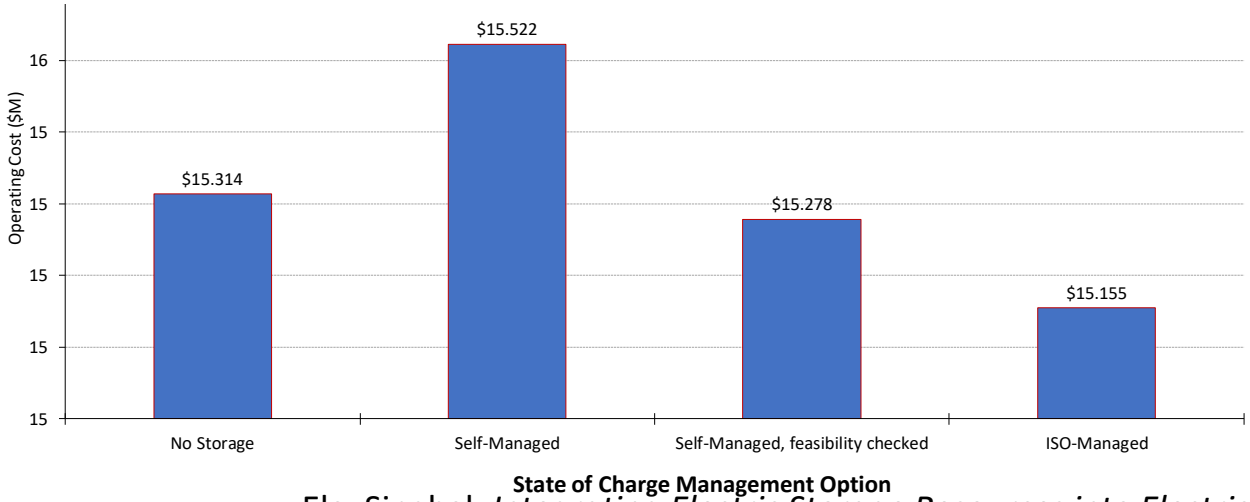
New features not currently part of expansion processes (i.e., for Integrated Resource Plans) may need to be considered.

State of Charge Management: Options

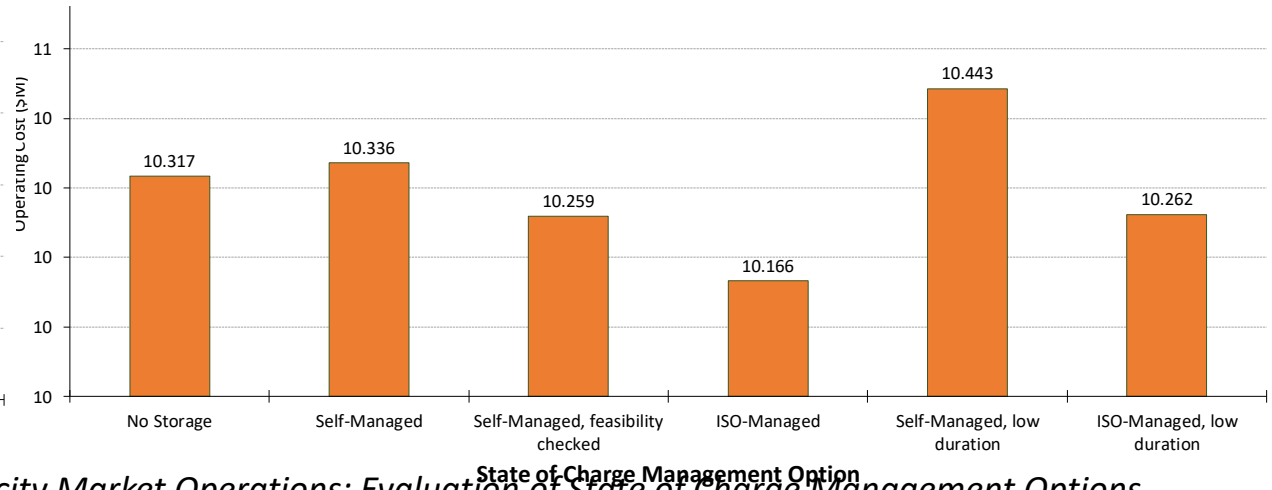


Operation and Market design

Low Renewable Scenario



High Renewable Scenario

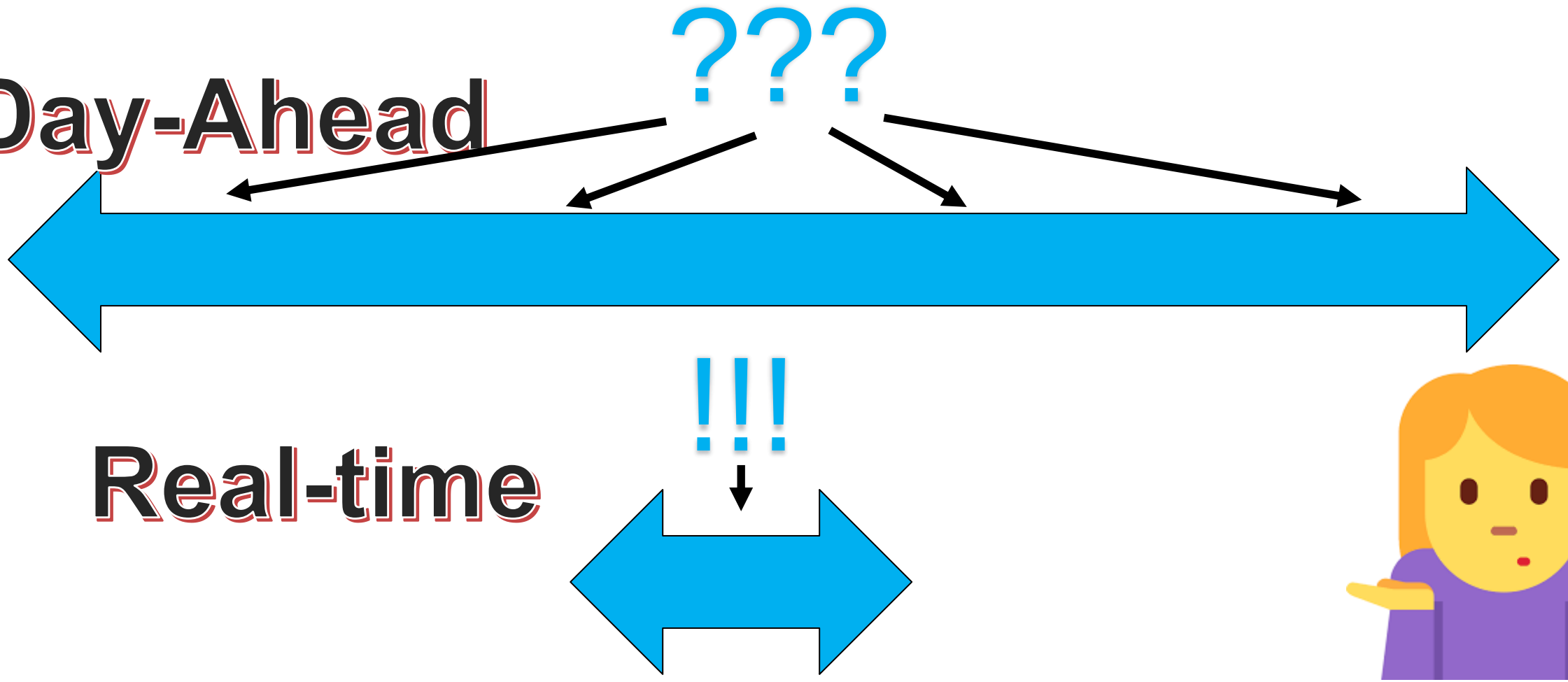


Ela, Singhal, *Integrating Electric Storage Resources into Electricity Market Operations: Evaluation of State of Charge Management Options,* EPRI, Palo Alto, CA: 2019. 3002013868.

- ✓ Self-management found to *increase* costs when storage deployed
- ✓ *Greatest* cost reduction and profits observed when ISO manages state of charge and optimizes to lower costs
- ✓ Self-management still benefits efficiency if feasibility checked, allowing *greater flexibility* for participant
- ✓ Challenges may be *exacerbated* by duration of storage, amount of storage, and amount of renewables

The way electric storage is operated and how it participates within the market may have a substantial impact on the magnitude of benefits it provides to the system.

The Storage Forecast Dilemma



Lots of data, but potentially "bad data" vs. Good data, but not much of it…