DOE-OE Energy Storage Technology Advancement Partnership (ESTAP) Webinar

State of the US Energy Storage Industry: 2021 Year in Review

February 24, 2022

U.S. DEPARTMENT OF ENERGY

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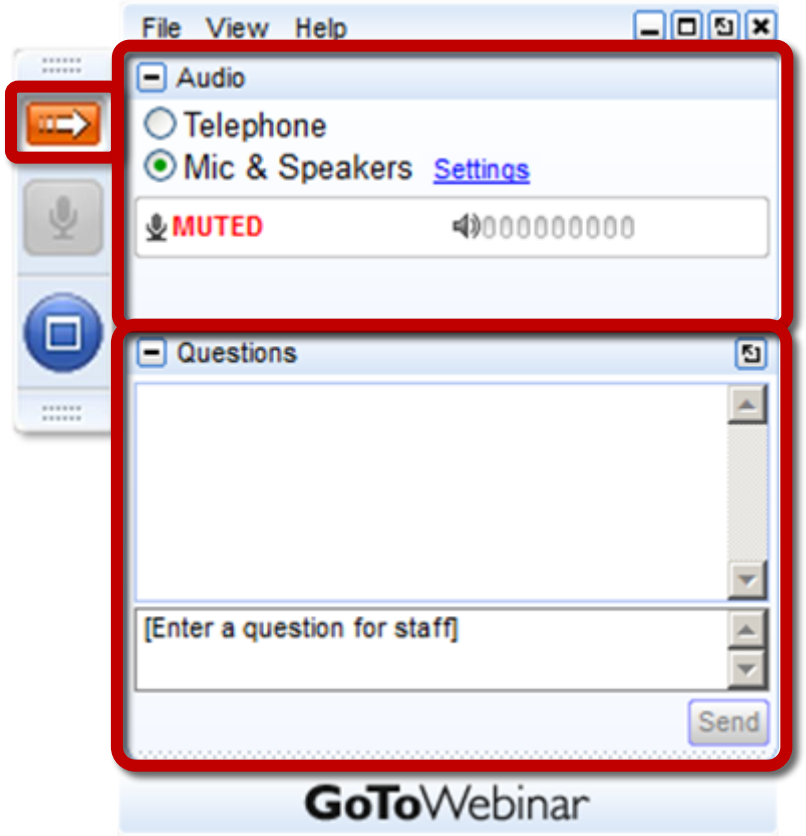
Webinar Logistics



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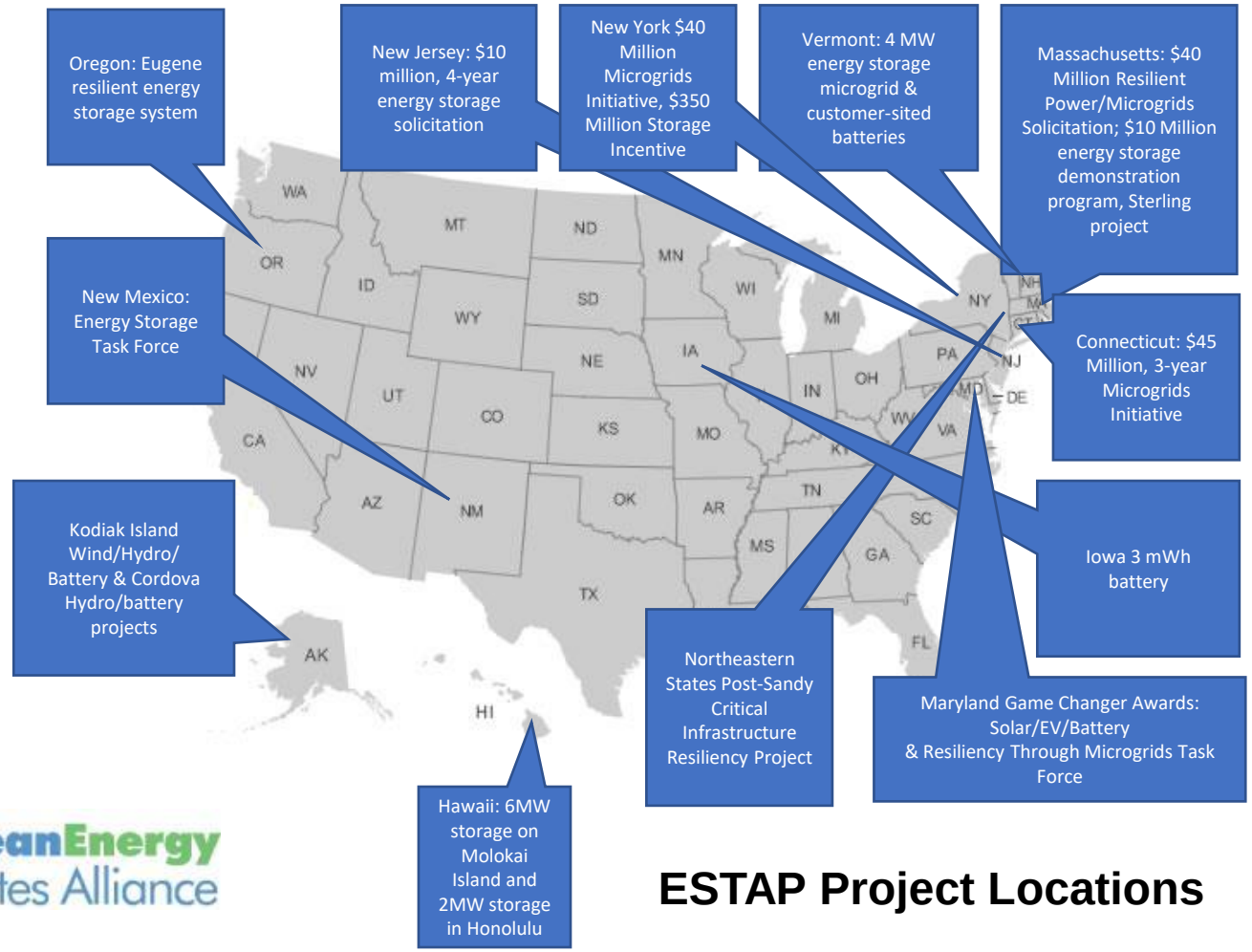
DOE-OE Energy Storage Technology Advancement Partnership

The Energy Storage Technology Advancement Partnership (ESTAP) is a US DOE-OE funded federal/state partnership project conducted under contract with Sandia National Laboratories.

ESTAP Key Activities:

1. Facilitate public/private partnerships to support joint federal/state energy storage demonstration project deployment
2. Disseminate information to stakeholders
   - ESTAP listserv >5,000 members
   - Webinars, conferences, information updates, surveys.
3. Support state energy storage efforts with technical, policy and program assistance



ESTAP Project Locations

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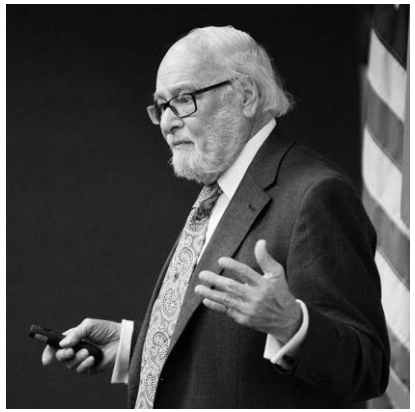
Thank You!



Dr. Imre Gyuk
Director, Energy Storage Research,
U.S. Department of Energy

Dan Borneo
Engineering Project/Program Lead,
Sandia National Laboratories

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Webinar Speakers

- **Dr. Imre Gyuk**, Director, Energy Storage Research, DOE Office of Electricity
- **John Fernandes**, Senior Consultant – Emerging Technologies, Customized Energy Solutions
- **Val Stori**, Project Director, Clean Energy States Alliance (moderator)

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The Company

Established in 1998, **Customized Energy Solutions (CES)** is a consulting and services company that assists clients in managing and staying ahead of the changes in the wholesale and retail electricity and natural gas markets. Serving hundreds of clients, Customized Energy Solutions offers best-in-class hosted energy market operations platforms and a wide spectrum of consulting services. CES is committed to promoting economic development through the advancement of transparent, efficient, and non-discriminatory wholesale and retail electricity and natural gas markets.

Presence

Headquartered
Philadelphia, PA

Over 200 Associates across 9 Regional offices in United States, Canada, India, Japan & Mexico. We support clients in all 7 US ISOs and RTOs

Resources

>11000 MW assets under Active Management

>300 MW Energy Storage assets under Management

Awards and Recognitions

Inc. 5000 – Eleven Time Honoree, Philadelphia 100 - 2001, 2004 – 2012, 2019
Best Places to work: 2014, 2016

2016 Energy Storage Association Brad Roberts Award Winner

Clients

500+ Clients Worldwide

Our consulting services enables competitive suppliers, technology providers, marketers, utilities and customers to prosper through change, by turning knowledge into value

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CES Business Lines

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- Scheduling
- Monitoring
- Bidding
- Telemetry
- Settlements
- 24 Hour Desk
- Market Optimization
- DA / RT Strategies

CES|GOLD

- Congestion Management
- ARR Analysis
- FTR Analysis
- Congestion Analysis
- Power Flow Studies

Retail Services

- Market Entry
- EDI/Billing
- Forecasting
- Scheduling
- Settlements
- Pricing
- Headroom Analysis
- Managed Portfolio Services

CES|BLUE

- Renewable Management
- RPS Management
- Plant Registration
- REC Optimization
- Compliance

Market Intelligence

- Comprehensive Markets Coverage
- ISO Rules & Reporting
- Market Rule Changes
- Regulatory Proceedings

CES | MARKETIQ

pjm · ISO new england · ISO NEW YORK INDEPENDENT SYSTEM OPERATOR · SPP Southwest Power Pool · California ISO · ercot · MISO · ieso

Future Grid

Distributed Market Integration

- Market Rules and Entry
- Market Integration Consulting
- Revenue Modeling
- Telemetry & Resource Registrations
- Market Operations
- Scheduling, Dispatch and Control

CES|GREEN

- Demand Response Mgmt
- GridBOOST
- SecureNet
- Tracking
- Settlement

Emerging Technologies

- Policy Tracking and Engagement
- Storage Revenue Modeling
- CoMETS Valuation Models
- Bid Advisory Services
- Energy Market Forecasts
- Market Sizing, Entry, Strategy
- Technology Due Diligence
- Financial Services
- Microgrids

CES | StorageIQ

CES' business lines support market participants from conceptualization to operations

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CES Emerging Technologies

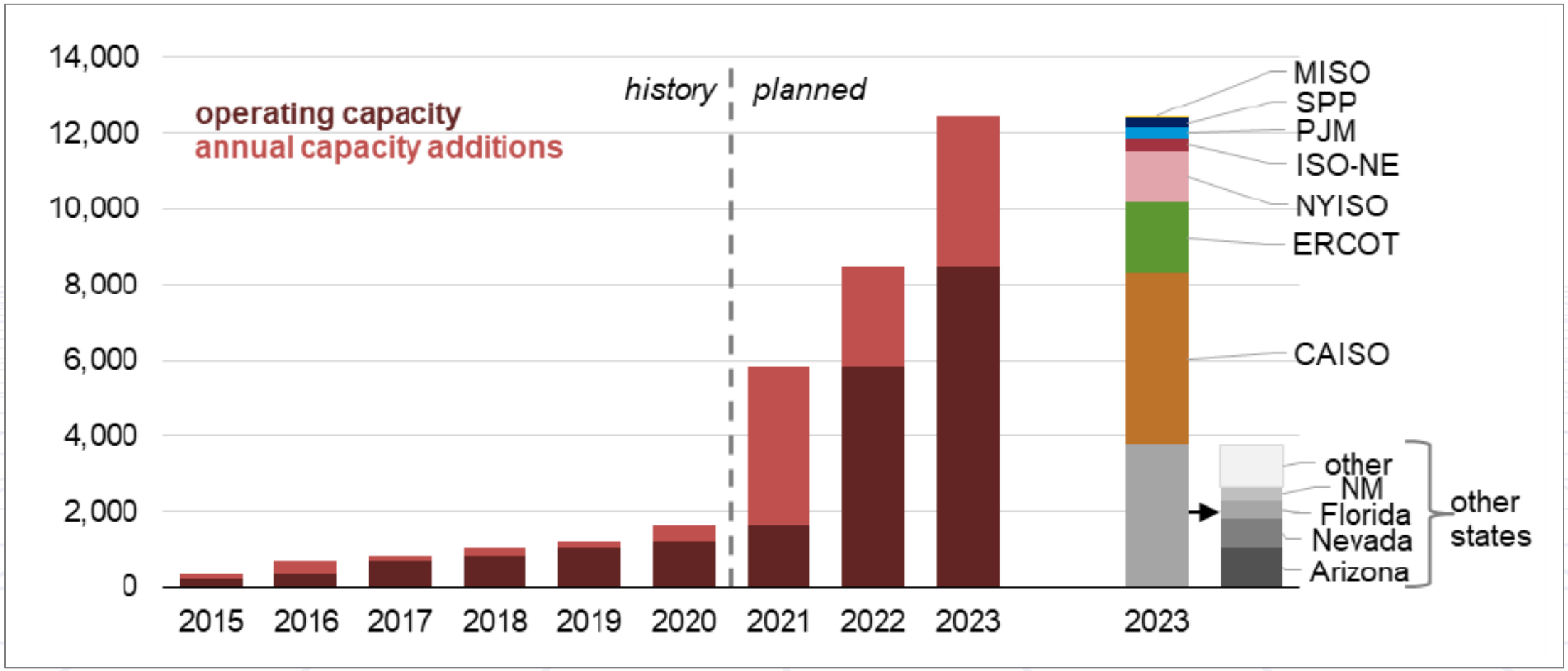
CES Emerging Technologies practice offers a range of consulting, software and services around Energy Storage Systems (ESS), their technology and market applications, to help project developers, investors, technology companies and other clients understand the evolving market rules and the value proposition of new technologies

Market Advisory Services	*Our market advisory services help clients understand energy market opportunities, developments and policies*	Market Overview	Bid Advisory	Policy Support
		Market Forecast	StorageIQ	Trainings
Financial Services	*Our financial services help clients understand Business trends, estimate revenues and cash Flows, optimize investments and abate risks*	Financial Modeling	Risk Analysis	
		Due Diligence	Investment Advisory	
Software Services	*Our software services and analytical tools help clients simulate dispatch of energy storage projects and make critical investment decisions*	CoMETS	Behind-the-Meter	Microgrid
		In-Front of the Meter	RE Integrated Layouts	Bespoke Solutions
Strategy Consulting	*Our strategy consulting services help clients successfully enter and navigate the energy storage market to achieve key objectives*	Market Potential	Market Entry	
		Investor Search	Business Accelerators	

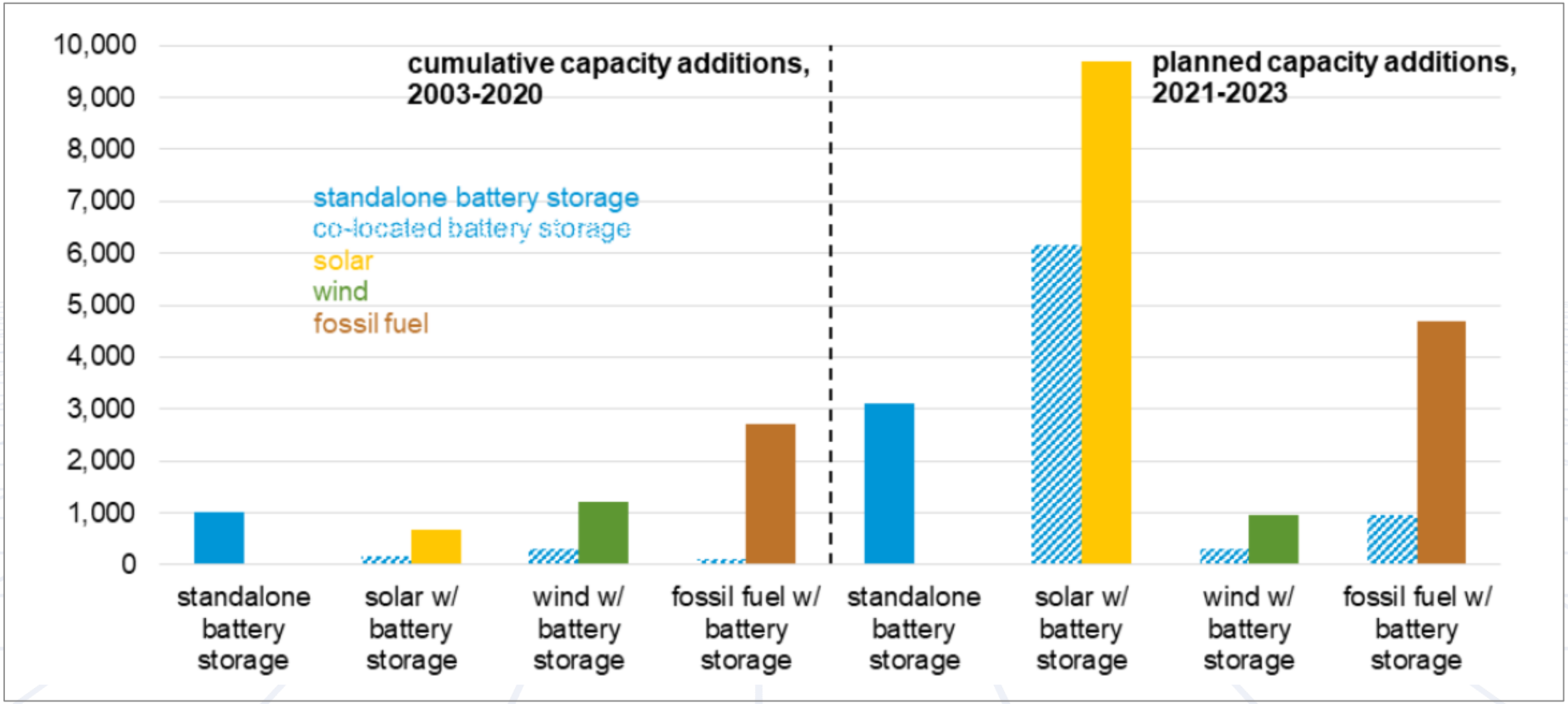
Backed by our practical experience of running day-to-day operations of over 300 MW of energy storage facilities in competitive markets, our team brings unparalleled value to customers via our consulting services

Industry Trends

Large-Scale Storage Cumulative Capacity



Large-Scale Storage Cumulative Capacity



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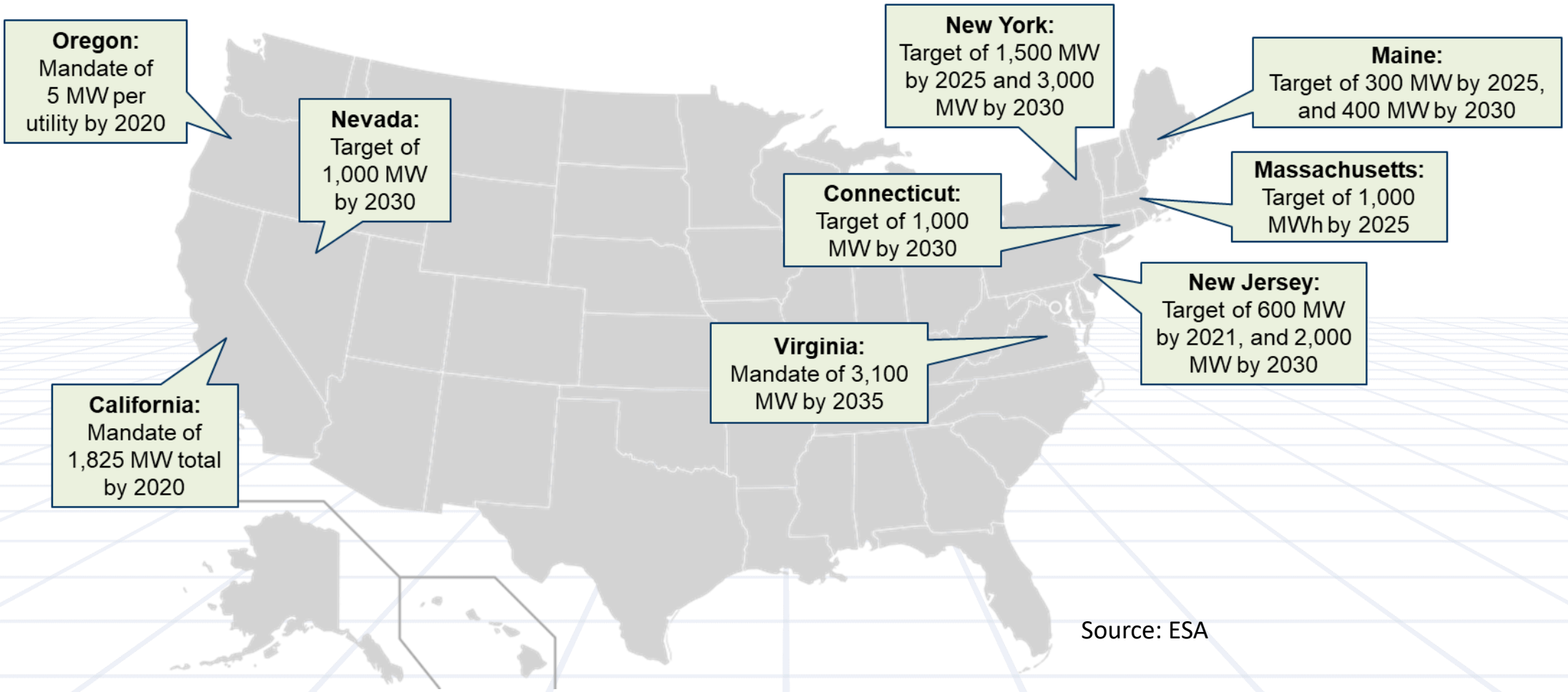
State Targets and Mandates



Source: ESA

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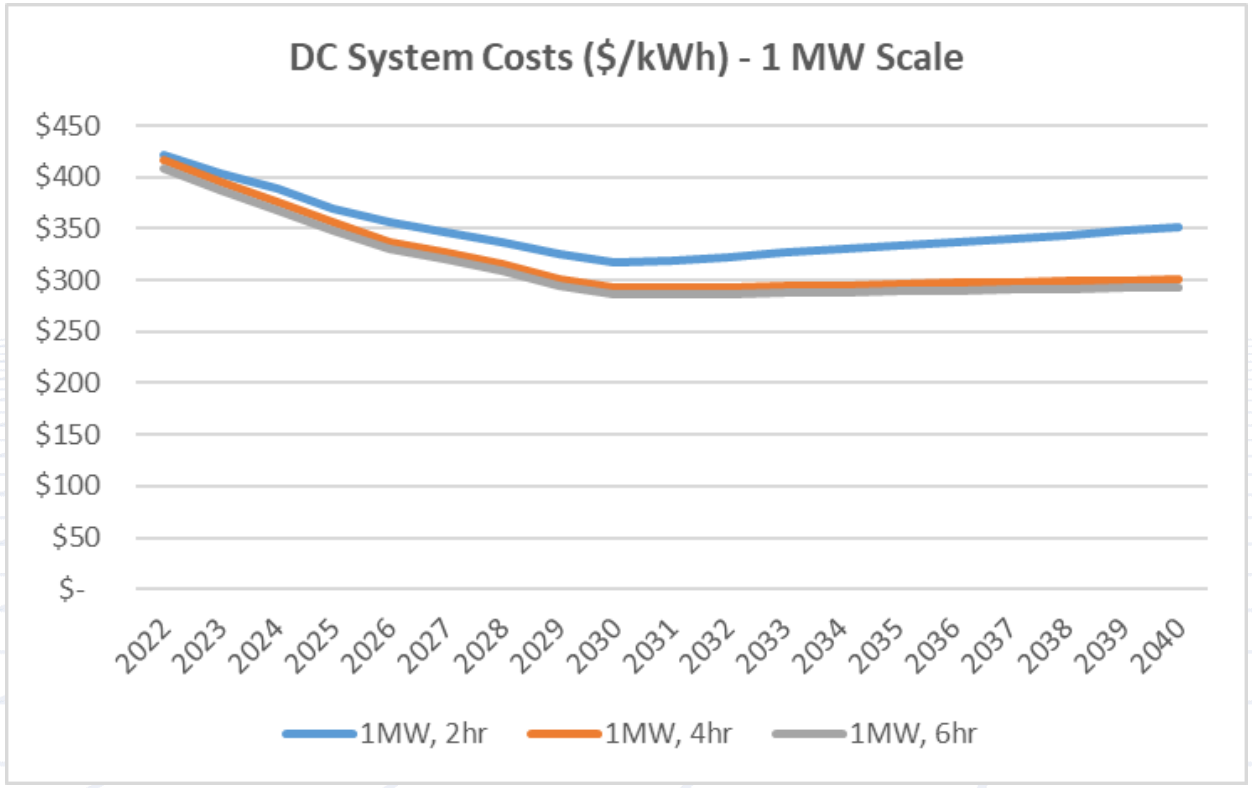
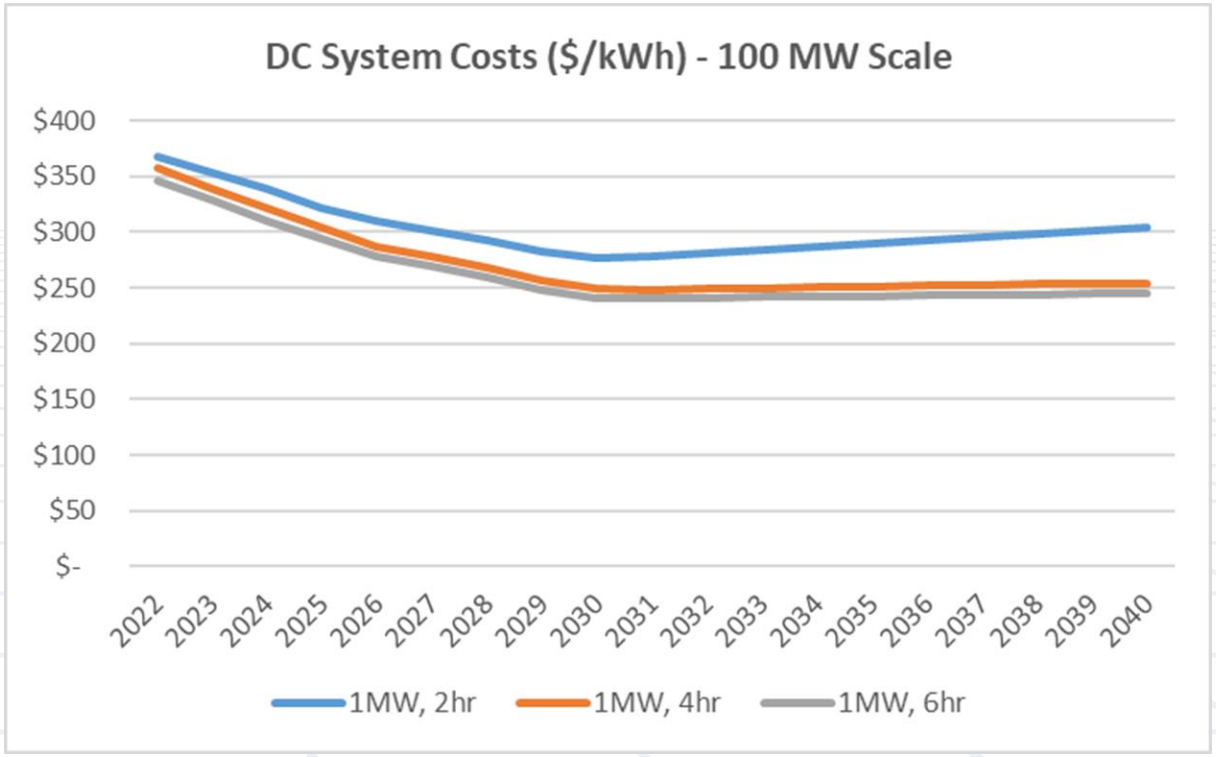
Battery Cost Curves





Market Trends: Hybrid Storage

Is it worth adding storage?

Sizing Decisions

- PV: Oversize the array vs. not oversizing the array
- Battery: Hi-power/short duration battery vs. low-power/long duration battery
- Should the solar + storage MWs be larger or equal to the point-of-interconnection (POI)
- Build upfront vs. scale storage capacity in the future
- Supply more Capacity or not, and if so, how much

Configuration Decisions

- Hybrid vs. Co-located & AC vs. DC-coupling
- Solar ITC for storage vs. waiting for a standalone storage ITC
- Charge from the grid vs. no grid charging

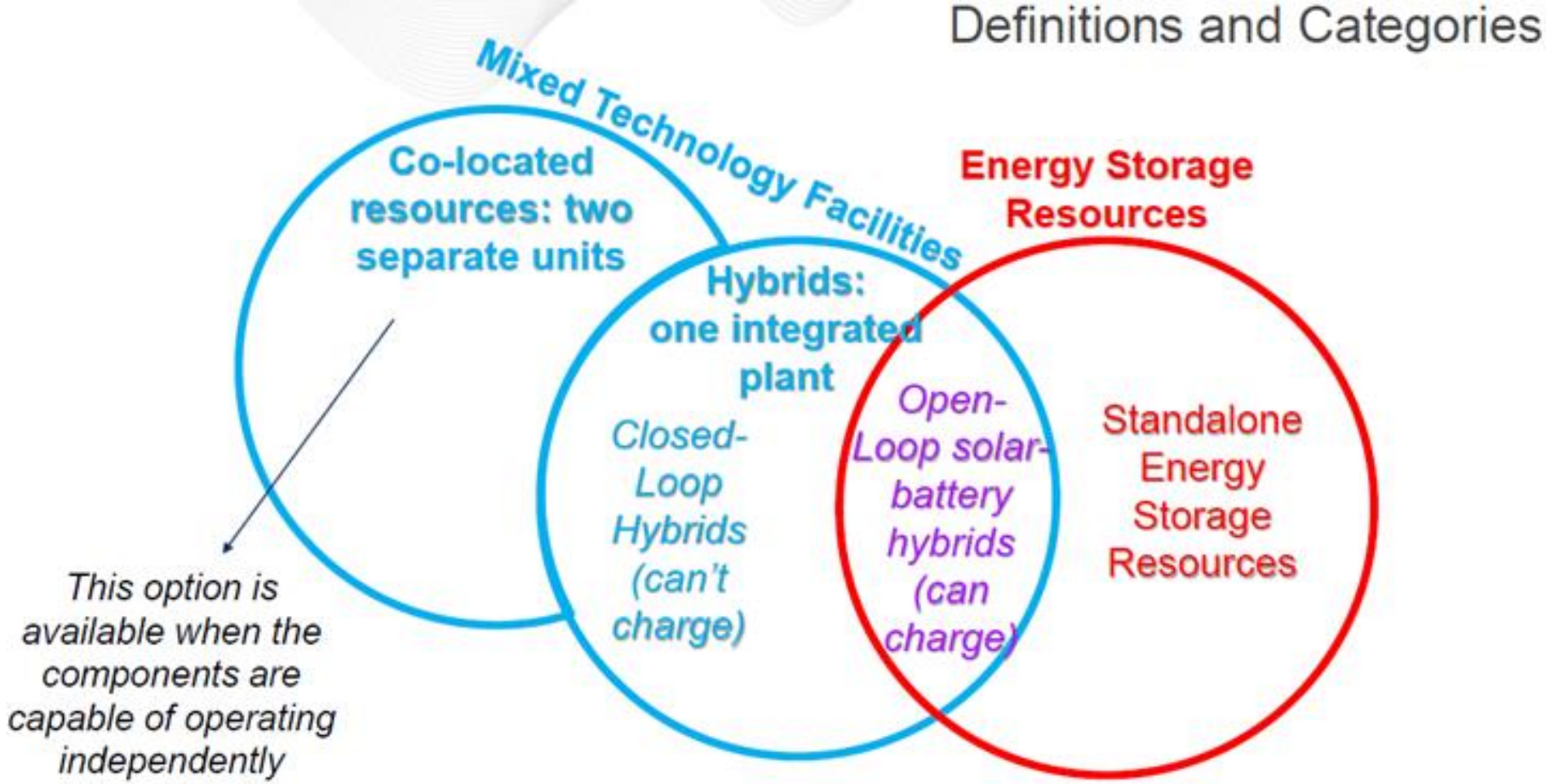
Merchant Operational Decisions

- Energy arbitrage (buy low, sell high) vs. provide Ancillary Services (high-cycling)
- What grid services to bid and when?
- What bidding strategy and automation maximizes revenue?

Hybrids in ERCOT

- NPRR 1029 – DC Coupled Resources
  - A DC-Coupled Resource shall be treated in the same manner as an ESR for Deviation Charges and Deployment Performance when
    - The resources was awarded AS
    - The instantaneous MW Injection or Withdrawal includes non-zero MW from the storage component
    - The HSL or LSL includes the storage capability
  - At all other times, a DC-Coupled Resource shall be treated as an IRR
  - A QSE representing a DC-Coupled Resource may override the COP HSL value with a value that is lower than the ERCOT-populated value, and may override with a value that is higher than the ERCOT-populated value if the ESS component of the DC-Coupled Resource can support the higher value
- NPRR 1026 - Self-Limiting Facilities
  - QSEs shall be responsible for limiting their combined COP HSL and LSL, telemetered HSL and LSL, and total generation exports into or withdrawals from the ERCOT grid in order to avoid exceeding their IA Pmax or operating below their Pmin

Mixed Technology Facilities in PJM



CAISO: Active Rule Development

- **Hybrid** resources are configured with a single resource ID with mixed technology components behind a single Point of Interconnection (POI)
  - Single bid curve for overall resource, allows/requires resource scheduling coordinator to optimize underlying components to meet CAISO awards and dispatch
- **Co-Located** resources are configured with two or more resource IDs behind a single POI
  - Each resource is modeled individually, submits bids independently, and is awarded and settled separately
- New provisions for managing hybrid resources allow hybrid resources to provide ancillary services and enables hybrid resources to communicate their generation availability in real-time through new functionality
  - Proposal allows for updates to hybrid availability in real-time market on five-minute basis to ensure feasible market awards and dispatch
- For hybrid resources that are not providing ancillary services, the CAISO will not require separate metering and telemetry requirements for each underlying component of a hybrid resource, but only the renewable resource component(s)

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Hybrid Storage Telemetry (ERCOT)

Telemetry item	Units	Comments
Gross Megawatts	MW	Gross MW injection measured on AC side of shared/common DC-coupled Resource inverter. Gross MW >= 0
Net Megawatts	MW	Net MW from GR injected as measured at POI.. Net MW >= 0
Gross Megavars	MVar	Gross MVar from GR (positive or negative) measured on AC side of shared/common DC-coupled Resource inverter.
Net Megavars	MW	Net MVar from GR (positive or negative) as measured at POI.
Resource Status	state	
Normal Ramp Rates (Up and Down)	MW/Min	
Emergency Ramp Rates (Up and Down)	MW/Min	
High and Low Emergency Limit (HEL, LEL)	MW	
High and Low Sustained Limit (HSL, LSL)	MW	
AS Qualifications (Reg-Up, Reg-Dn, RRS-PFR, RRS-FFR, ECRS, Non-Spin)	MW	
Regulation Participation Factors (Up and Down)	number	
AS Schedules (RRS-PFR, RRS-FFR, ECRS, Non-Spin)	MW	Per Nodal Protocols, Guides or Other Binding Documents applicable to a Generation Resource that is part of a combo-model ESR
Raise/Lower Block Status	Flag	
Voltage Regulator	Flag	
Power System Stabilizer	Flag	
Station: Breaker/Switch Status for AC equipment	Open/Close	
Station: Branch flows for AC equipment	MW,MVAr	
Station: Transformer tap position	Flag (open/close)	
Station: Reactor/Capacitor banks status	Flag (energized/de-energized)	

Hybrid Injection

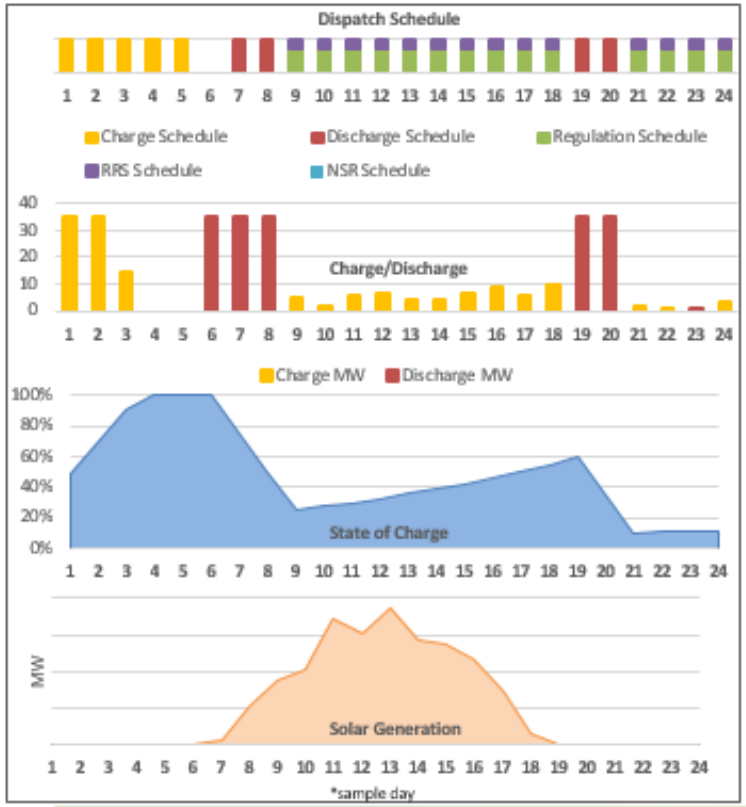
Telemetry item	Units	Comments
Net Load Megawatts	MW	Net MW withdrawal (charge) of CLR as measured at POI. Net MW >= 0
Net Megavars	MW	Net MVar from CLR (positive or negative) as measured at POI.
Resource Status	state	
Normal Ramp Rates (Up and Down)	MW/Min	
Emergency Ramp Rates (Up and Down)	MW/Min	
High and Low Emergency Limit (HEL, LEL)	MW	
High and Low Sustained Limit (HSL/MPC, LSL/LPC)	MW	
AS Responsibilities (RegUp, RegDn, RRS-PFR, RRS-FFR, ECRS, Non-Spin)	MW	
Regulation Participation Factors (Up and Down)	number	
AS Schedules (RRS-PFR, RRS-FFR, ECRS, Non-Spin)	MW	Per Nodal Protocols, Guides or Other Binding Documents applicable to a CLR that is part of a combo-model ESR
Raise/Lower Block Status	Flag	
Voltage Regulator	Flag	
Power System Stabilizer	Flag	
Station: Breaker/Switch Status for AC equipment	Open/Close	
Station: Branch flows for AC equipment	MW,MVAr	
Station: Transformer tap position	Flag (open/close)	
Station: Reactor/Capacitor banks status	Flag (energized/de-energized)	

Storage Withdrawal

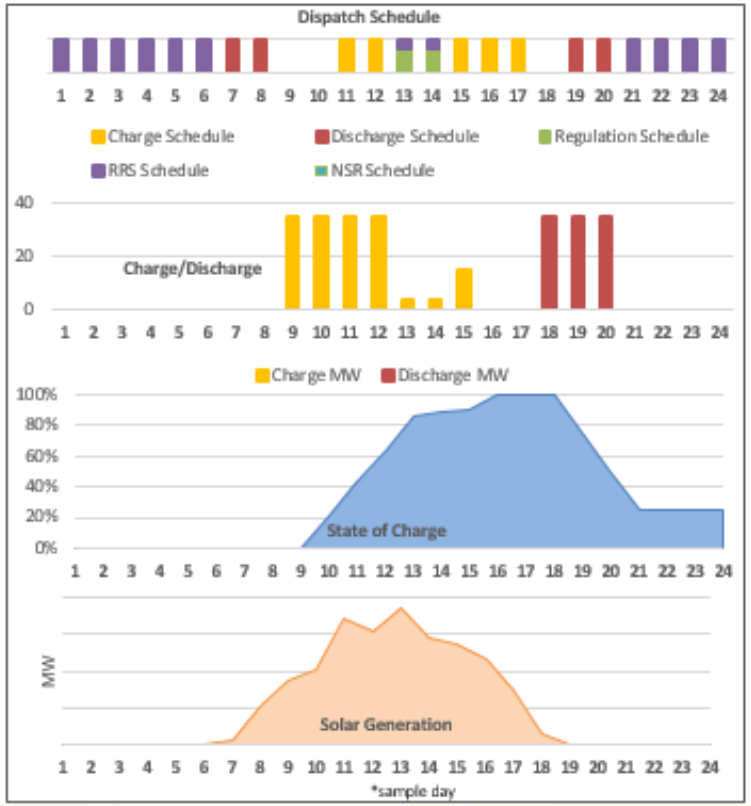
Hybrid Project Optimization

BESS providing Energy Arbitrage, Frequency Regulation (FRS) and Spinning Reserve (RRS) Services to the ERCOT Market

BESS Coupled with Grid

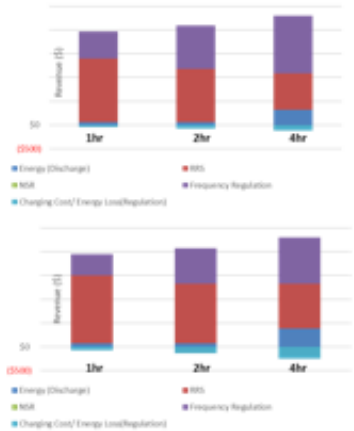


BESS Coupled without Grid



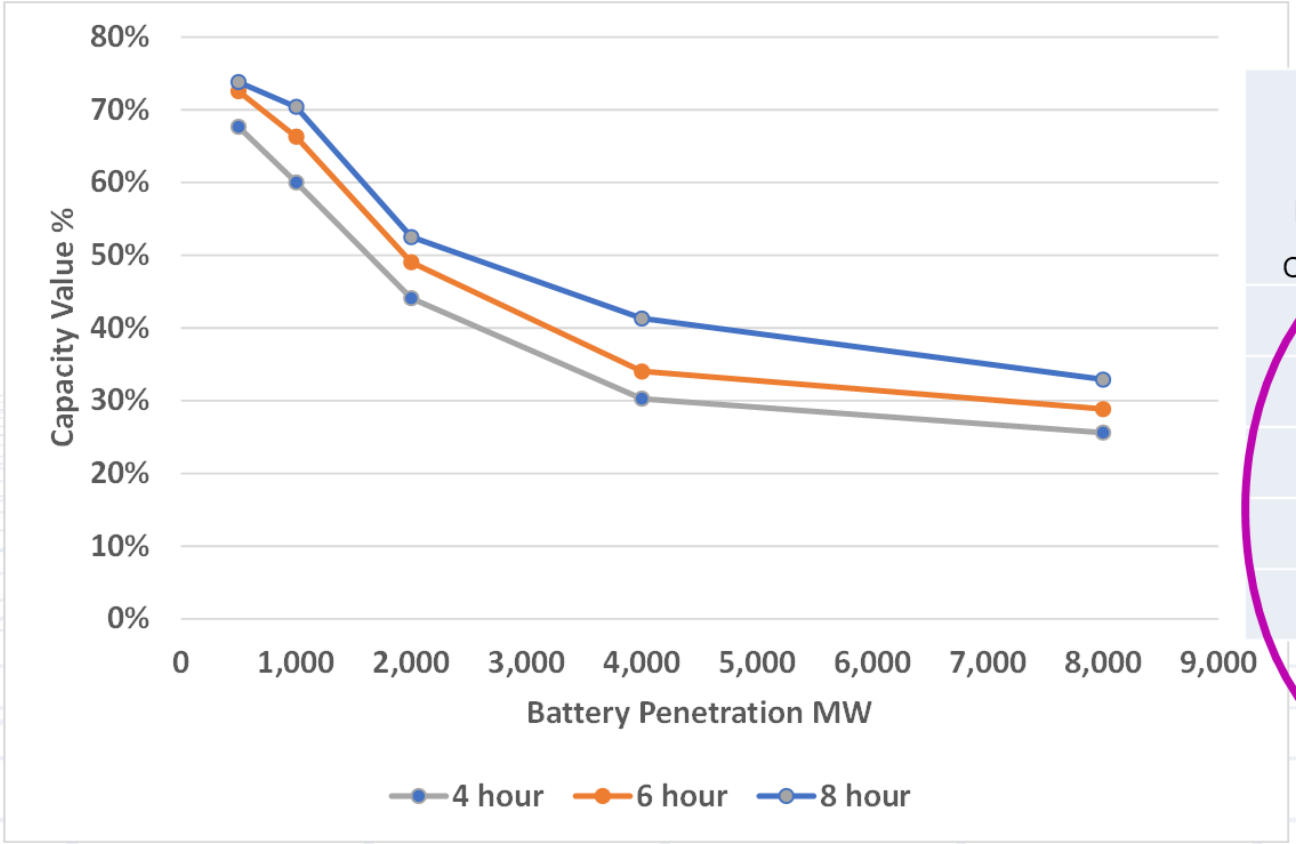
Factors Influencing BESS Dispatch

- Availability of RE generation
- PPA commitments, hedging contracts
- BESS sizing, reserve capacity
- Opportunity Costs of RE Generation
- Market participation rules
- Selection of services
- State of Charge Management
- Battery Degradation and Cycling
- Provision of multiple services in the same market hour
- Value Stacking



Market Trends: Storage Accreditation

ELCC in SPP

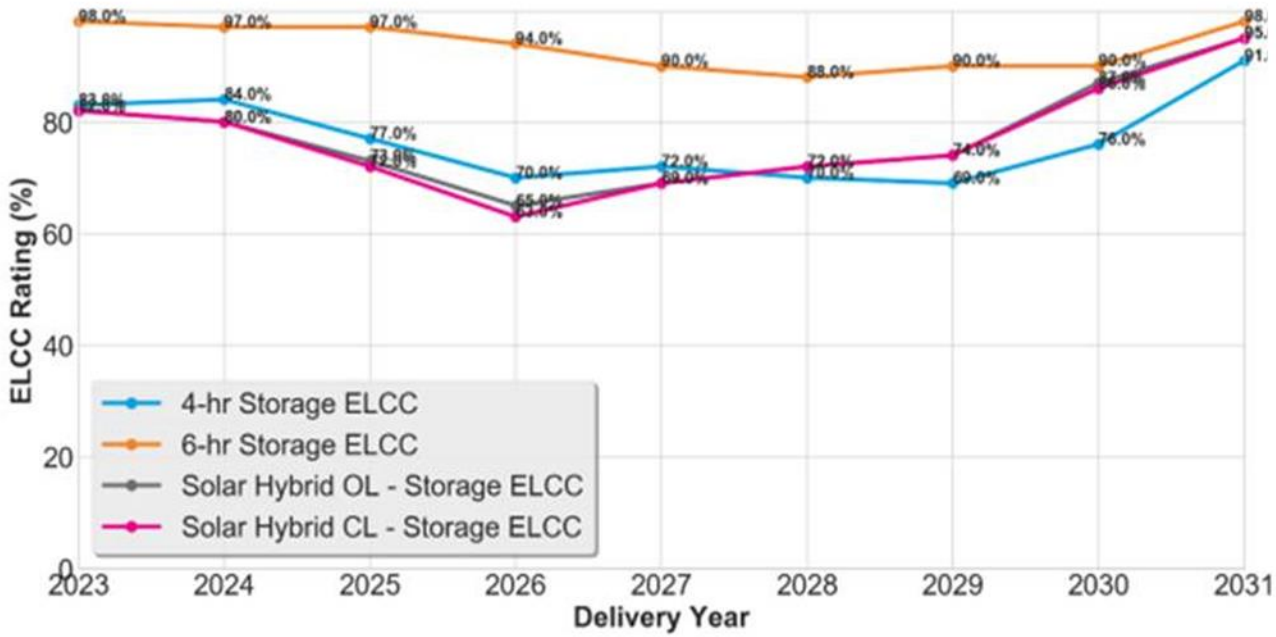


Battery Capacity	4-hour Economic Arbitrage	6-hour Economic Arbitrage	8-hour Economic Arbitrage
500	68%	73%	74%
1,000	60%	66%	70%
2,000	44%	49%	53%
4,000	30%	34%	41%
8,000	26%	29%	33%

* Astrape results from the 2021 LOLE Study year

ELCC in PJM

Figure 4: 2023 – 2031 ELCC Class Ratings for 4-hr Storage, 6-hr Storage, Solar Hybrid Open Loop (OL) - Storage Component, Solar Hybrid Closed Loop (CL) - Storage Component



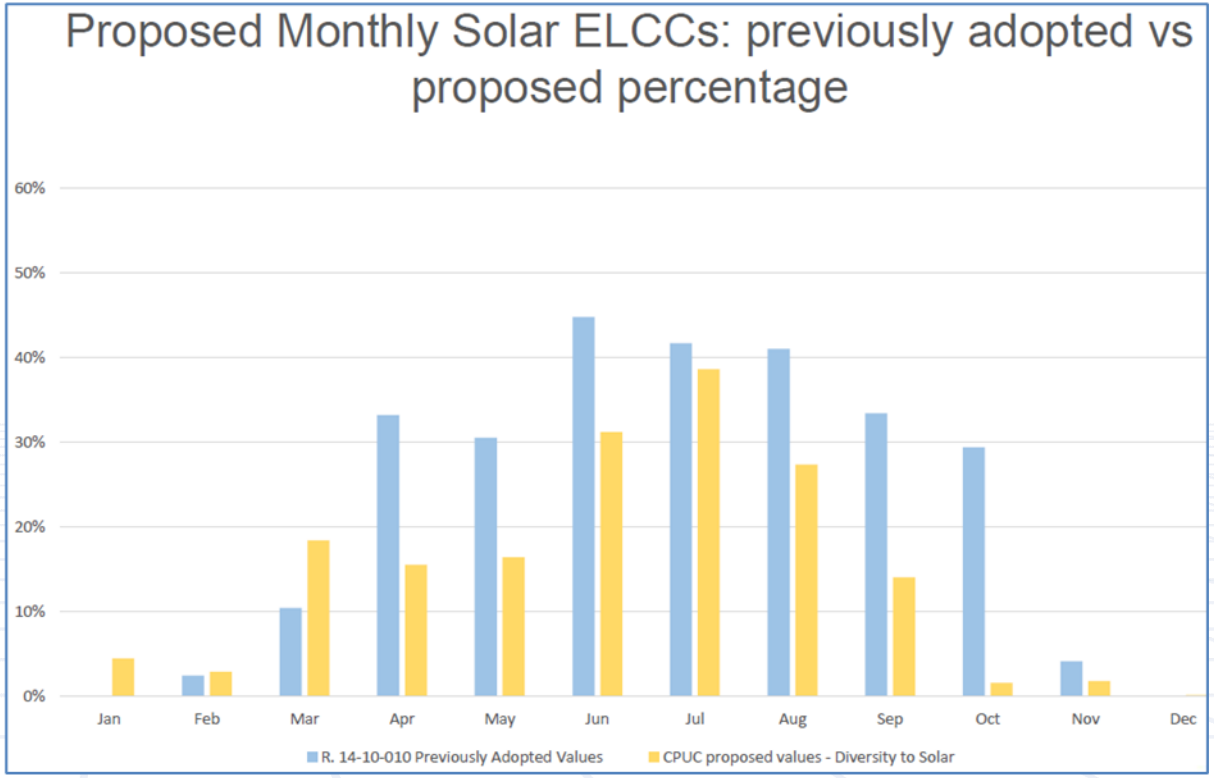
ELCC Class Ratings for 2023/2024 BRA

ELCC Class	ELCC Class Rating for 2023/2024 BRA
Onshore Wind	15%
Offshore Wind	40%
Solar Fixed Panel	38%
Solar Tracking Panel	54%
4-hr Storage	83%
6-hr Storage	98%
8-hr Storage	100%
10-hr Storage	100%
Solar Hybrid Open Loop - Storage Component	82%
Solar Hybrid Closed Loop - Storage Component	82%
Hydro Intermittent	42%
Landfill Gas Intermittent	59%
Hydro with Non-Pumped Storage*	96%

* PJM performs an ELCC analysis for each individual unit in this class. The value shown in the table is a representative value provided for informational purposes

ELCC in CAISO

- ELCC studies lead by CPUC, not CAISO, and since it is done under regulatory proceeding, stakeholders have input
- ELCC studies are done for each Transmission Owner territory
- ELCC %'s are updated periodically and translated into monthly amounts to reflect seasonal differences (see graph)
- ELCC calculations are impacting the amount of RA accredited for solar
- Hybrids/co-located ELCC values sum the renewable and storage parts,



➢ Notice these solar accreditation %'s proposed in 2021 (yellow) are mostly lower than previous %s (blue).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Thank You

John Fernandes

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This webinar was presented by the DOE-OE Energy Storage Technology Advancement Partnership (ESTAP)

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Upcoming Webinars

- Connecticut's New Energy Storage Solutions Program: How it Provides Benefits to Ratepayers, Participants and the Grid (3/1)
- Introduction to Power Markets (3/11)
- Putting Policy into Practice: How the CT Green Bank, Eversource & Avangrid will Partner on Connecticut's Energy Storage Solutions Program (3/15)
- How CEG and CT Green Bank are Helping Connecticut Affordable Housing Facilities Install Resilient Solar+Storage (3/29)

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