Energy Storage Procurement Study

Stakeholder Workshop #2: Preliminary Results & Observations

Prepared for:

California Public Utilities Commission and Stakeholders

September 30, 2021

Photo: iStock

Goals for Today's Meeting

- **Discuss and respond to stakeholder feedback from workshop #1**
- **Share preliminary results and observations on project use cases and operations**
- **Learn more about stakeholder perspectives on actual energy storage development and operations to date**
- **Solicit additional stakeholder questions and feedback on our initial results and observations**

All results in this presentation are preliminary draft and subject to further review and revision. Any changes will be reflected in the final study report.

Workshop Agenda

Approx. Time (PDT)	Minutes	Topic	Q&A
10:00–10:15 a.m.	15	Introductions	Polls
10:15–10:25 a.m.	10	Recap on study purpose and timeline	5 min
10:25–10:45 a.m.	20	Stakeholder feedback and final evaluation framework	5 min
10:45–11:00 a.m.	15	Data collection	
11:00–11:05 a.m.	5	—BREAK—	
11:05–11:45 a.m.	40	Energy storage market evolution	10 min
11:45 a.m.–12:15 p.m.	30	—BREAK—	
12:15–12:35 p.m.	20	Energy & ancillary services market value	5 min
12:35–12:55 p.m.	20	GHG emissions impact	5 min
12:55–1:10 p.m.	15	Avoided renewable curtailments	5 min
1:10–1:15 p.m.	5	—BREAK—	
1:15–1:40 p.m.	25	Resource adequacy counterfactuals & value range	5 min
1:40–1:50 p.m.	10	Customer outage mitigation potential	
1:50–2:00 p.m.	10	Closing Remarks	

Meeting Logistics

Audio All participants are muted; please "raise hand" to be unmuted during Q&A

Video Sharing your video is optional, but we highly recommend video off to avoid bandwidth issues

Chat We encourage you to chat during presentations to share ideas

—Please keep your comments friendly and respectful

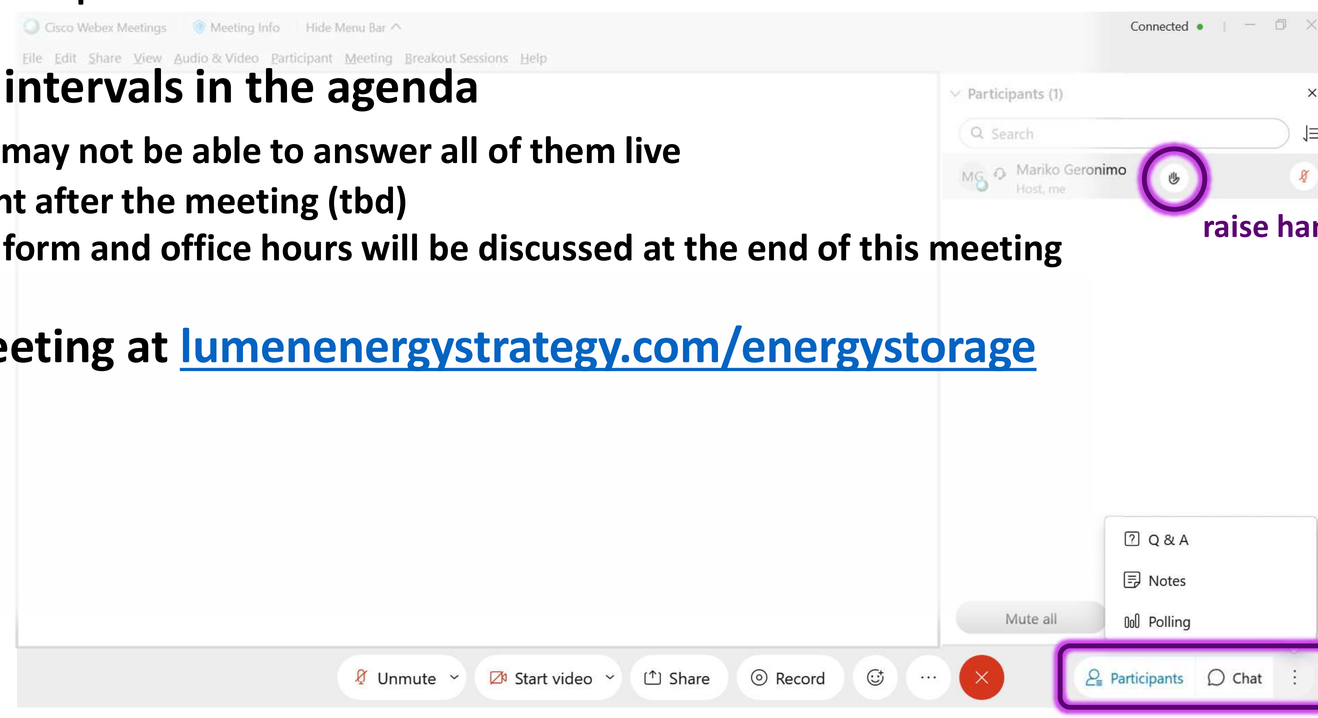
Q&A We will open Q&A at designated intervals in the agenda

—Depending on volume of questions, we may not be able to answer all of them live

—We may follow-up with a Q&A document after the meeting (tbd)

—We would like your feedback: feedback form and office hours will be discussed at the end of this meeting

Presentation Slides will be posted after the meeting at lumenenergystrategy.com/energystorage



Audience Polls

Recap: Purpose of Study

CPUC Decision 13-10-040 requires the CPUC Energy Division to conduct a comprehensive program evaluation of the CPUC Energy Storage Framework and energy storage procurement in compliance with Assembly Bill (AB) 2514 (Skinner, 2010)

Determine whether the CPUC Energy Storage Procurement Framework and design program and all other energy storage procurement meets the stated purposes of optimizing the grid, integrating renewables, and/or reducing greenhouse gas (GHG) emissions

- Determine progress towards energy storage market transformation
- Learn from actual storage operations and cost data
- Determine best practices for safe operations
- Also investigate other procurement policies in practice, realized value stacking, how to get the most ratepayer value from currently deployed and future procurement, peaker replacements, and recycling and end-of-life options

Recap: Why Now?

- California—through AB 2514 and other energy storage procurement directives and initiatives—is a pioneer in energy storage development.
- Ten years ago, energy storage was mostly an **emerging technology**, with many unknowns in terms of costs, operating capabilities, ability to participate in wholesale markets, and long-term cost-effectiveness. At the time, the technology was too new for investors and developers to clearly see a business use case and value proposition for energy storage.
- The CPUC identified this technology as potentially game-changing for providing crucial services to the grid and to customers as the state moves towards an **increasingly clean and sustainable energy future**.
- The CPUC carved a path forward by creating demand for energy storage development, and, in the process, the CPUC has been working to break down barriers to the energy storage market.
- As a result of these directives and initiatives, California now has more than 2,000 MW of operational energy storage, with much more in development and another 10,000 MW cost-effective energy storage identified in the IRP (as of September 2021).
- With the energy storage market accelerating rapidly, now is a critical time to study the performance of the energy storage on the system and discover the technology's ability, in practice, to meet the state's objectives of grid optimization, renewable integration, and GHG emissions reductions.

Study Timeline

2020

CPUC issued a Request for Information (RFI) to determine desired study scope, timeline and contractor requirements (Mar 2020)

CPUC incorporated RFI responses and released a competitive solicitation to select a contractor to support CPUC for the energy storage study (Aug 2020)

Notice of Intent to Award (Dec 2020)

2021

Contract award & study kickoff (Mar 2021)

STAKEHOLDER WORKSHOP 1 (May 2021)
- Study purpose and objectives
- Framework for project evaluation

STAKEHOLDER WORKSHOP 2 (Sep 2021)
- Final evaluation framework
- Initial observations on project use cases and operations

2022

STAKEHOLDER WORKSHOP 3 (Q1 2022)
- Preliminary findings on project evaluations
- Notable successes and challenges

DRAFT STUDY REPORT & STAKEHOLDER WORKSHOP 4 (Q2 2022)
- Final project evaluations and scoring
- Draft study recommendations

FINAL STUDY REPORT (Q3 2022)

Q&A

—Study purpose and timeline

Stakeholder Feedback

Workshop #1: Stakeholder Feedback

Stakeholder feedback is largely supportive, with most suggestions in alignment with the planned framework.

Stakeholder-suggested refinements include:

Study scope

- Coordinate with MUA proceedings and refining MUA rules
- Coordinate with microgrid proceedings
- Rate design analysis?
- Analysis of cancelled projects?

Historical cost and benefit metrics

- Clarify approach to customer bill-related impacts
- Clarify approach to indirect impacts
- Consider alternative marginal GHG emission rates
- Clarify role of CPUC cost-effectiveness tests and ACC
- Include administrative costs

Energy storage market evolution

- Prospective analysis?
- Acknowledge role of CCAs and ESPs in procurements

Responses to Stakeholder Feedback

- **Study refinements:**
  - Consideration of MUA and microgrid proceedings, and how study findings can help inform them
  - Consideration of how retail rate design can increase benefits, to inform CPUC's upcoming flexible loads proceeding (see draft DER Action Plan)
  - Some information on canceled project and barriers to achieving operations (but not a full study)
  - Consideration of administrative costs, subject to data availability
  - More information and discussion of CCA and ESP roles in procurement
  - Consider WattTime's empirical model for marginal GHG emissions
- **Clarifications and additional discussion on:**
  - How we will analyze customer bill impacts, indirect impacts on wholesale markets and GHG emissions
  - Role of Avoided Cost Calculator and Standard Practice Manual in our study
  - Prospective analysis

Coordination with Other CPUC Proceedings and Efforts

- Track key policy questions and progress
- Consider guidelines for approach and data sources (e.g., value of resiliency)
- Determine how our scope of efforts may contribute insights
- Aim to provide observations and policy recommendations helpful to a variety of energy storage-related CPUC proceedings and efforts
- But limited by our scope of work

Proceeding(s)	Status	Primary Coordination Efforts
Microgrid R.19-09-009 Track 2	Ongoing	Consider working group's materials on value of resiliency and interconnection
Station Power R.15-03-011 Track 2	Reopened Mar 2021	Comment on operating practices and incentives under standalone vs. hybrid configurations
Multi-Use Applications R.15-03-011 Track 2	Closed Jan 2018	Consider and comment on adopted interim MUA rules and working group's recommendations
DER Action Plan 2.0 (2021–2026)	Ongoing	Identify changes in customer-sited energy storage policies and market enhancements that can improve the future operation and procurement of energy storage
High DER Future R.21-06-017	Opened Jun 2021	(TBD) may comment on topics such as data collection and management practices, how retail rate design can increase benefits
IRP & Summer Reliability R.16-02-007; R.20-11-003	Ongoing	Suggest enhancements to evaluation framework and modeling of future value streams

Energy Storage Market Evolution

As part of our historical analysis, evaluate progress and key trends in energy storage development in California

- **Technological maturity**: Breakthroughs, current status, emerging technologies, and a global context
- **Value propositions**: Cost trends, marketable benefits, and a national context
- **Ecosystem of competition and innovation**: phases of development, parties involved, and change in suppliers of energy storage resources over time

Clockwise from top left: Olivenhain Reservoir (Lake Hodges pumped storage), image credit: San Diego County Water Authority; Gateway Project, image credit: LS Power/Silverline Productions, Inc./Vimeo (company video); Tesla Powerpack system, image credit: Tesla, Inc.; Thermal energy storage (TES) tank at Chaffey College, image credit: HPAC Engineering.

Other Special Studies

In addition to our historical analysis, we will conduct several special studies* to inform energy storage policy

- Case Studies on Energy Storage Procurement Policies in Other States
- Case Studies on Energy Storage End Use and Multiple Applications
- Cost-Benefit Analysis of Additional Energy Storage Procurement in California (Forward Looking)
- Evaluation of Gas Plant Replacement w/ Storage in California
- Evaluation of Recycling, Disposal, and Reuse Options for Li-Ion Batteries

*The scope of these studies were developed through a public RFI process and reflected in the final RFP issued by the CPUC on August 12, 2020 (RFP 18NC0548).

Clarifications on Behind the (Utility) Meter Impacts

- **Customer-sited resources: mostly developed under SGIP + 80 MW operating under utility contracts**
- **Indirect wholesale market value**
  - Energy value based on CAISO sub-LAP locational marginal prices
  - Resource adequacy value based on vintage and location
  - GHG emissions and renewable curtailment impacts follow same methodology as in-front-of-the-meter storage
- **Customer bill impacts**
  - From time-of-use (TOU) and demand charge savings
  - Are not additive to grid-level benefits
  - Primary focus is to understand rate design-related synergies vs. barriers to meeting AB 2514 goals
  - We will rely on the SGIP impact studies for data collection and observed usage patterns and bill impacts (see right)
  - Incremental analysis will include locational granularity on avoided system costs and simulation of “optimal dispatch” under grid-level price/GHG signals

Selected Results from 2018 SGIP Impact Study*

FIGURE 4-31: NONRESIDENTIAL MONTHLY CUSTOMER BILL SAVINGS ($/KW) BY RATE GROUP AND PBI/NON-PBI

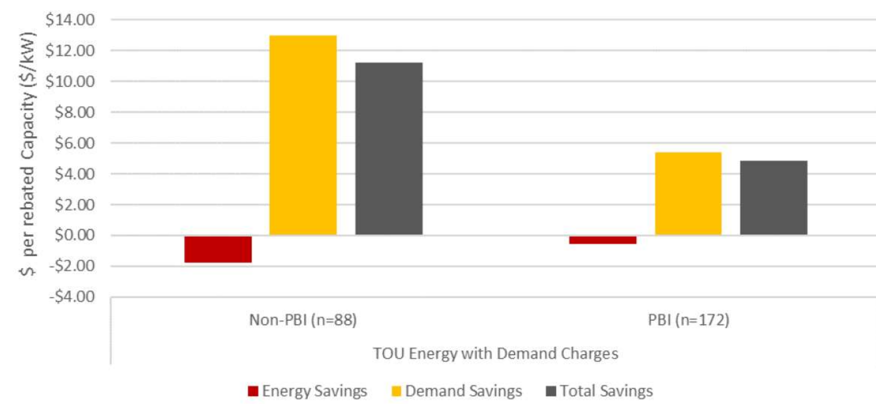
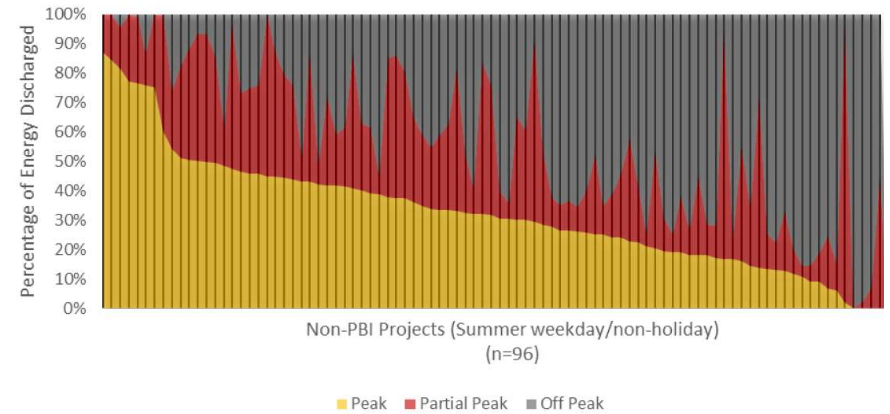


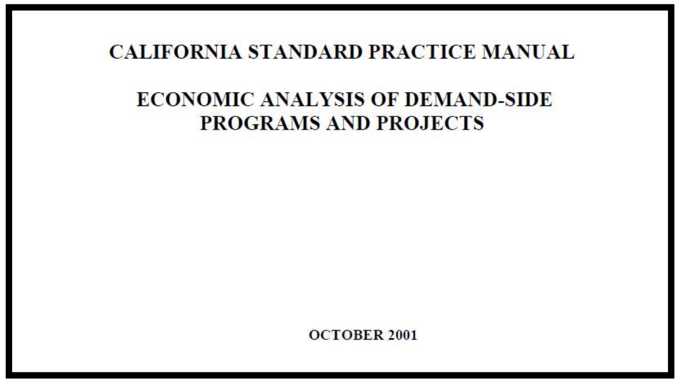
FIGURE 4-15: 2018 SGIP NONRESIDENTIAL NON-PBI PROJECT DISCHARGE BY SUMMER TOU PERIOD



Source: Itron, “2018 SGIP Advanced Energy Storage Impact Evaluation,” January 29, 2020.

*Study analyzed both residential and non-residential customers and reported several performance statistics and estimated customer impact metrics.

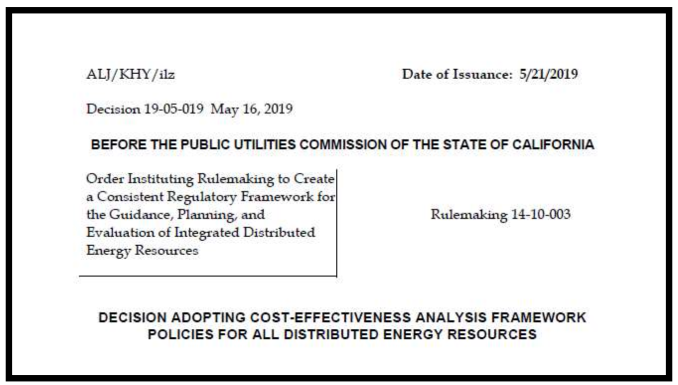
CPUC Standards for Cost-Effectiveness Analysis



CALIFORNIA STANDARD PRACTICE MANUAL

ECONOMIC ANALYSIS OF DEMAND-SIDE PROGRAMS AND PROJECTS

OCTOBER 2001



ALJ/KHY/ilz Date of Issuance: 5/21/2019

Decision 19-05-019 May 16, 2019

BEFORE THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA

Order Instituting Rulemaking to Create a Consistent Regulatory Framework for the Guidance, Planning, and Evaluation of Integrated Distributed Energy Resources	Rulemaking 14-10-003

DECISION ADOPTING COST-EFFECTIVENESS ANALYSIS FRAMEWORK POLICIES FOR ALL DISTRIBUTED ENERGY RESOURCES

- At the foundation: cost-effectiveness tests outlined in the California Standard Practice Manual (SPM)
  - Total resource cost; societal test as variant
  - Program administrator cost (all ratepayers)
  - Ratepayer impact measure (non-participants)
  - Participant cost
- Decision 19-05-019 reflects CPUC's current guidelines for applying the SPM
  - Applies to distributed energy resources
  - Requires total resource cost as primary test for all Commission activities, plus program administrator cost and ratepayer impact measure as secondary tests
  - Refines societal test and GHG emissions-related assumptions
  - **Takes a step closer to a universal approach to resource evaluation across all domains**

Our evaluation framework applies a consistent approach to all projects, including customer-sited, distribution-sited, and transmission-sited resources

Q&A

—Study team's responses to stakeholder feedback on final evaluation framework

Data Collection

Status of Data Collection for Historical Analysis

				DATA COLLECTED		
RESOURCE TYPE	# Projects	Operational MW (as of April 2021)	Share of total operational MW	Operating profiles	Solicitation & contract details	Cost data (ratepayer)
Transmission-Sited **limited history*	8	865	59%	55%	51% Not Contracted	51%
Distribution-Sited	33	236	16%	15%	14%	16%
SGIP Customer-Sited **as of Q1 2021*	~16,000	284	19%	7%	19%	19%
Non-SGIP Customer-Sited	15	80	5%	0%	5%	5%
		1,465 MW	1,465 MW 100%	1,128 MW 77%	1,308 MW 89%	1,340 MW 91%

Preliminary Observations on Data Management

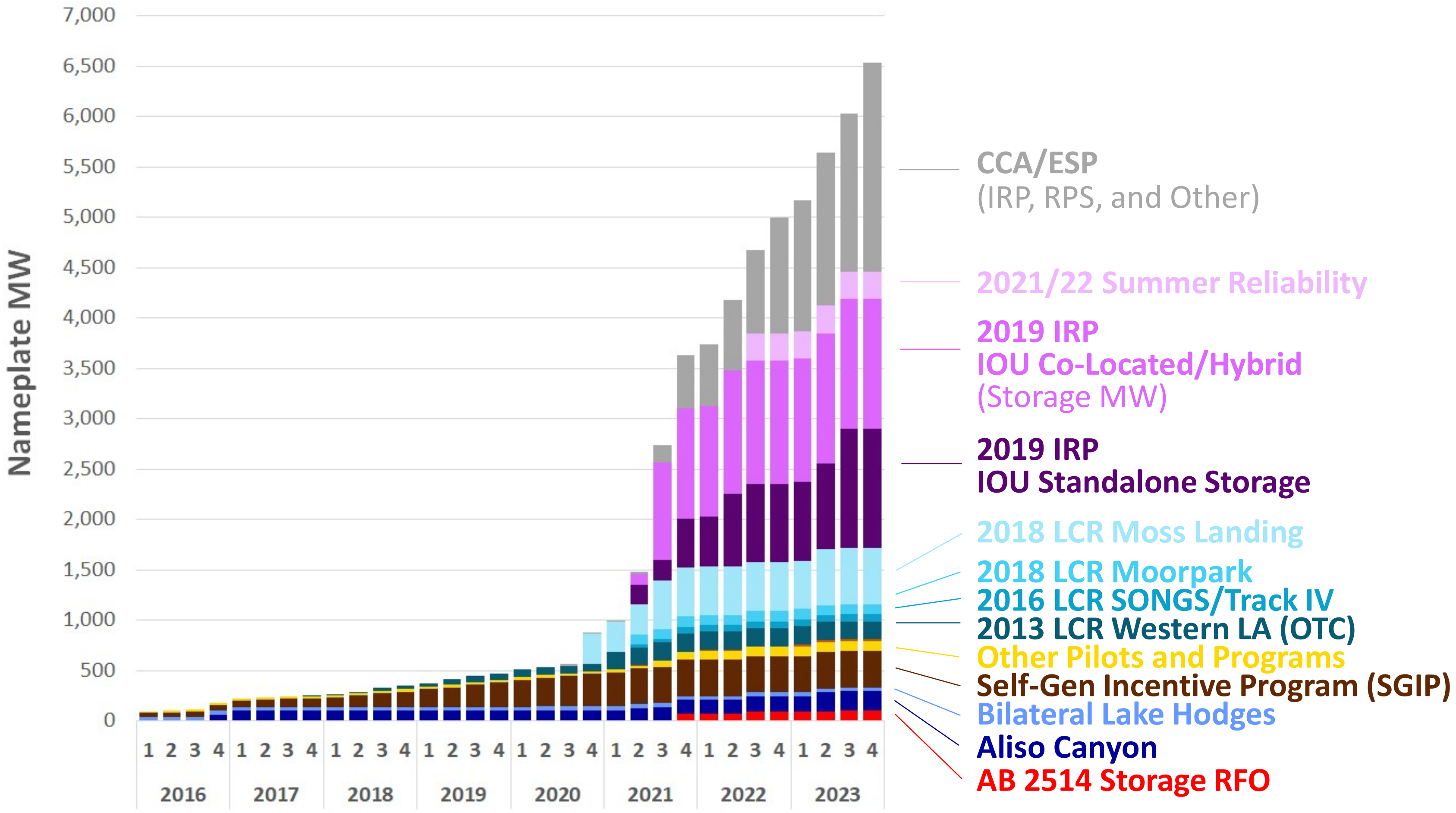
- **Data management for an energy storage portfolio requires an unprecedented breadth of expertise**
  - Spans customer, distribution, and transmission systems, operations, markets, and proceedings
  - Challenge: Barriers in sharing data and expertise among traditionally separated departments makes evaluation of energy storage performance at the portfolio level very difficult
- **Operating profiles for customer- or 3rd party-owned resources are generally not reported to contracting utilities or their regulators**
  - Exceptions: Resources under SGIP Performance-Based Incentives, utility or regulator audits
  - Challenge: Unobserved operating behavior cannot be managed or understood
  - (Note the DER Action Plan vision for improving DER customer program includes, "Data from smart meters and other ratepayer-funded 'smart' devices is available for research purposes while retaining privacy protections and is used to improve program design and marketing.")
- **State of charge (SOC) data not reliable and/or not retained**
  - Challenge: Without state of charge data, (a) potential benefits and barriers to optimal dispatch and (b) reliability performance cannot be fully understood

5-MINUTE BREAK

NEXT UP: ENERGY STORAGE MARKET EVOLUTION

Energy Storage Market Evolution

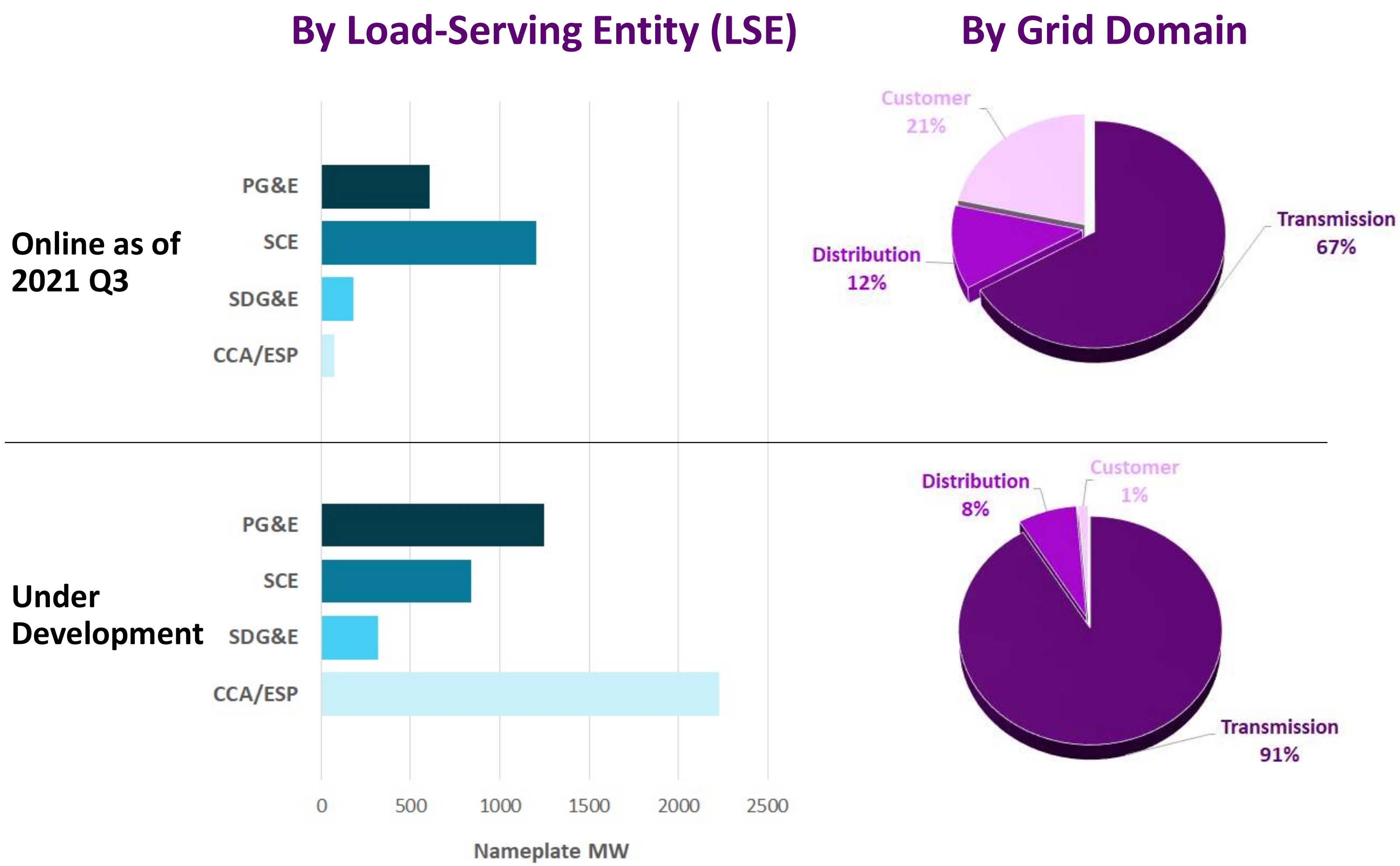
Energy Storage by Procurement Track



Source: Lumen research on utility applications and CPUC decisions on various resource procurement tracks, and other public information on project status. (IRP = Integrated Resource Plan; RPS = Renewable Portfolio Standard; LCR = Local Capacity Requirement; OTC = Once-Through Cooling (retirements); RFO = Request for Offers; CCA = Community Choice Aggregator; ESP = Electric Service Provider.)

- Significant growth in energy storage capacity driven by various procurement tracks
- Current capacity surpassed 2,000 MW, which is >4x relative to last year
- With the upcoming projects, there will be over 3,500 MW online by the end of this year; approaching 6,500 MW in 2023

Energy Storage by LSE and Grid Domain

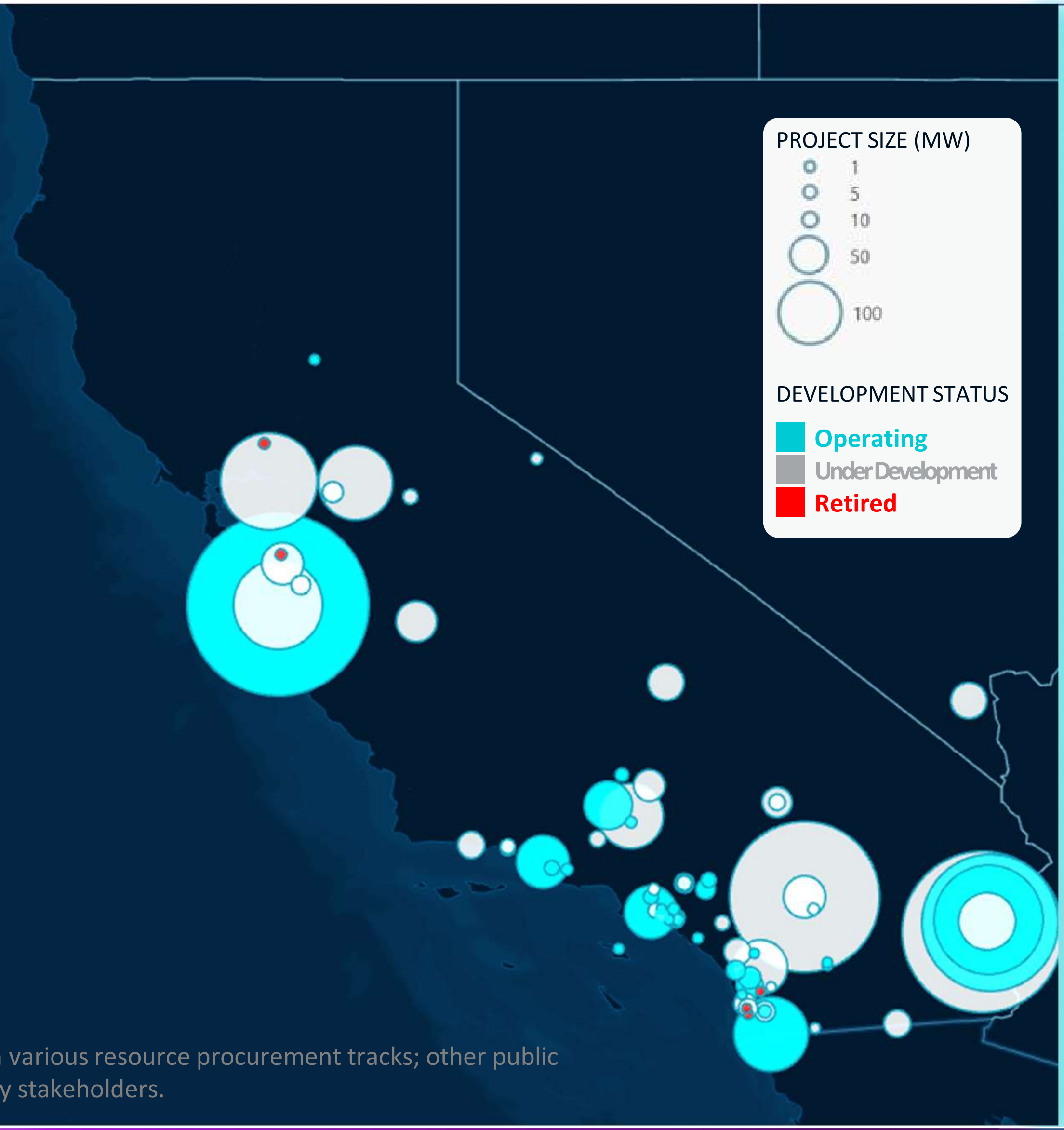


- Current storage mix:
  - 2/3 IFOM transmission-connected
  - 1/3 distribution-connected and BTM customer-sited
- Most near-term resources procured at the transmission domain
- Customer-sited projects will likely continue to grow due to Self-Generation Incentive Program (SGIP)
  - SGIP future growth not shown in the charts here

Source: Lumen research on utility applications and CPUC decisions on various resource procurement tracks, and other public information on project status.

IOU Procurements by Location

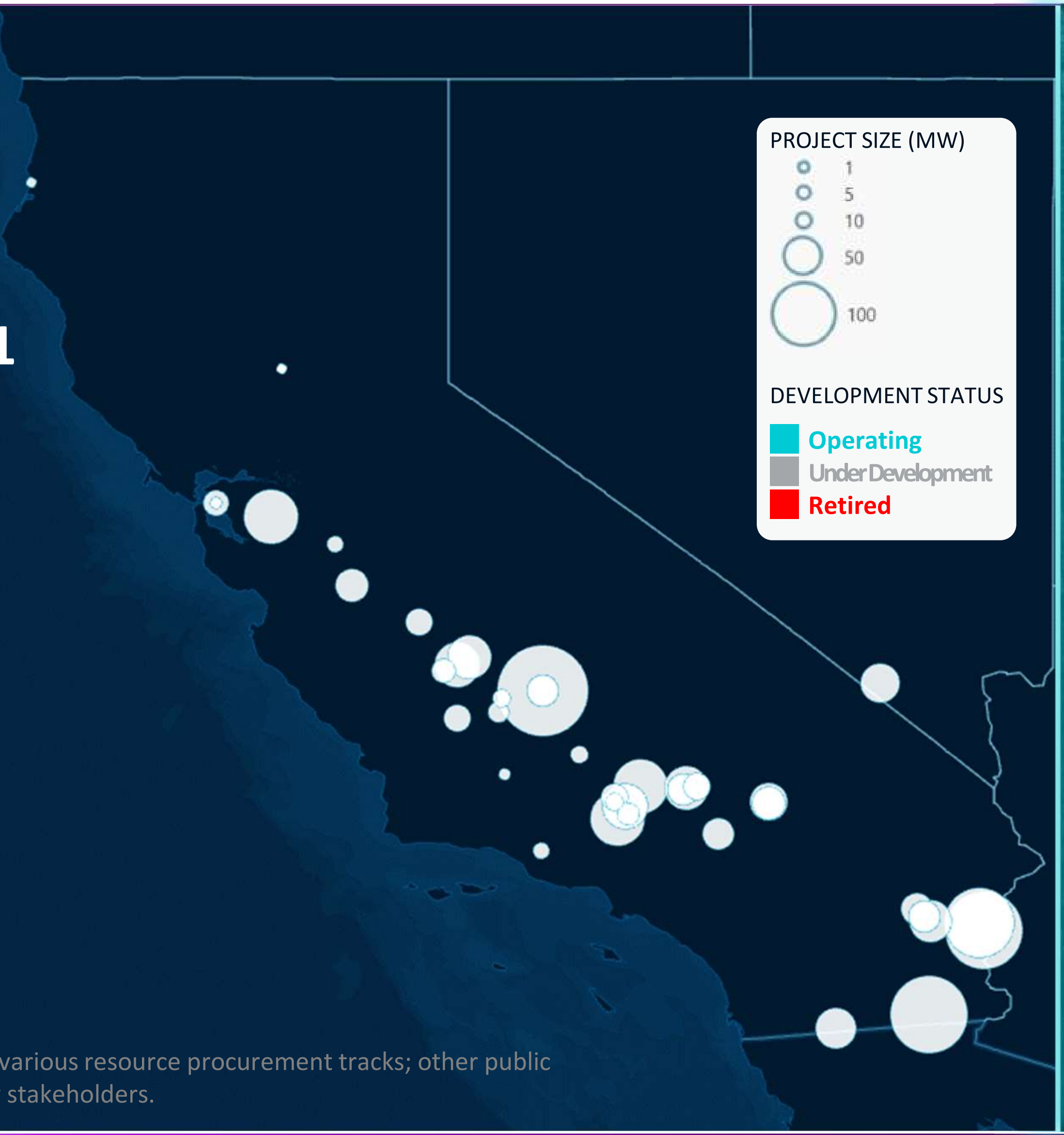
- **Transmission- and distribution-sited shown**
- **Operating: concentrated in or near load centers**
- **Under development: concentrated in areas with high solar potential**
  - Many planned via IRP are co-located with solar
- **Retired: small pilot and proof-of-concept projects**



Source: Lumen research on utility applications and CPUC decisions on various resource procurement tracks; other public information on project size, location, and status; and data provided by stakeholders.

CCA/ESP Procurements by Location

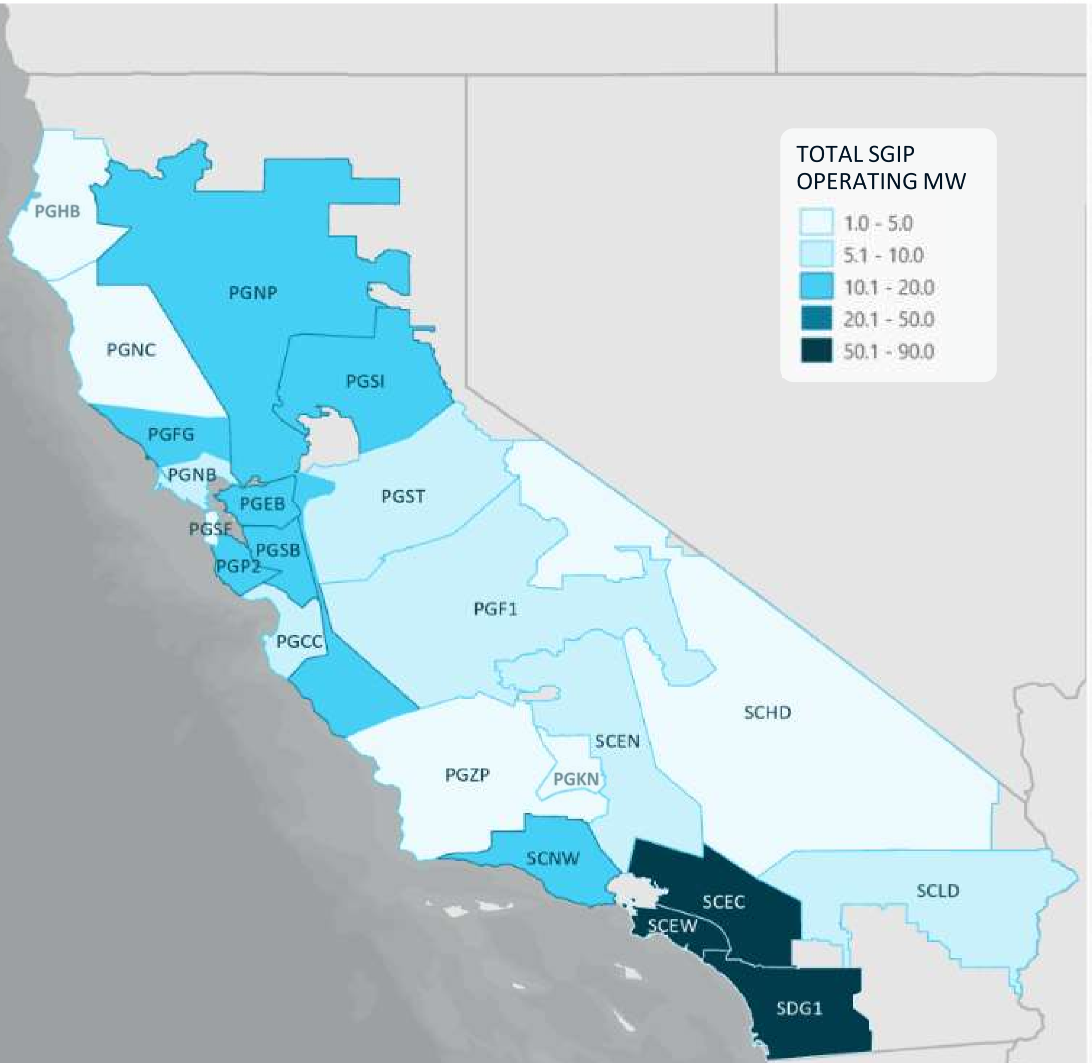
- Transmission- and distribution-sited shown
- No operating as of Aug 2021
- Under development: concentrated near transmission corridors and areas with high solar potential
- Almost all projects solar+storage



Source: Lumen research on utility applications and CPUC decisions on various resource procurement tracks; other public information on project size, location, and status; and data provided by stakeholders.

Customer-Sited Builds by Location

- **SGIP-funded energy storage resources with payments complete or in progress**
- **Concentrated in or near load centers in southern California**
  - Areas with relatively high potential for energy impact and GHG reduction



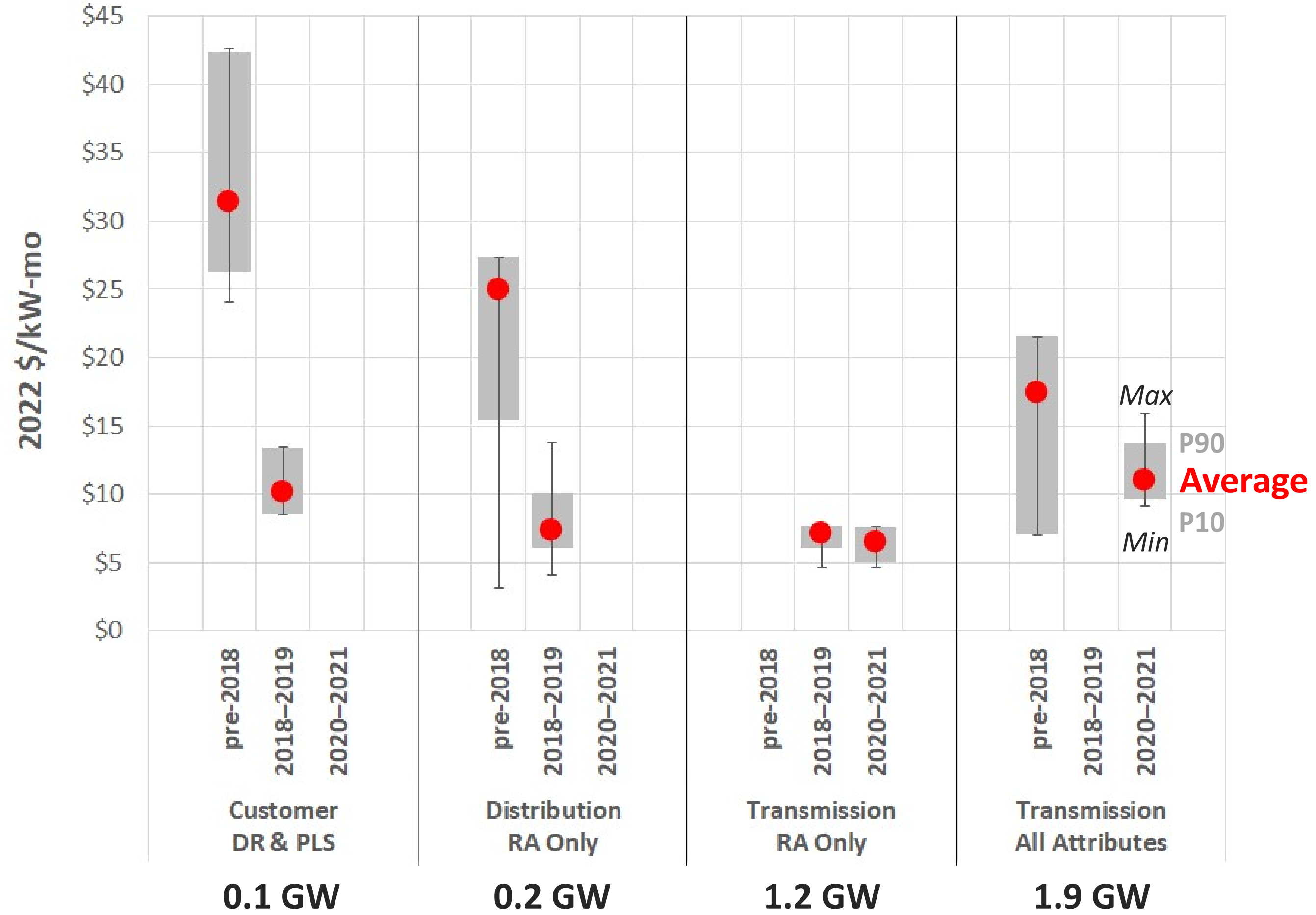
Source: Lumen analysis based on Self-Generation Incentive Program Weekly Statewide Reports and data provided by stakeholders.

3rd-Party Contracts

- Wide range of prices depending on vintage, grid domain, procurement track, and project size
- Earlier energy storage projects have been significantly more expensive
- Recent projects in the transmission domain are contracted for $5–$8 for RA only and $9–$14 for all attributes

(in 2022 $/kW-month)

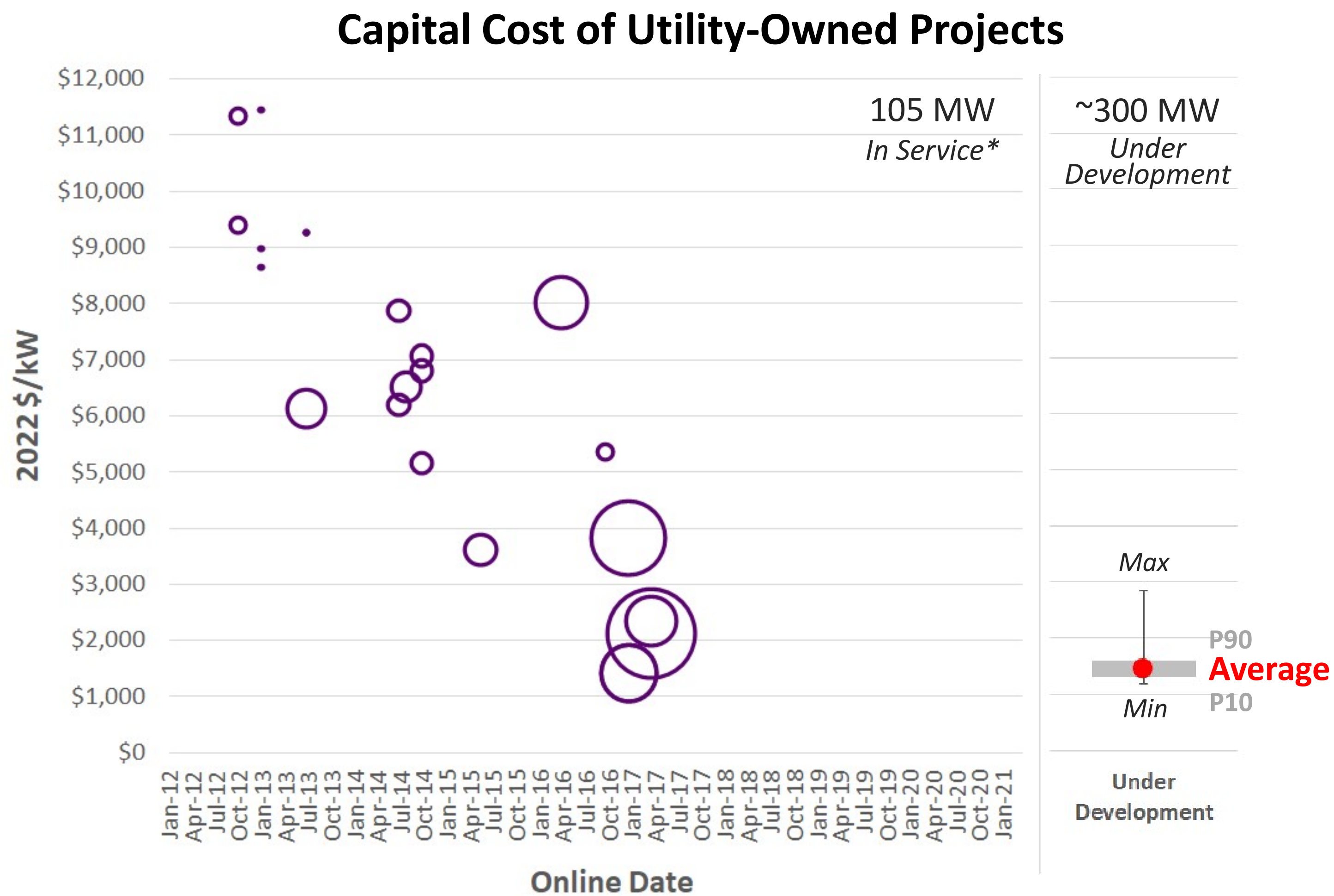
3rd-Party Contract Prices
by Grid Domain and CPUC Approval Year



Source: Lumen research and analysis based on utility applications and CPUC decisions on various resource procurement tracks, and data provided by stakeholders.

Utility-Owned Storage

- Installed cost of utility-owned storage projects declined significantly over the past decade
- Initial pilot projects on the top of the cost curve required >$6,000 per kW
- New utility-owned storage projects expected in the range of $1,200–$1,600 per kW (except for a few very small storage projects above that range)



Source: Lumen research and analysis based on utility applications and CPUC decisions on various resource procurement tracks, and data provided by stakeholders. End of 2018 data points are omitted to preserve data confidentiality.

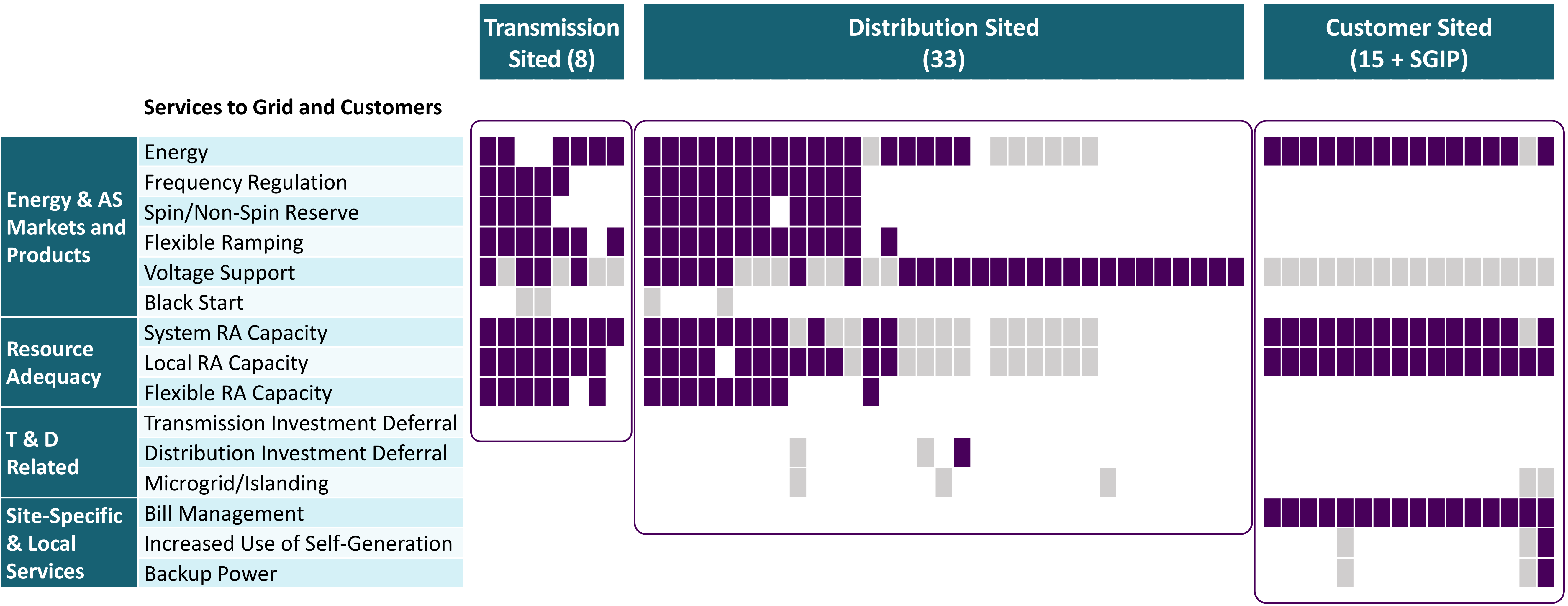
Potential Value to Grid and Customers

	Services to Grid and Customers	*Services that can be provided based on* **Grid Domains** Transmission	Distribution	Customer
Energy & AS Markets and Products	Energy	✓	✓	✓
	Frequency Regulation	✓	✓	✓
	Spin/Non-Spin Reserve	✓	✓	✓
	Flexible Ramping	✓	✓	✓
	Voltage Support	✓	✓	✓
	Black Start	✓	✓	✓
Resource Adequacy	System RA Capacity	✓	✓	✓
	Local RA Capacity	✓	✓	✓
	Flexible RA Capacity	✓	✓	✓
T & D Related	Transmission Investment Deferral	✓	✓	✓
	Distribution Investment Deferral		✓	✓
	Microgrid/Islanding		✓	✓
Site-Specific & Local Services	Bill Management			✓
	Increased Use of Self-Generation			✓
	Backup Power			✓

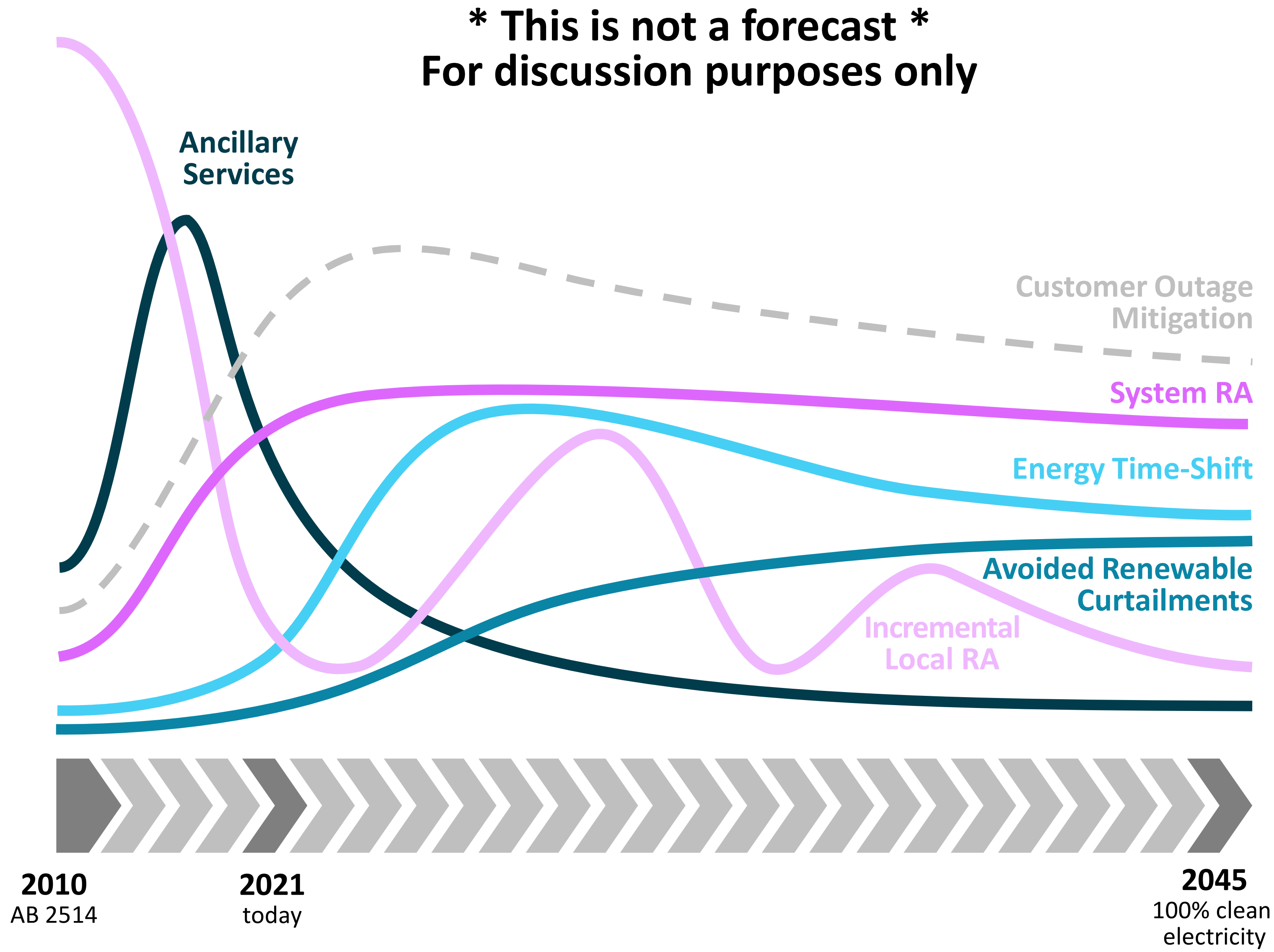
Energy storage projects could (in theory) stack more services and value as they are sited closer to the customer

Categories of Actual Observed Impacts

Observed impacts
Unclear; TBD
No observed impacts



Illustrative Changes in Energy Storage Value over Time



Distributed only; value may decline as grid is hardened and most vulnerable customers/sites are protected

May persist as conventional generation retires, but will require longer duration to get full RA value

Energy value now rising; future depends on high renewables driving RT price volatility vs. storage saturation

May grow as system experiences more curtailment events at high renewable penetration levels

Incremental local RA value cyclical depending on growth in load and transmission

A/S value now declining as market saturates

Q&A

- MW procured by LSEs over time
- Resource locations
- Contract and capital costs over time
- Actual and potential value streams

30-MINUTE BREAK

NEXT UP: ENERGY STORAGE IMPACTS (2017–2021)

Energy & Ancillary Services Market Value

Energy & Ancillary Services Market Value

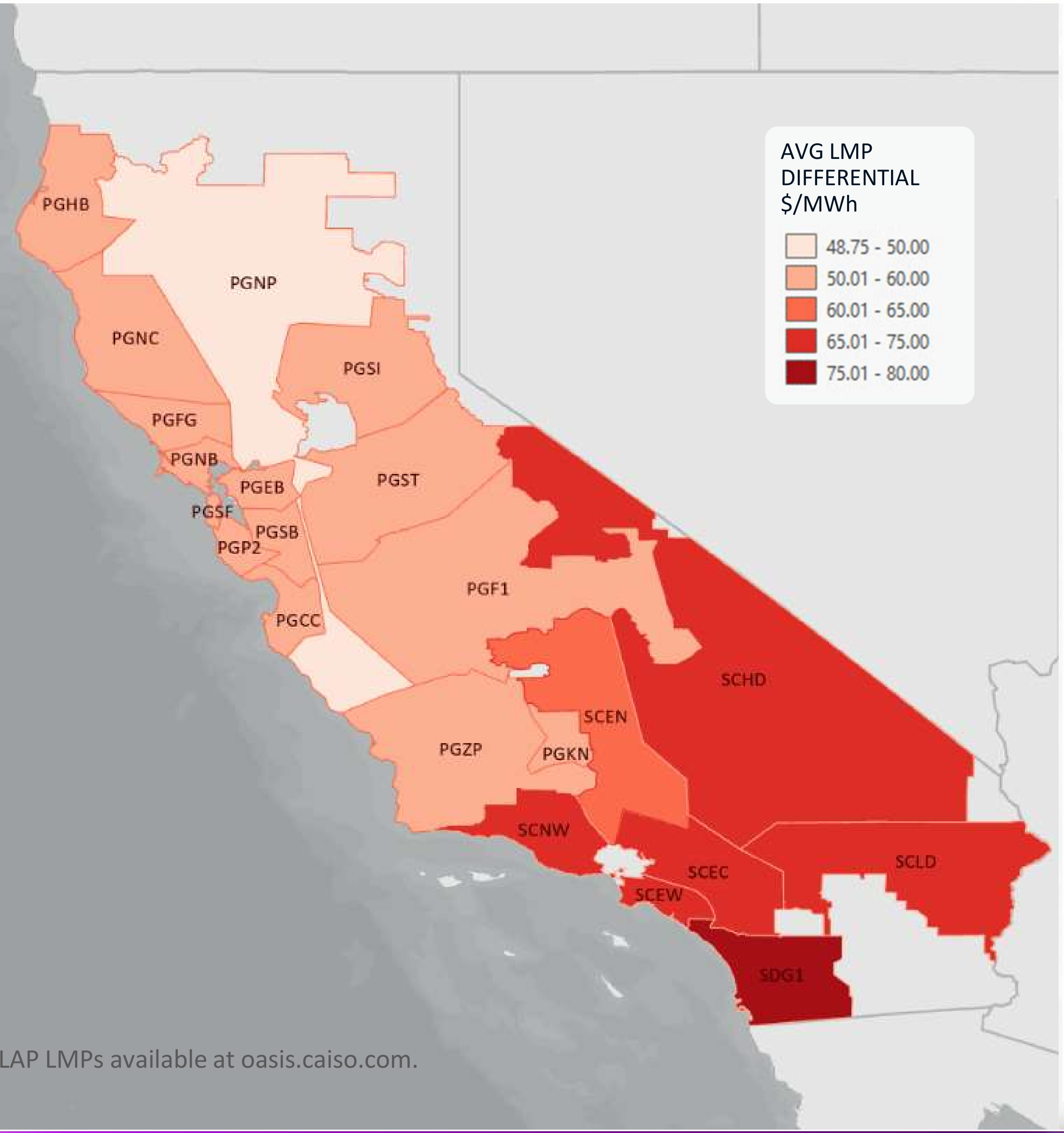
	CAISO Market Participants (including demand response)	Non-Participant Behind CAISO Meter
✓ Energy	Valued at actual nodal DAM and RTM market prices and settlements	Valued at RTM price
✓ Frequency Regulation		n/a
✓ Spin/Non-Spin Reserve		n/a
Flexible Ramping		n/a
Voltage Support	Based on CAISO contract payments	n/a
Black Start		n/a

IN PROGRESS (Flexible Ramping, Voltage Support, Black Start)

IN PROGRESS: Partial results presented today

Potential Energy Time Shift Value by Location

- **Average differential between LMPs in top 4 and bottom 4 hours**
  - Range: $50–80/MWh
  - Shown by CAISO Sub-LAP
- **Highest potential in parts of southern California, where differentials average $65–80/MWh**
- **Highly correlated with GHG reduction potential**



Source: Lumen analysis of June 2018–July 2021 CAISO real-time sub-LAP LMPs available at oasis.caiso.com.

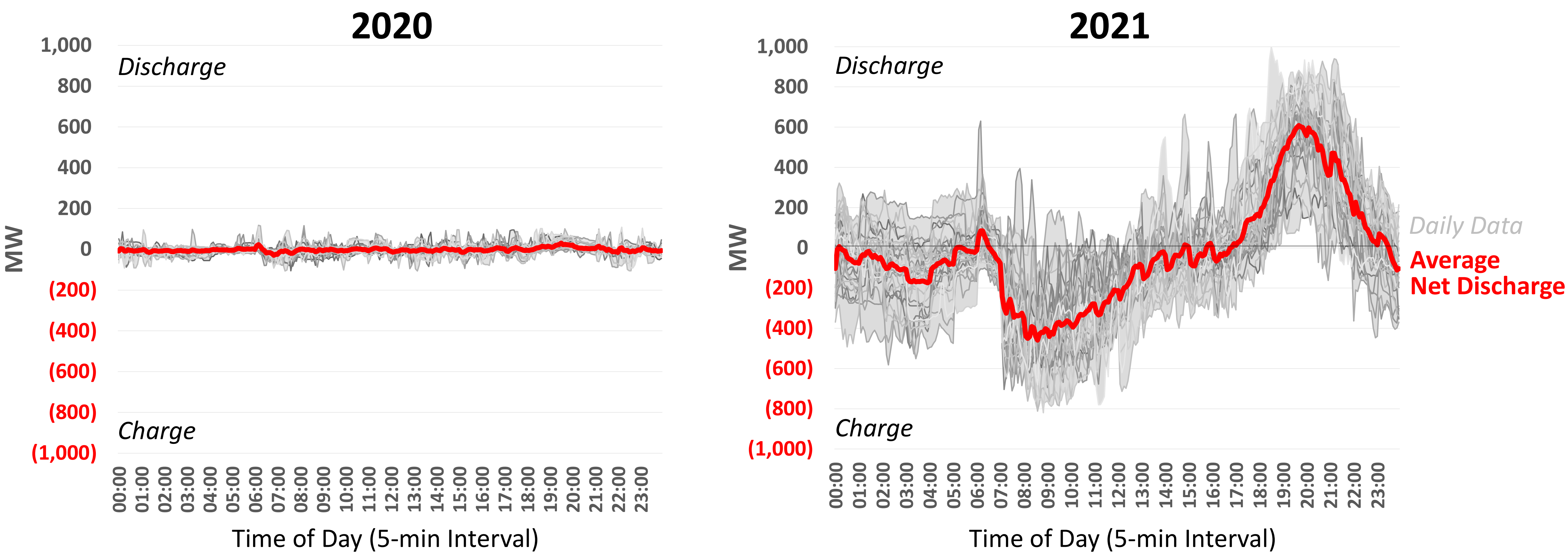
$50–$80/MWh price differential translates to $5–$8/kW-month for 4-hr storage w/ 85% efficiency

We estimated only 70–80% of this value can be captured due to market uncertainty:

$4–$6/kW-month potential

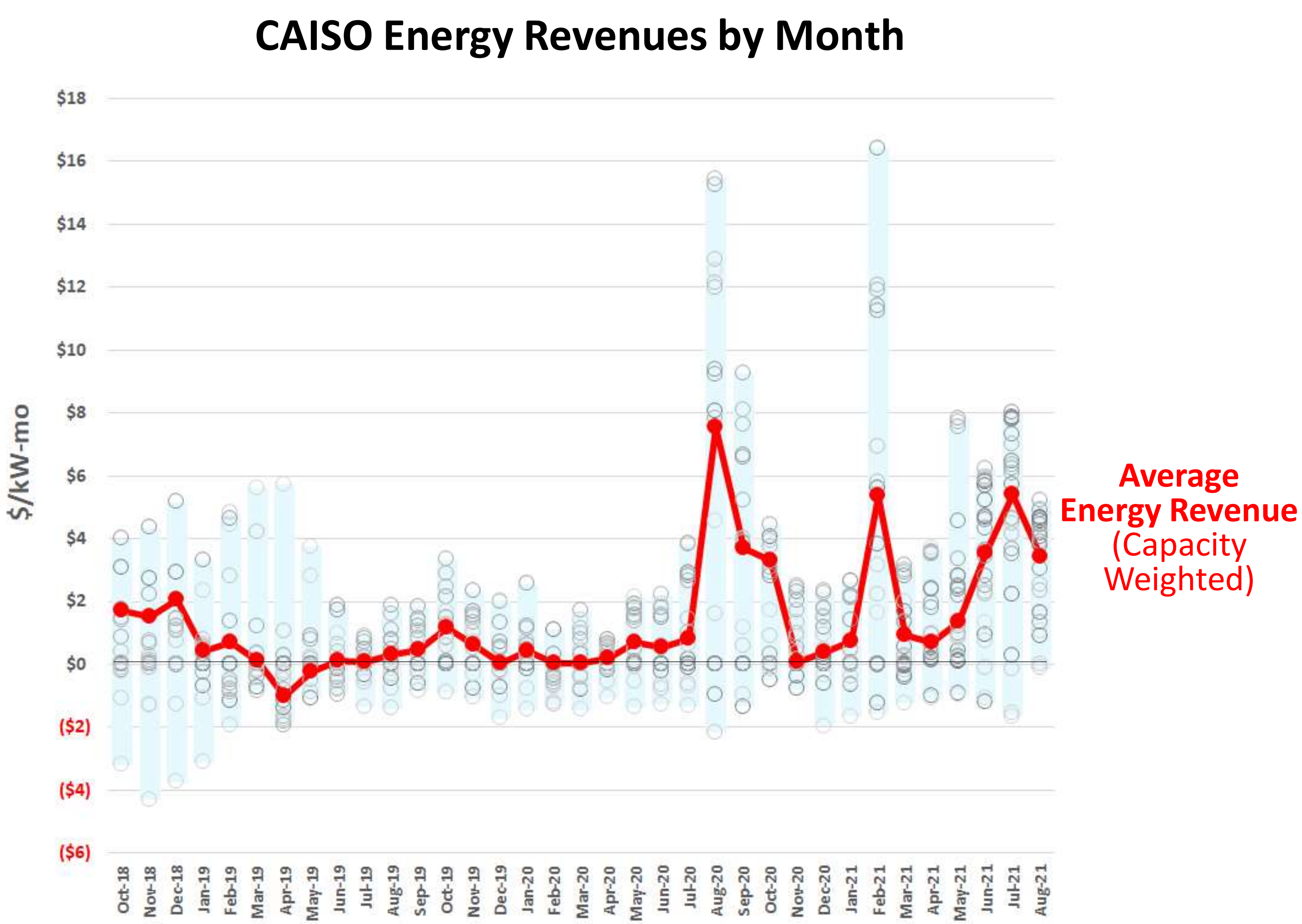
Observed Shift in Value Proposition

CAISO Aggregate Battery Output (June 10–July 10)



Source: Lumen analysis of CAISO battery supply operational data available at http://www.caiso.com/TodaysOutlook/Pages/supply.html.

Energy Value of Storage over Time



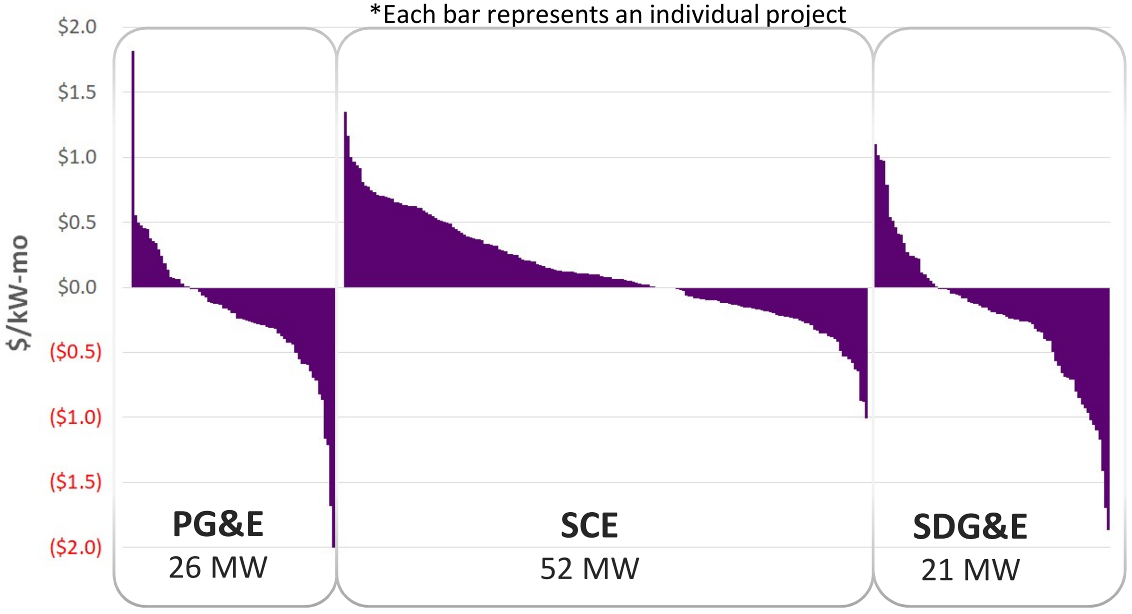
Source: Lumen analysis of CAISO day-ahead and real-time market settlements. Results normalized by nameplate capacity (MW). Each circle represents an individual resource.

- With increased use for energy arbitrage and peak capacity, energy value of storage is growing
- But average realized energy value is still relatively small compared to potential (~$6/kW-month based on historical price diff.)
- Looking forward, energy value of storage will continue to increase as ancillary services market saturates and increased renewables leads to higher RT price volatility

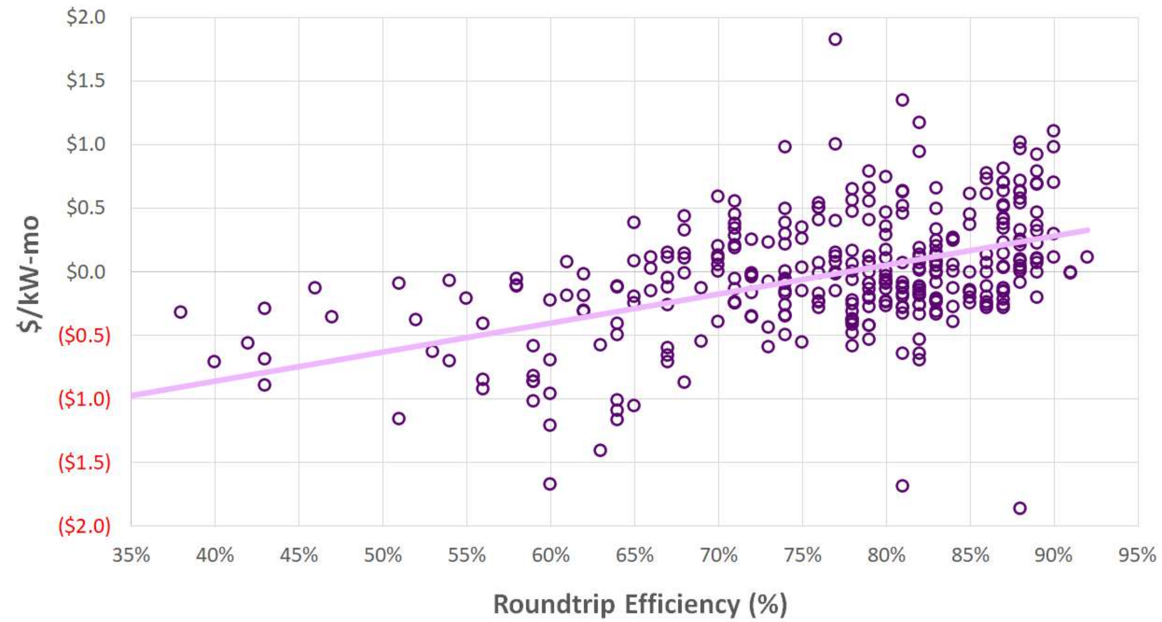
Energy Value of SGIP Projects (non-Residential PBI)

Average Energy Value of SGIP PBI Projects (June 2018–December 2019)

By Utility



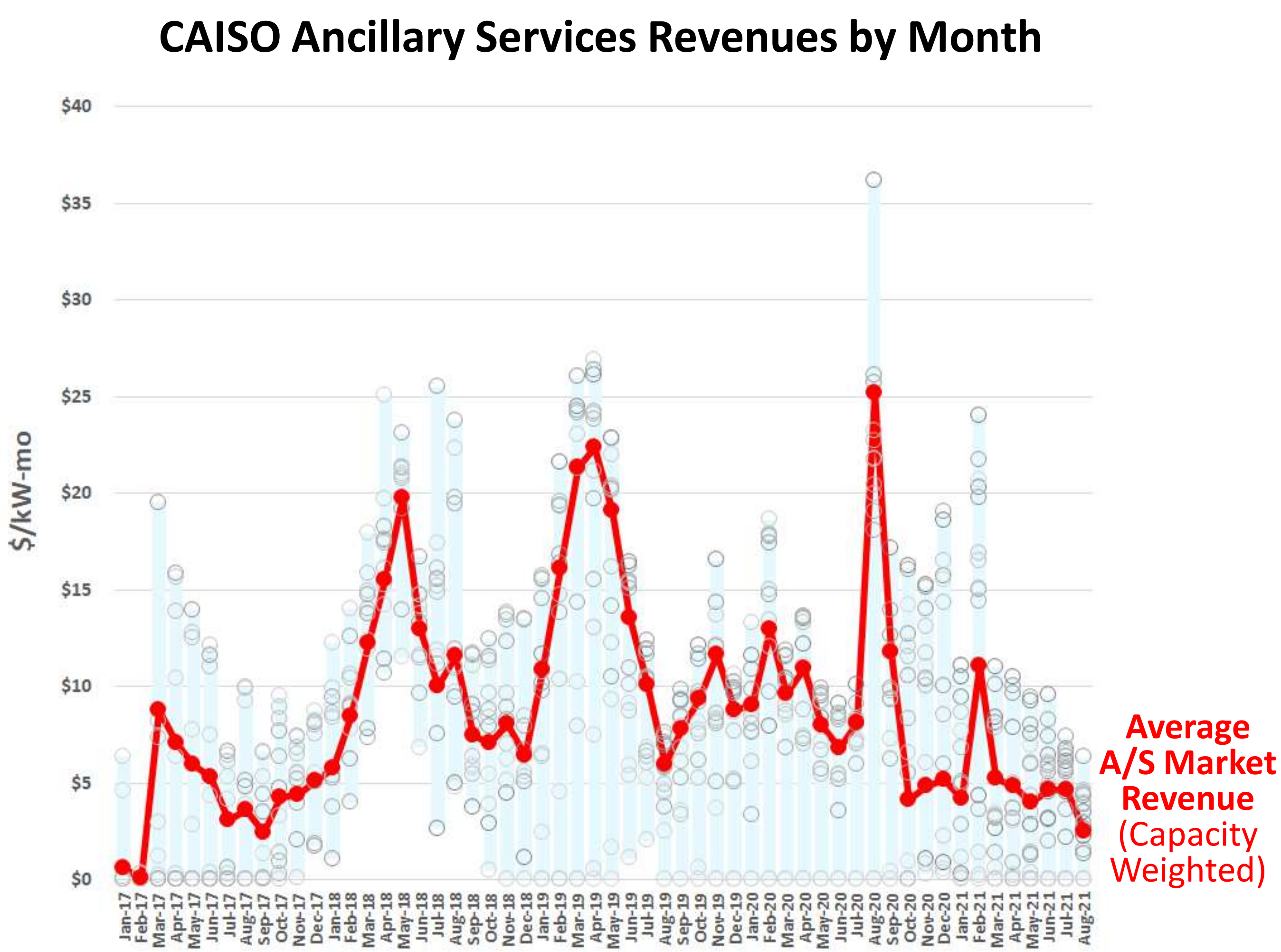
Impact of Efficiency



Source: Lumen analysis of resources subject to the Self-Generation Incentive Program's Performance-Based Incentives. Energy value is calculated based on corresponding CAISO sub-LAP prices.

- Initial energy value analysis utilize limited data collected so far
  - Operational data of PBI projects for 2017–2019
  - CAISO real-time LMPs for June 2018–present
- Most PBI projects operate to maximize bill savings (esp. demand charges)
- Without a price signal on grid conditions, even most efficient projects provide little/no energy value

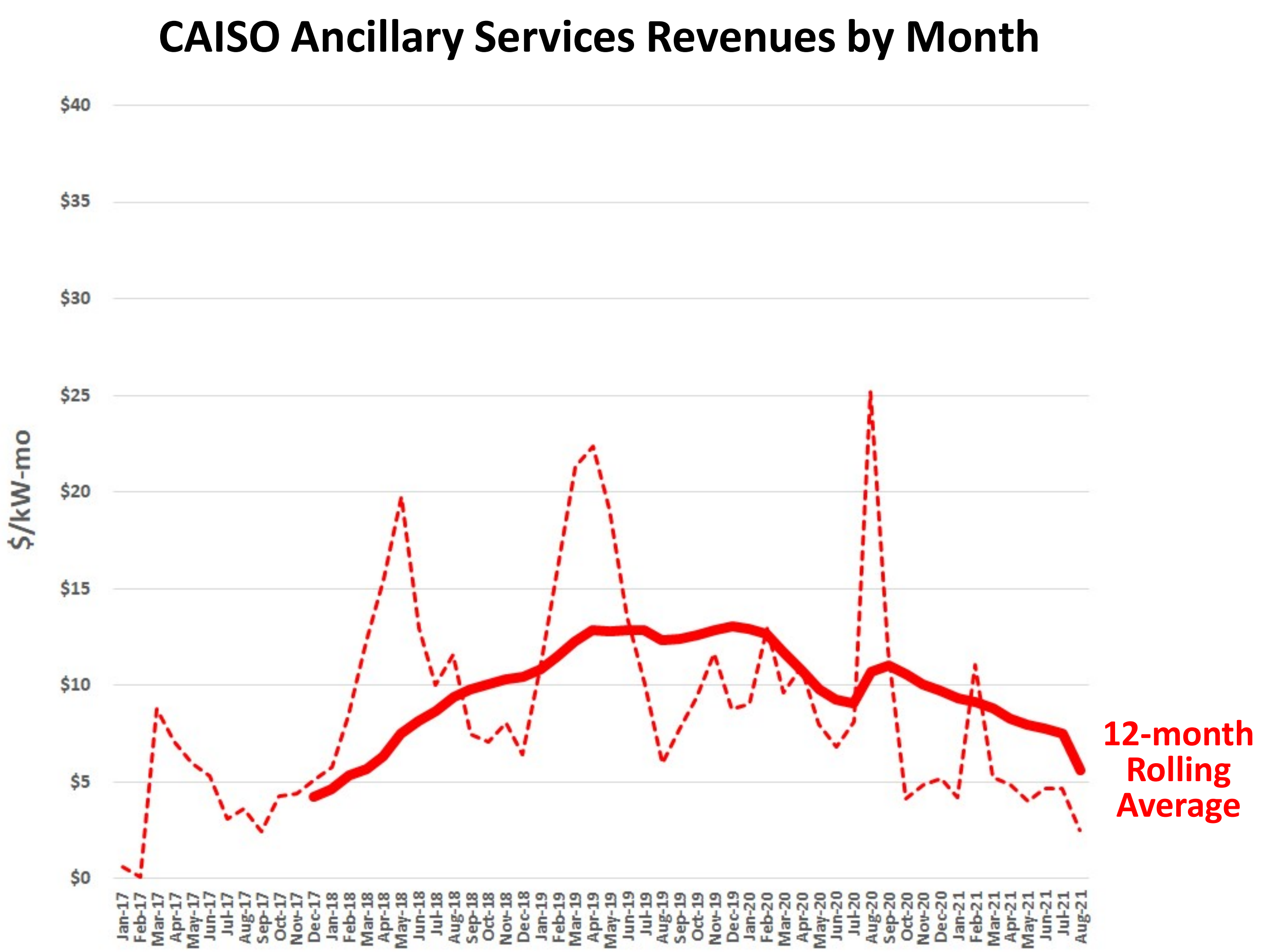
Ancillary Services Value of Storage over Time



Source: Lumen analysis of CAISO day-ahead and real-time market settlements. Results normalized by nameplate capacity (MW). Each circle represents an individual resource.

- Ancillary services have been a significant value stream for IFOM storage participating in the CAISO market
- A/S value has been volatile due to market fluctuation; Historical value averaged at $10–$15 per kW-month with >90% from regulation
- With more flexible resources on the system, A/S market is expected to saturate (despite growing A/S req.) so future A/S value will be much lower than historical levels

Ancillary Services Value of Storage over Time



Source: Lumen analysis of CAISO day-ahead and real-time market settlements. Results normalized by nameplate capacity (MW).

- Ancillary services have been a significant value stream for IFOM storage participating in the CAISO market
- A/S value has been volatile due to market fluctuation; Historical value averaged at $10–$15 per kW-month with >90% from regulation
- With more flexible resources on the system, A/S market is expected to saturate (despite growing A/S req.) so future A/S value will be much lower than historical levels

Next Steps on Energy & Ancillary Services Value

- Expand energy value analysis of customer-sited projects
  - Add residential SGIP and non-SGIP customer-sited projects, subject to data availability
  - Add more recent years (2020–2021), subject to data availability
- Review customer rates and bill impact results (from SGIP impact studies) to understand rate design-related synergies vs. barriers
- Review CAISO storage energy & ancillary services bid data to understand bidding patterns and market participation over time

Q&A

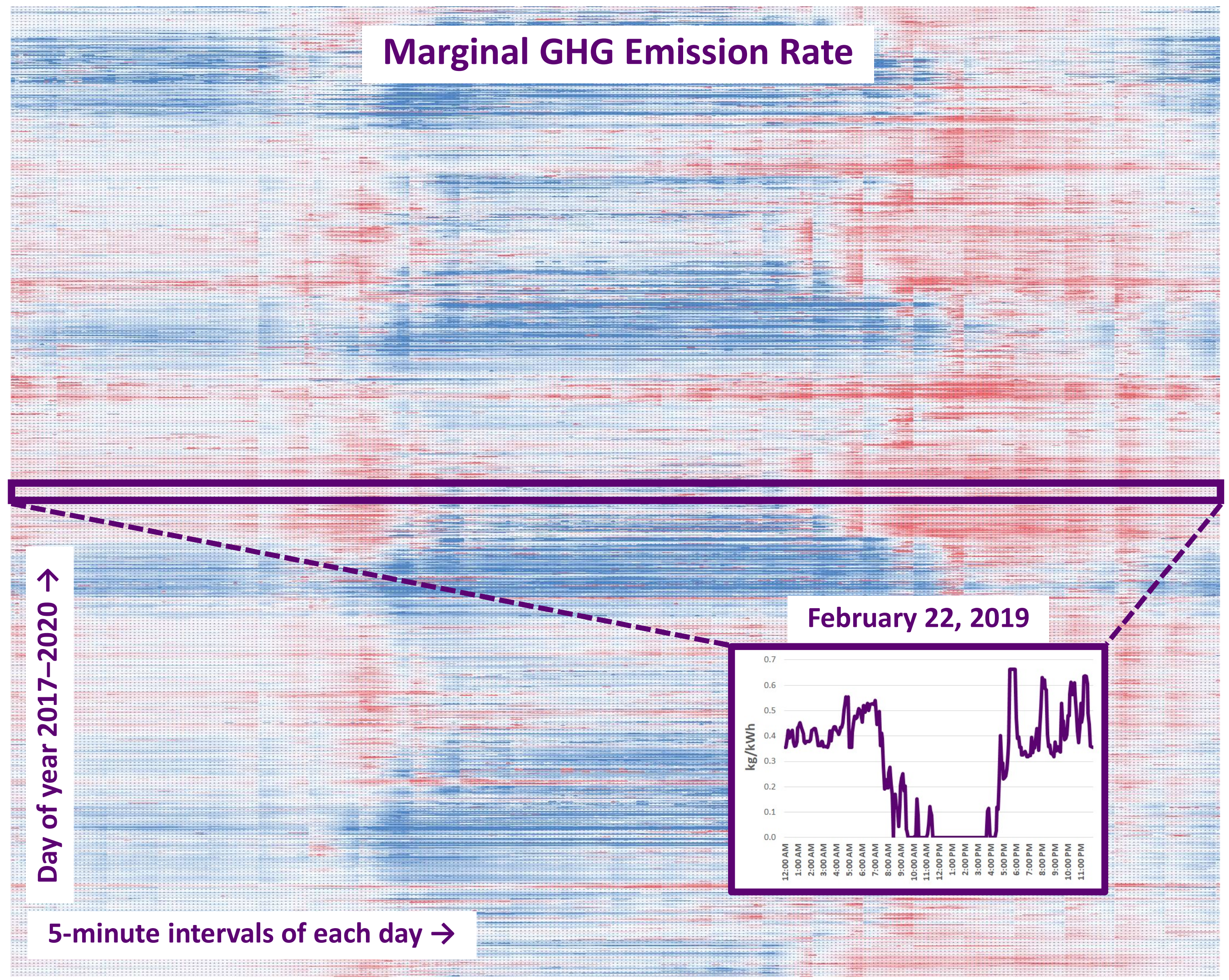
- Observed energy value
- Observed ancillary services value
- Observed shift in value proposition

GHG Emissions Impact

Approach to GHG Emissions Impact

High marginal GHG rate
Low marginal GHG rate

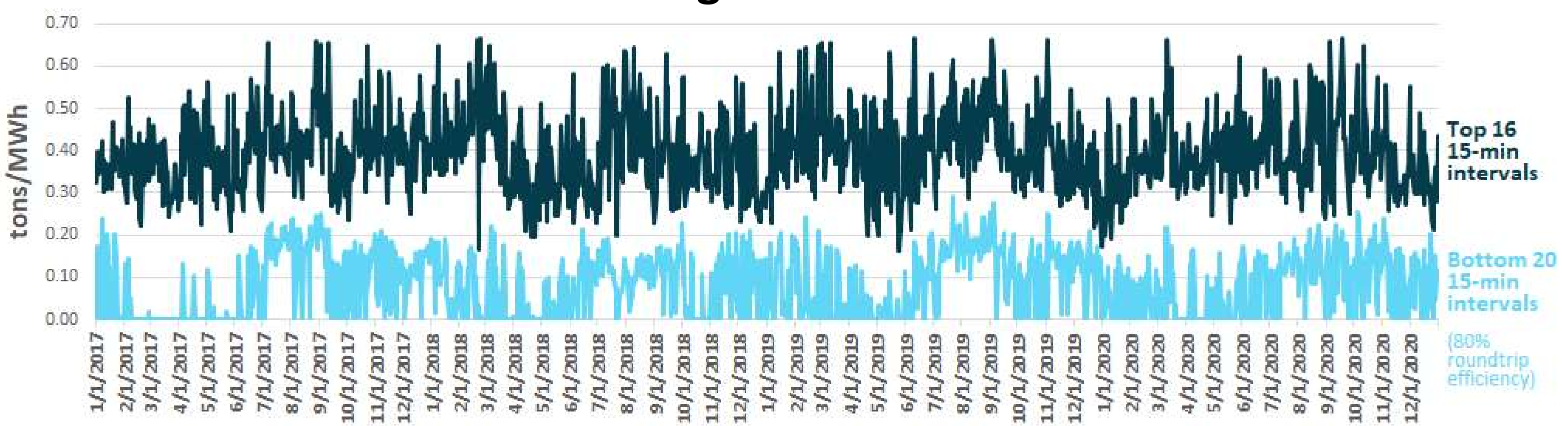
- **System-level emission impacts of energy charge/discharge using marginal GHG emission rates**
  - Will utilize historical GHG signals developed for SGIP projects' compliance with GHG reduction requirements
  - Zonal GHG signals created by WattTime using CPUC-approved methodology (D. 19-08-001)
- **Additional impacts from:**
  - Capacity-related attributes, such as avoiding output from local RMR units with higher GHG emissions than marginal rates
  - Renewable overbuild related to changes in curtailments



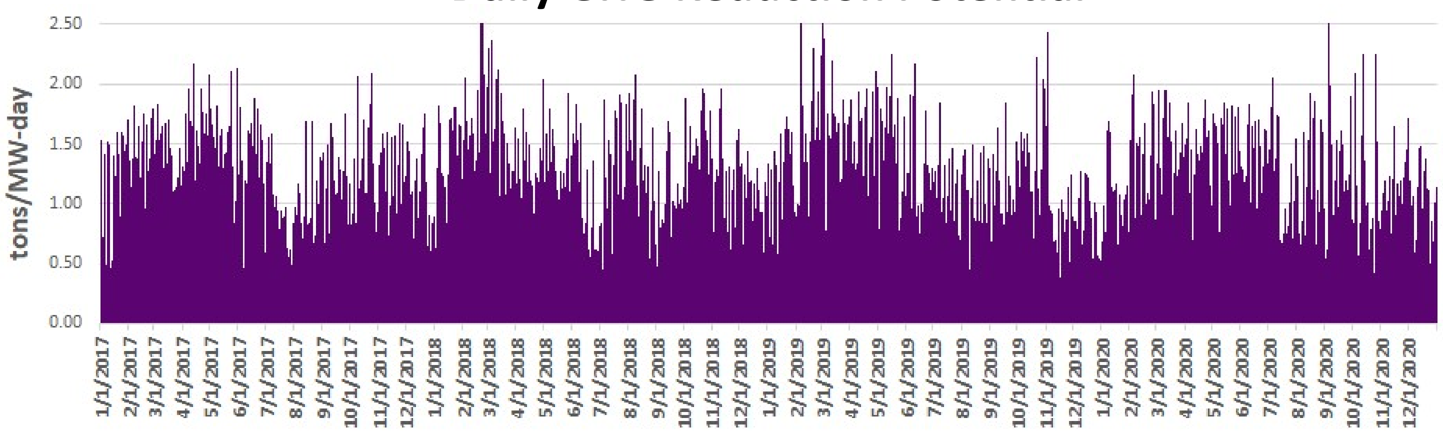
Source: WattTime's historical marginal greenhouse gas (GHG) signal for the Self-Generation Incentive Program (SGIP), available at sgipsignal.com.

GHG Reduction Potential

Average GHG Rate



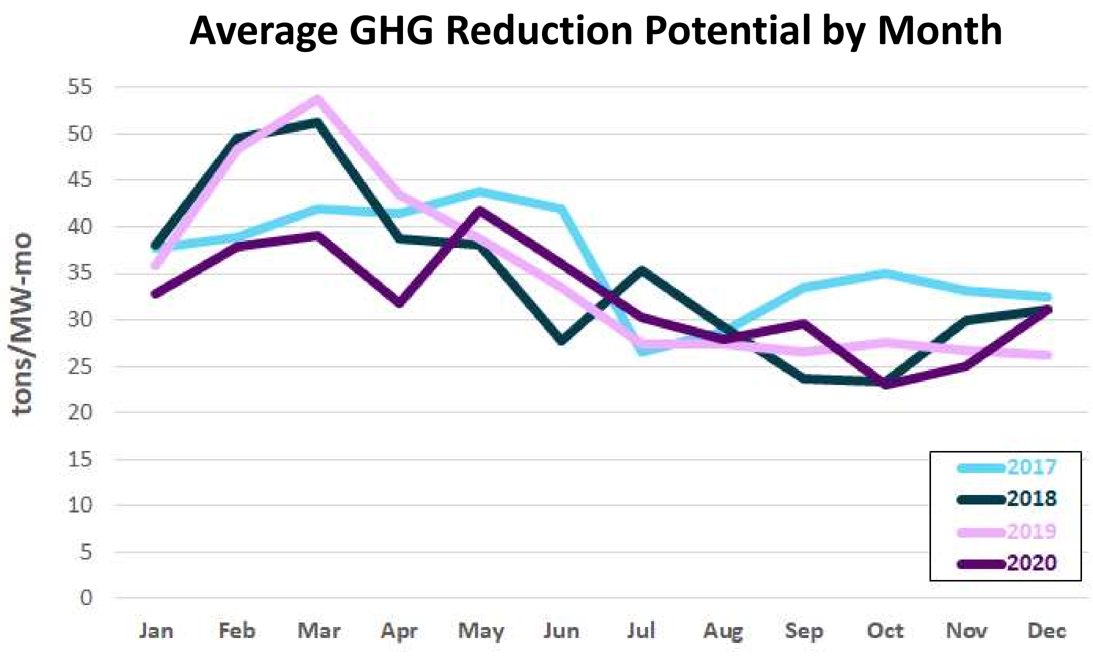
Daily GHG Reduction Potential

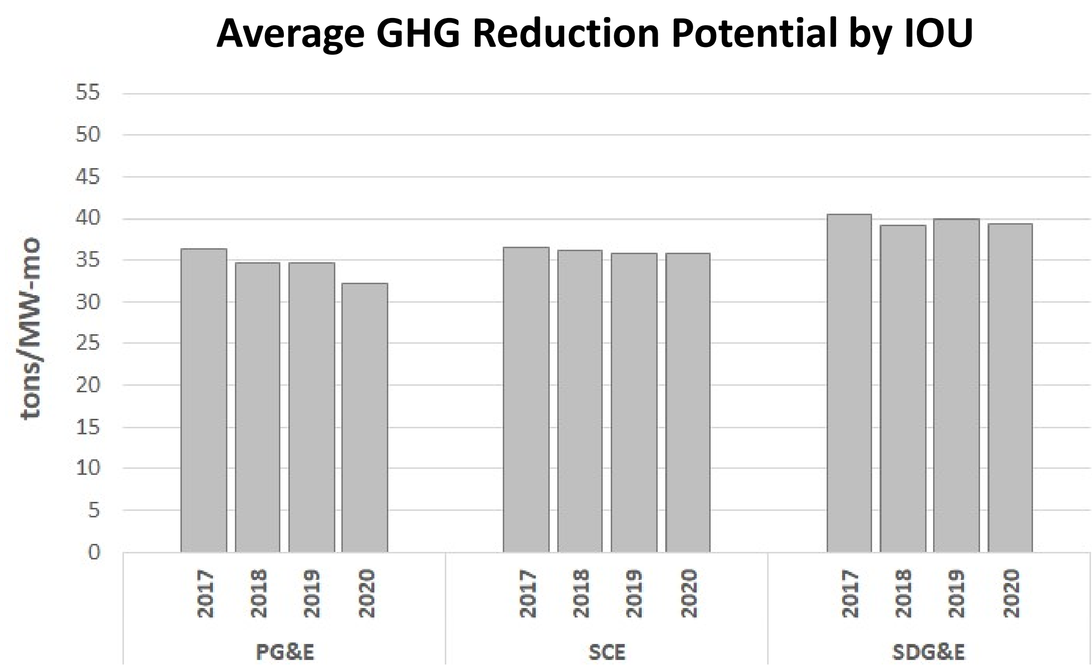


Source: Lumen analysis using WattTime's GHG signal for SGIP.

- 4-hour storage with 80% roundtrip efficiency would optimally charge in bottom 20 15-minute intervals and discharge in top 16 intervals
  - Hypothetical assuming no other dispatch signal
  - One cycle per day
- Yields an average of ~1 ton per MW-day in GHG emissions reductions
  - Reference: Solar running at 25% CF would reduce GHG emissions by 2.5 ton/MW-day if it displaced gas

Sensitivity to Market Conditions



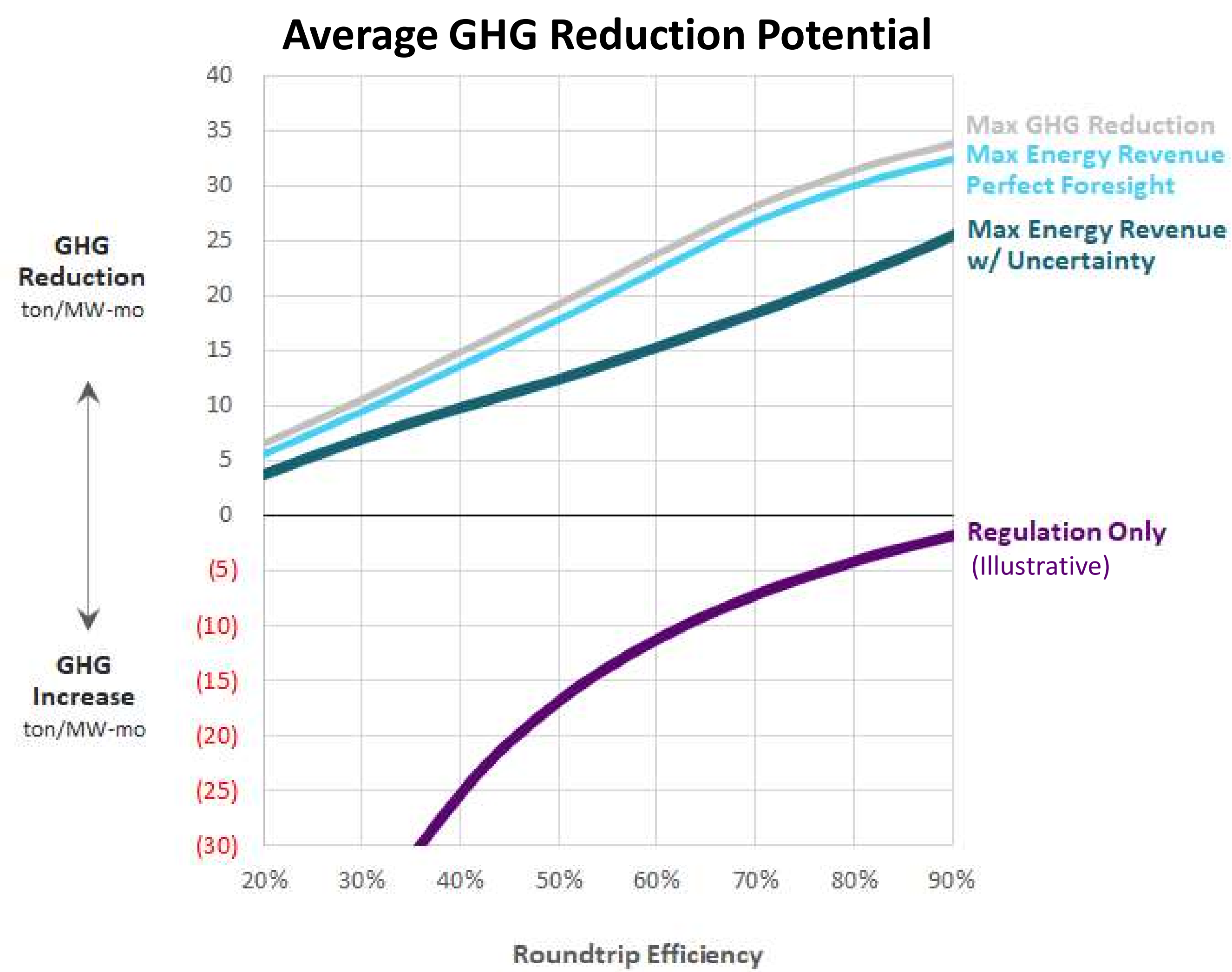


Source: Lumen analysis using WattTime's GHG signal for SGIP.

- GHG reduction potential tends to be seasonal (higher in Spring) and depends on location (higher in southern California)
- Largest GHG reduction opportunities in days/locations when renewables are on the margin (GHG rate is zero) during charging

Sensitivity to Use and Operating Constraints

- Potential GHG emissions reductions are sensitive to:
  - Roundtrip efficiency
  - Market foresight & uncertainty
  - Use case: Energy vs. A/S
- **Modeled regulation-only dispatch increases emissions**
  - Regulation signals uncorrelated with GHG rates + mileage amplifies volume of losses
- We also note that extended standby lowers efficiency and reduces GHG benefits

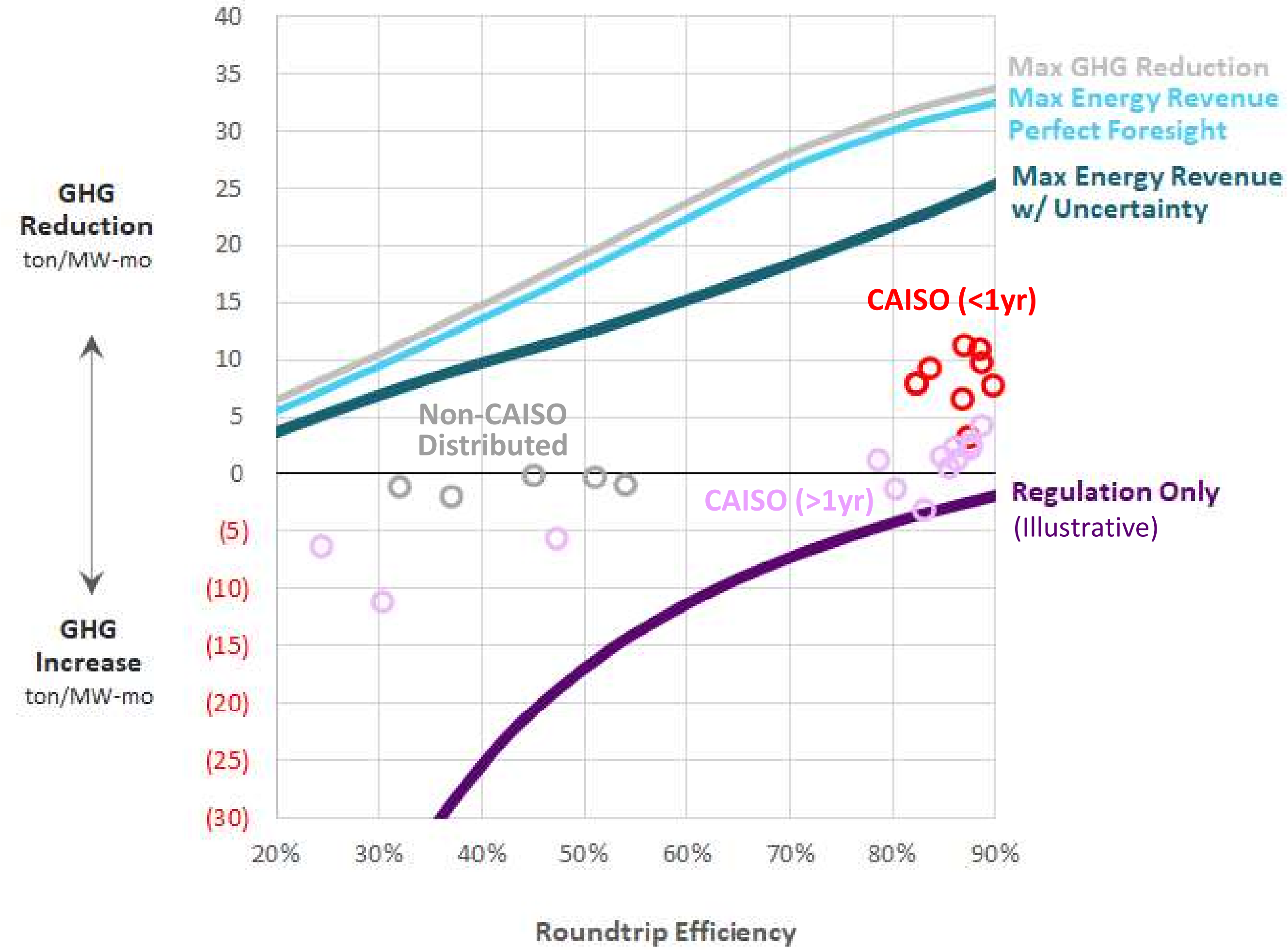


Source: Lumen analysis using WattTime's GHG signal for SGIP and CAISO historical real-time and day-ahead LMPs.

Preliminary GHG Impact Results

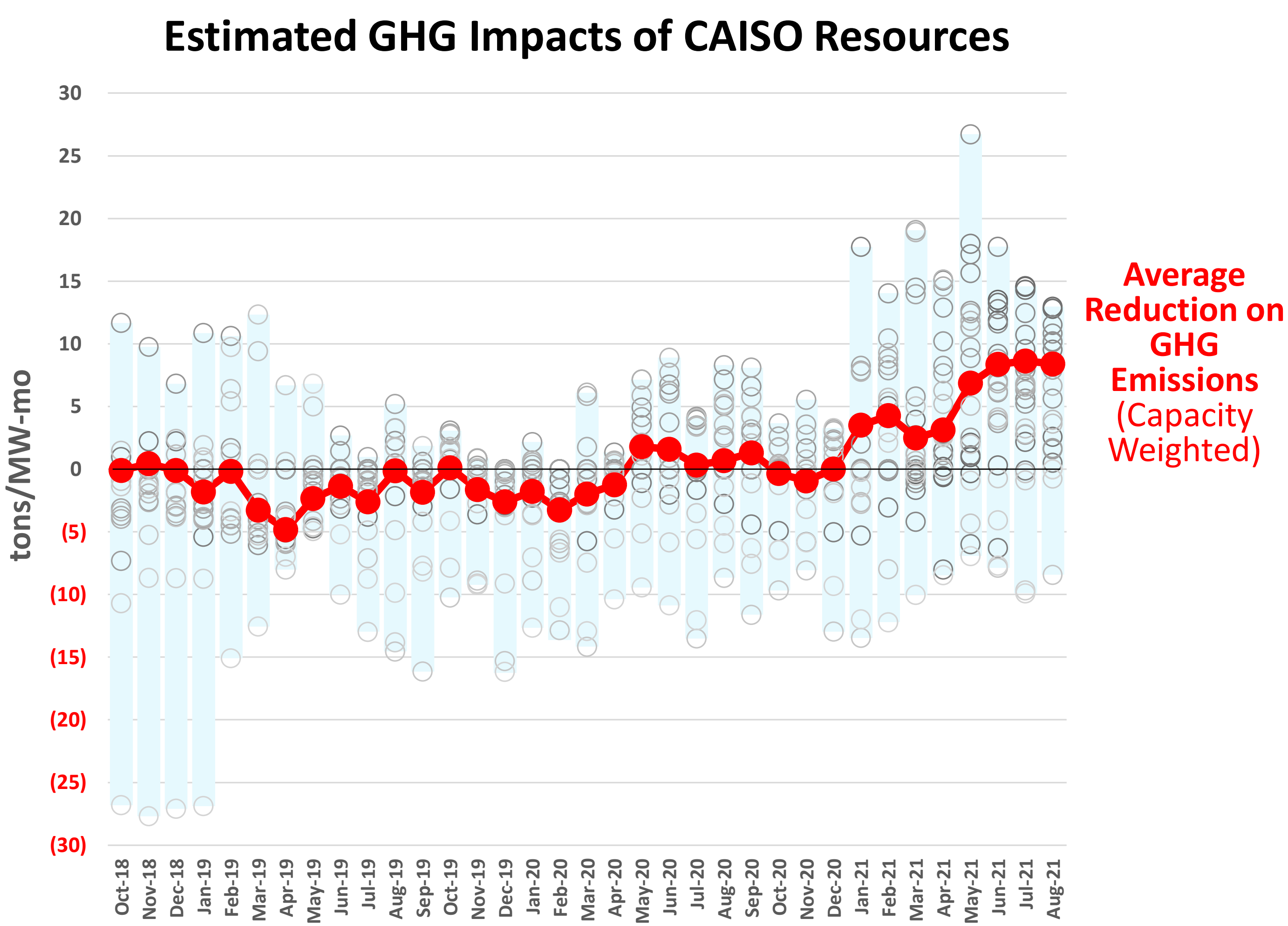
- While most CAISO-participating projects helped reduce GHG emissions, their impact has been lower relative to abatement potential
  - Older CAISO-participating resources reflect GHG increases from a more regulation-focused dispatch (purple markers)
  - Newer CAISO-participating resources reflect GHG reductions from a more energy time shift-focused dispatch (red markers)
  - Non-CAISO-participating resources reflect slight GHG increases from distribution-level use cases with storage mostly on standby (grey markers)

Average Estimated GHG Impact



Source: Lumen analysis using WattTime's GHG signal for SGIP, CAISO historical real-time and day-ahead LMPs, and energy storage operational data provided by stakeholders.

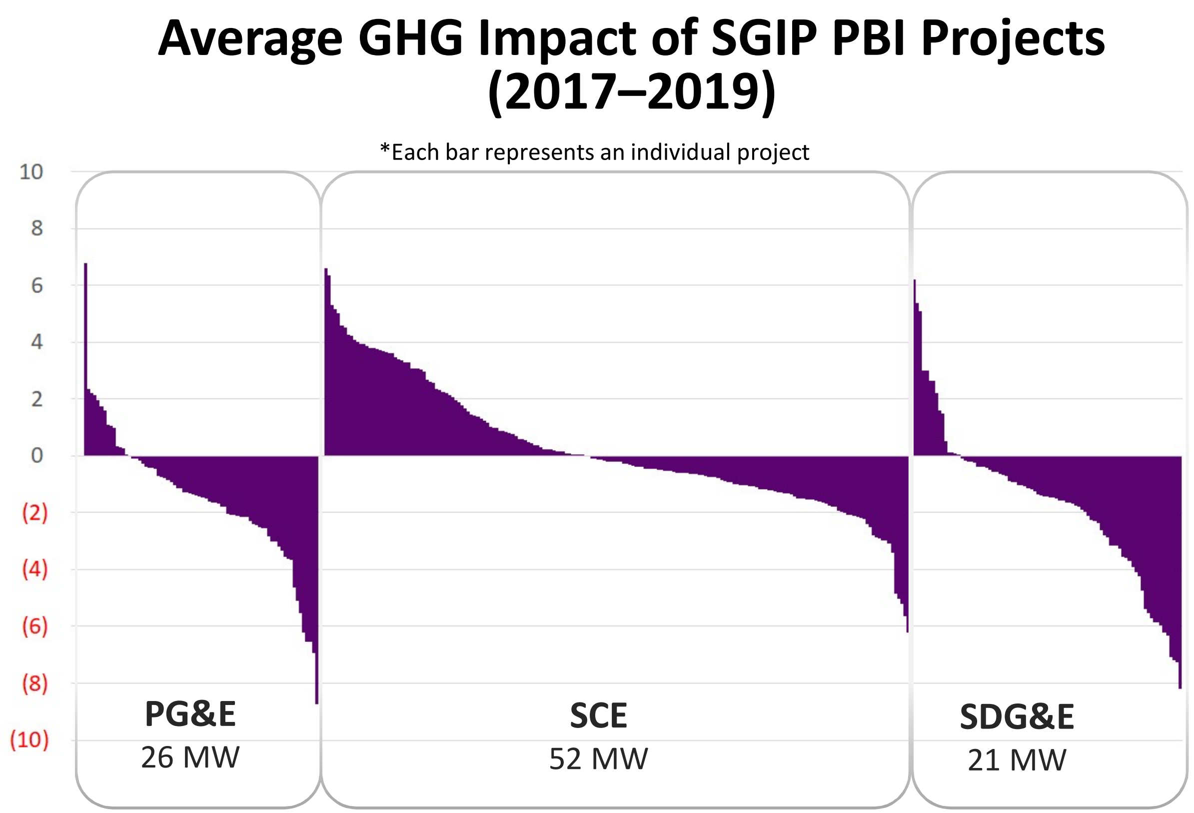
GHG Impact of Storage over Time



- With more focus on ancillary services and inefficient operations of earlier pilot projects, the average GHG impact of energy storage fleet have remained small or negative until recently
- Increased use for energy time-shift and peak capacity created an upward trend in GHG savings in 2021
- This recent trend will likely continue going forward

Source: Lumen analysis based on 5-minute metered quantity reported under CAISO energy market settlements and WattTime's GHG signal for SGIP. Results normalized by nameplate capacity (MW). Each circle represents an individual resource.

GHG Impact of SGIP Projects (non-Residential PBI)



Source: Lumen analysis of resources subject to the Self-Generation Incentive Program's Performance-Based Incentives. GHG impact is calculated based on WattTime's GHG signal for SGIP.

- Without a market signal on grid conditions, most PBI project had little GHG savings or contributed to increase in GHG emissions through 2019
- This is recognized in SGIP impact studies and CPUC incorporated GHG signals for program compliance starting 2020 (same signals utilized in our analysis; developed by WattTime)
- We will evaluate how this affected GHG emissions during 2020–2021 (data pending)

Next Steps on GHG Impacts Analysis

- Expand analysis of customer-sited projects
  - Add residential SGIP and non-SGIP customer-sited projects, subject to data availability
  - Add more recent years (2020–2021), subject to data availability, and observe effects of newer PBI rules
- Run sensitivity using WattTime's alternative marginal GHG rate calculation methodology which uses a statistical approach instead of implied market heat rates
- Estimate avoided GHG abatement costs
  - Short-term marginal cost of GHG abatement based on cap & trade market already included in energy value calculations
  - Will only include "GHG adder" for meeting GHG reduction goals through investments in electricity sector based on RESOLVE GHG shadow prices used in CPUC's 2021 Avoided Cost Calculator

Q&A

—Drivers of GHG reduction potential

—Estimated GHG impacts

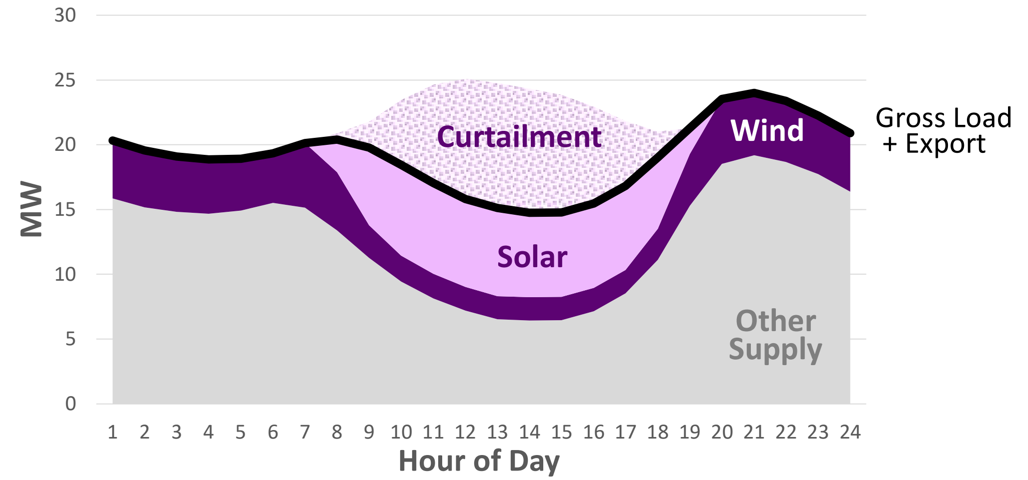
—Observed change in GHG impacts over time

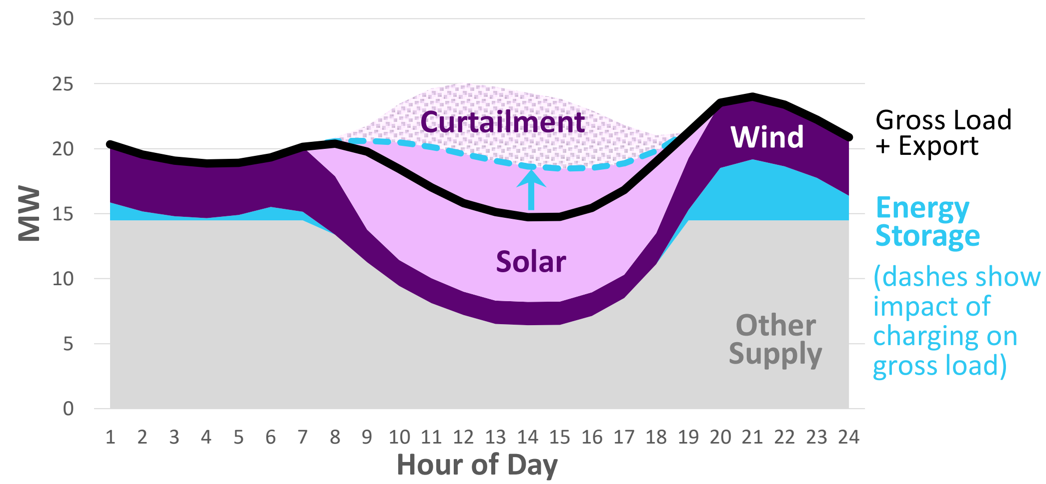
Impact on Renewable Curtailments

Impact on Renewable Curtailments

- **Analyze historical storage charge/discharge during periods with actual renewable curtailments**
  - Charging reduces curtailments by mitigating oversupply conditions
  - Discharging increases curtailments by exacerbating oversupply conditions
  - Important to differentiate curtailments driven by local vs. system-wide constraints
- **Avoided renewable curtailments reduces the need (and costs) to procure additional resources to meet Renewable Portfolio Standard targets**

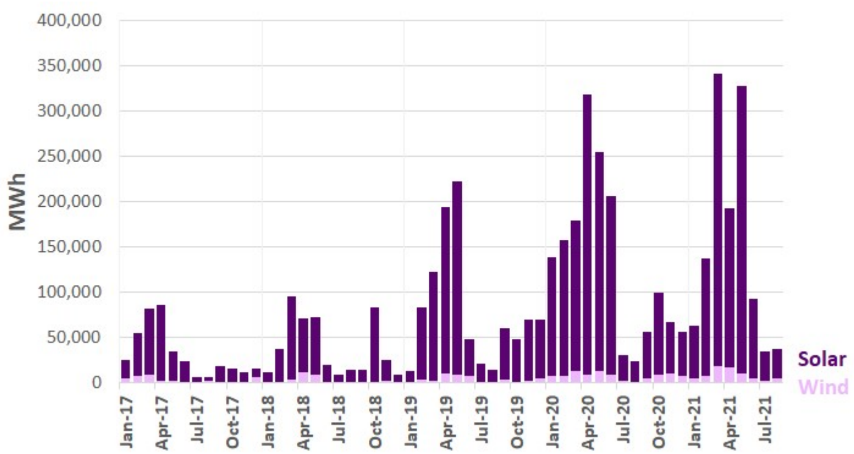
Illustration of Renewable Curtailments with and without Energy Storage



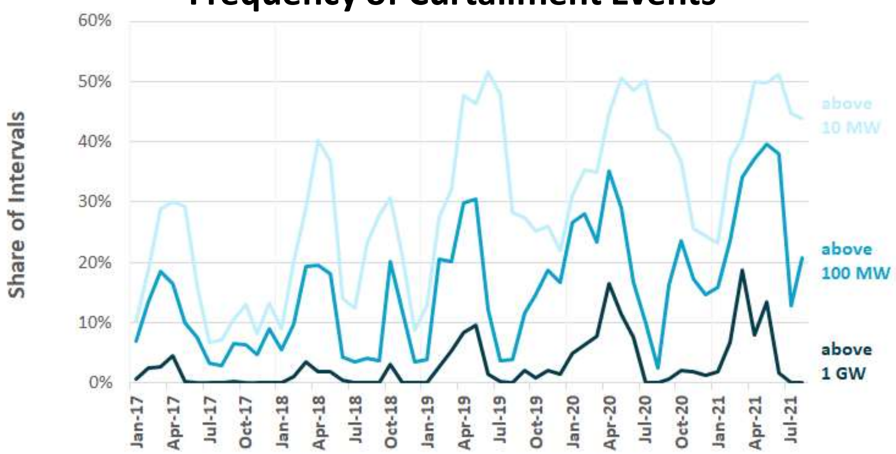


Curtailment Trends and Value Potential

Aggregate Renewable Curtailments in CAISO



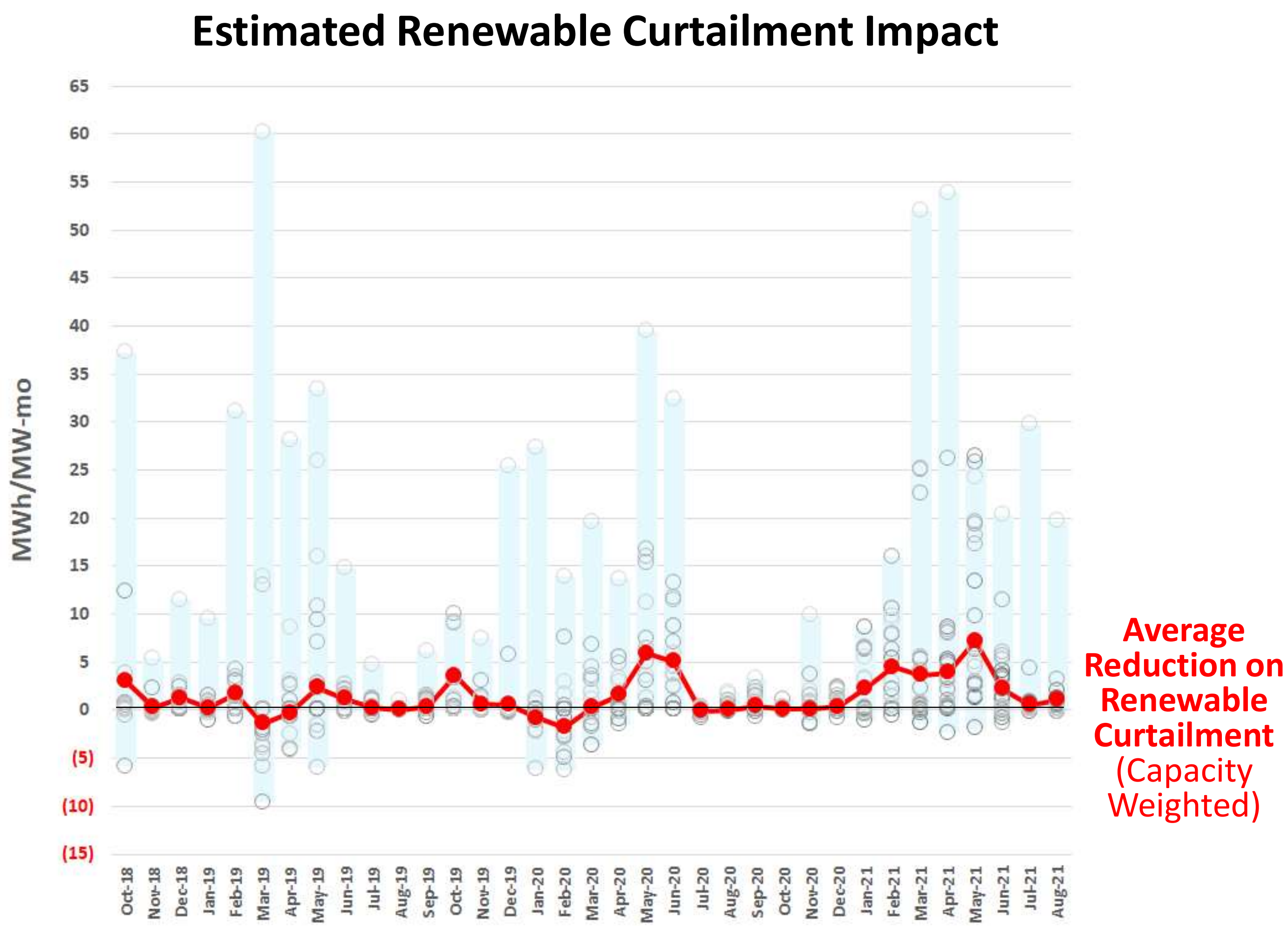
Frequency of Curtailment Events



Source: Lumen analysis of CAISO renewable curtailment data available at www.caiso.com/informed/Pages/ManagingOversupply.aspx.

- Curtailments on the rise (esp. for solar)
- Most events driven by local constraints
- Use nodal LMP to determine if storage is in the area with local constraint driving curtailments
- Value potential:
  - Our analysis of historical curtailments and LMP data (2018–2021) suggest operational storage facilities could have reduced curtailments in 1–2 hours/day on average (depending on location) if they charged during intervals w/ curtailments
  - This translates to 30–60 MWh of monthly curtailment reduction per MW of storage capacity
  - At $50/MWh marginal REC cost, this would be $1.5–$3 per kW-month of potential value

Preliminary Results on Curtailment Impact



- Impact of storage resources on renewable curtailments has been relatively small so far—except for a few units
- Going forward, with more emphasis on energy time-shift (vs. AS) and increased system-wide curtailment events, we expect future impact to be higher than what we observed historically

Source: Lumen analysis based on 5-minute metered quantity reported under CAISO energy market settlements, CAISO renewable curtailments, and nodal LMPs. Results normalized by nameplate capacity (MW). Each circle represents an individual resource.

Next Steps on Renewable Curtailment Analysis

- Analyze impact of non-CAISO distribution- and customer-sited storage resources
- Monetize RPS benefit (or cost) for each resource
  - Lower curtailments reduce the need for overbuilding renewable resources to meet RPS targets
  - Incremental RPS benefits based on estimated REC value = marginal renewable cost net of energy and capacity value
- Consider possible GHG reductions in renewable overbuild counterfactual (to avoid double-counting RPS and GHG benefits)

Q&A

—Observed renewable curtailment trends

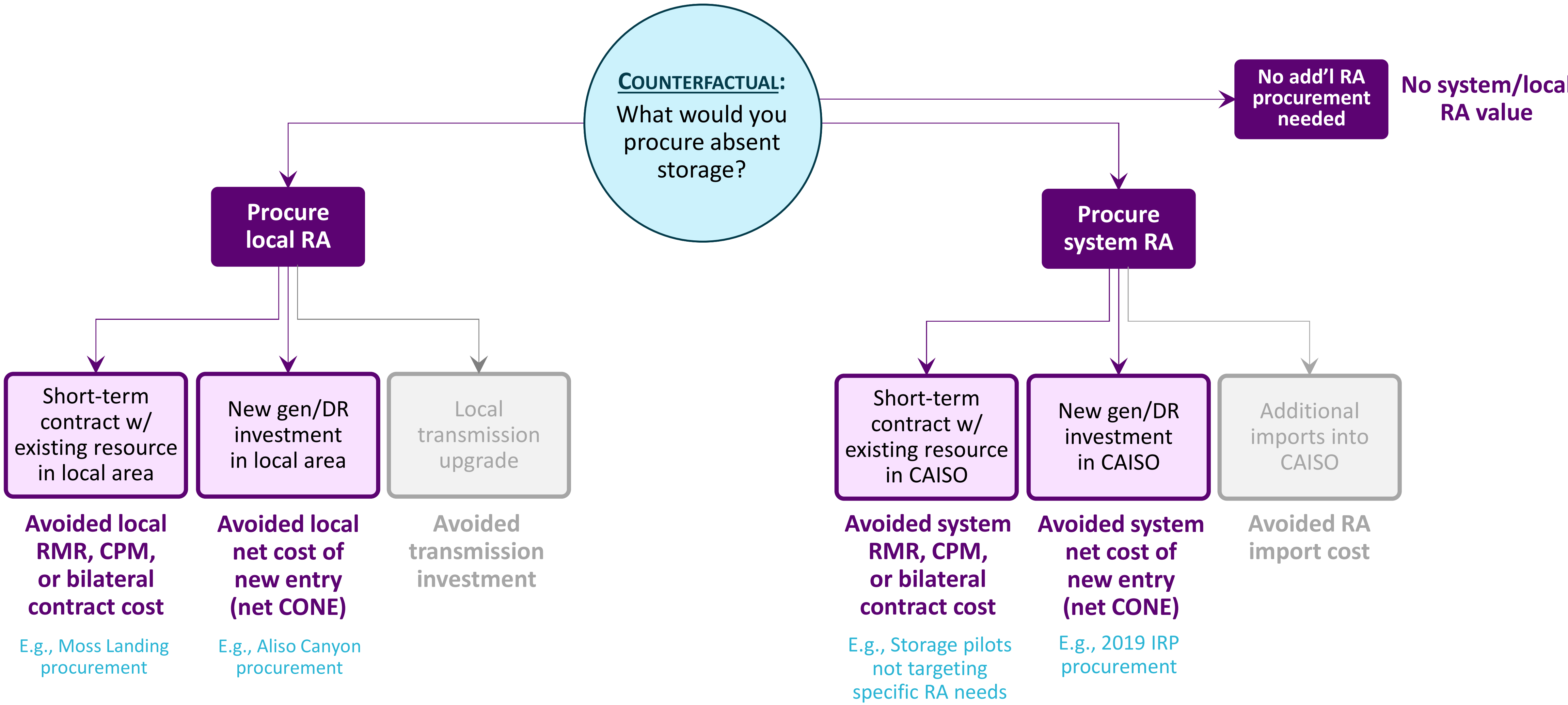
—Estimated curtailment impacts

5-MINUTE BREAK

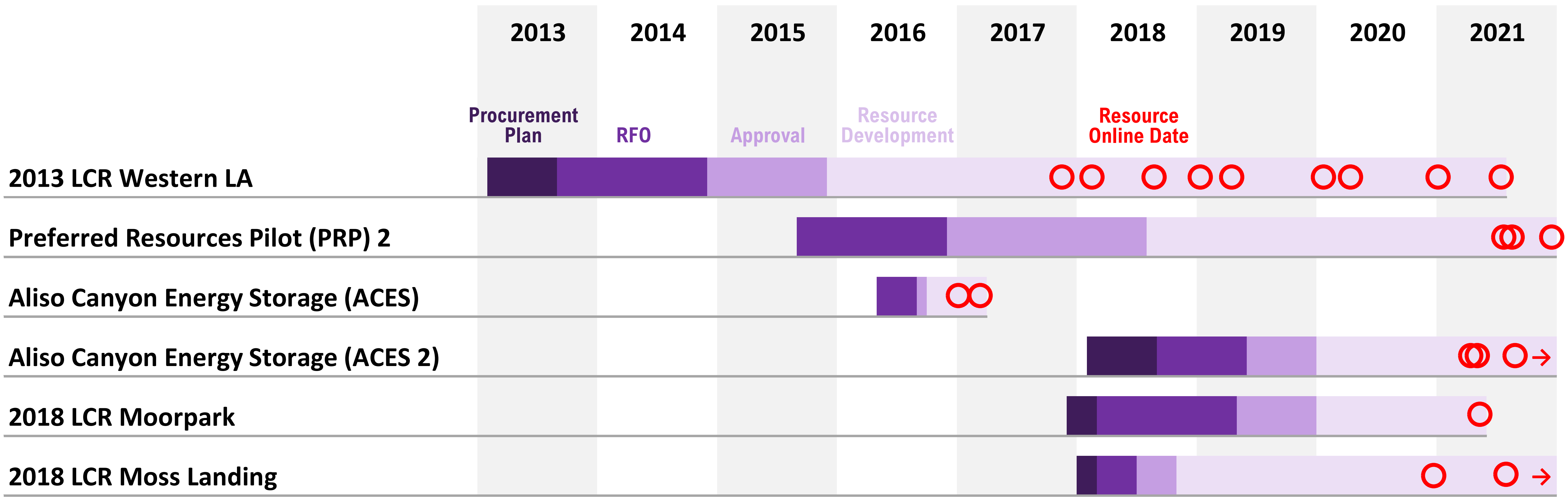
NEXT UP: RA COUNTERFACTUALS & VALUE RANGE

RA Counterfactuals & Value Range

Capacity Value: Creating the Counterfactual



Procurement Timeline



Source: Lumen research on utility applications and CPUC decisions on various resource procurement tracks, and other public information on project status.

2013 LCR Western LA

- CPUC authorized SCE to procure 1,900–2,500 MW of capacity in Western LA to meet long-term local capacity need by 2021
  - Minimum of 550 MW from Preferred Resources + 50 MW from Energy Storage
- SCE's LCR RFO selected:
  - 264 MW Energy Storage
  - 237 MW Preferred Resources (EE, DR, renewables)
  - 1,284 MW Gas Combined-Cycle
  - 98 MW Gas Peaker

Total ES + preferred resource procurement remained below requirement due to a last-minute withdrawal of a selected offer. Resulting "gap" addressed in the PPR 2 RFO (see next slide).

- Without energy storage and preferred resources carveout, it is likely that additional gas-fired resources would be procured to meet the local capacity need
- We will estimate RA value based on offer prices of marginal gas peakers participated in the same RFO

Preferred Resources Pilot (PRP) 2

- SCE's PRP 2 RFO intended to fill the gap from 2013 LCR RFO and help with the outstanding LCR need in Western LA driven by OTC and SONGS retirement
  - In 2013 LCR RFO, total amount of Preferred Resources + Energy Storage procured was below the minimum requirement due to last minute withdrawal of a project
- Timeline for the RFO overlaps with the unexpected challenges created by the Aliso Canyon gas leak in southern California in 2016
- New gas-fired generation would not be a plausible alternative for the PRP 2 projects, due to gas supply constraints related to Aliso Canyon
- Demand Response (DR) is the most viable resource to consider in the counterfactual case
- We will estimate RA value based on offer prices of non-storage DR resources participated in the PRP RFO and DRAM auctions

Aliso Canyon Energy Storage (ACES)

- Aliso Canyon gas leak in Southern CA reduced gas supply and created an unexpected and very urgent need to procure new resources to address reliability concerns
- Expedited procurement:
  - CPUC adopted Aliso Canyon Resolution (E-4791) ordering SCE to procure energy storage resources that can be online by Dec 31, 2016
  - Energy storage identified as a potential solution, because they are dispatchable resources and they can be deployed on a short timeline
  - Resources must be interconnected to the CAISO grid South of Path 26
- Demand Response (DR) appears to be the only viable alternative for counterfactual, given the expedited timeline
- We will estimate RA value based on incremental DR costs as of 2016/17
  - In June 2016, CPUC approved SCE's proposal to spend an additional $8.7 million on various DR programs to mitigate gas shortages related to Aliso Canyon

ACES 2 and 2018 LCR Moorpark

- Pursuant to SB 801, CPUC directed SCE to deploy at least 20 MW of storage to address continued reliability concerns related to Aliso Canyon
- In parallel, SCE was trying to procure resources to address local reliability concerns in Moorpark
  - Two RFOs (ACES 2 and Moorpark LCR) resulted in a combined 225 MW of energy storage in the Moorpark sub-area
- Without energy storage, local capacity need in Moorpark would be addressed by a combination of new gas-fired generation and DR
  - Moorpark LCR deficiency initially identified in 2013 driven by OTC retirements
  - 2013 RFO selected a 262 MW gas peaker at the time, but CEC eventually recommended against permitting the plant due to environmental concerns
  - CEC's decision informed by a CAISO study finding Preferred Resource alternatives are feasible, but their economic viability can only be established through a new expedited RFO
  - Non-storage DR is difficult to scale within the local sub-area, so counterfactual would include the cancelled gas peaker
- We will estimate RA value based on blended cost of the cancelled gas peaker and non-storage DR (up to 20 MW)

2018 LCR Moss Landing

- In 2018, CPUC ordered PG&E to procure energy storage or preferred resources to eliminate the need for RMR contracts in Moss Landing
- While PG&E was conducting the LCR RFO, CAISO identified transmission upgrades to address local deficiency in Moss Landing
  - CAISO continued to support energy storage procurement in Moss Landing to reduce risk of future deficiencies
- Even though CAISO's transmission solution addressed immediate RMR needs in Moss Landing, this would have been a temporary relief without energy storage
  - E.g., In CAISO's 2022 LCR study, Moss Landing subarea would have a capacity deficiency if storage and Metcalf were not included
- Based on this, we will assume counterfactual for Moss Landing projects would include RMR resources and will estimate their RA value using the negotiated 2018 contract price w/ Metcalf

RA Counterfactuals and Value Ranges

Procurement Track	Specific Capacity Need Addressed	Type of Resource Procured in Counterfactual	Approach to Estimate System/Local RA Value	Estimated System/Local RA Value (2022 $/kW-month)
2013 LCR Western LA	Local capacity needs in Western LA to replace OTC & SONGS retirements	New gas peaker	Net CONE based on 2013 LCR RFO bids	**$15–$20**
Preferred Resources Pilot (PRP) 2	Same as above; Fill in shortfall of Preferred Resources in the 2013 LCR relative to min. requirement	New demand response	Net CONE based on DR cost	**$20–$25**
Aliso Canyon Energy Storage (ACES)	Urgent reliability needs in Southern CA due to gas supply limitations related to Aliso Canyon	New demand response	Net CONE based on DR cost	**$20–$30**
Aliso Canyon Energy Storage (ACES 2)	Same as above; PLUS local capacity needs in Moorpark	New gas peaker and DR	Net CONE based on cancelled contract w/ gas peaker and DR costs	**$13–$17**
2018 LCR Moorpark	Local capacity needs in Moorpark to replace OTC retirements	New gas peaker and DR	Net CONE based on cancelled contract w/ gas peaker and DR costs	**$13–$17**
2018 LCR Moss Landing	Local capacity needs in Moss Landing to replace existing RMR generation	Existing RMR resources	Avoided RMR cost based on Metcalf contract	**~$7**
Other	N/A	Existing generic resources	Short-term bilateral RA contracts	**$3–$7**

Next Steps on RA Value

- Estimate project-specific RA values
  - CAISO resources: NQC
  - BTM load modifying resources: Capacity contribution based on net discharge during top hours w/ largest net system load
- Estimate incremental flexible RA values
  - Market data suggests little/no incremental value (historically)
  - Small difference when compare RA prices of resources providing flexible RA vs. not
  - Final determination based on statistical analysis of RA contract prices, using flexible RA attribute as an explanatory variable
- Report projects' performance during supply-constrained hours

Q&A

—Observed procurement track-specific circumstances and resource adequacy needs

—RA counterfactuals and value ranges

Customer Outage Mitigation Potential

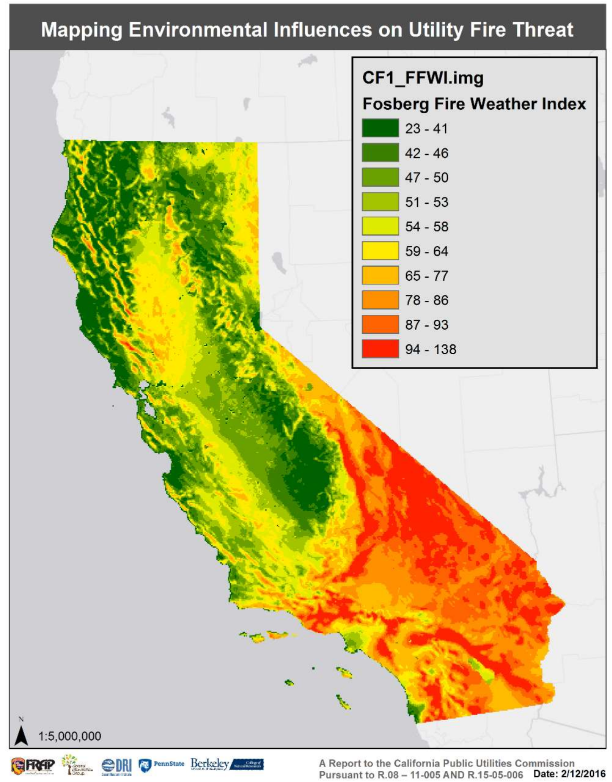
Purpose of Today's Discussion on Customer Outage Mitigation Value

- Estimates of actual historical impacts are in progress
- Value of lost load (VOLL) is a key piece of information… that is missing
  - VOLL is the cost to customers and the economy of not having electricity available due to service interruptions, typically expressed in $/MWh or $/kWh
- Certain investment decisions can be appropriately prioritized with relative VOLL estimates, rather than absolute $/MWh
- But since our historical study stacks multiple value streams of storage in all domains, we need an absolute outage mitigation impact metric that is monetized and comparable to energy and resource adequacy value
- Given the wide range of VOLL estimates available and lack of California-specific data on multi-day outage events, we plan to run sensitivities on VOLL inputs and welcome stakeholder feedback

Customer Outage Mitigation Value

- **Review operations of distributed & customer-sited storage projects during historical outage events**
  - Consider only “upstream” outages that can be mitigated
- **Estimate outage reduction value based on:**
  - Storage discharge during outage event
    - *May also count co-located solar MWh if it would have been disconnected during outages*
  - Mix of electricity customers downstream from the storage facility
  - Assumed value of lost load (VOLL) for each customer and outage type

Public Power Safety Shutoffs



Starting in 2017, California IOUs implement targeted extended outages (Public Power Safety Shutoffs) to mitigate short-term wildfire risk.

Image source: Sapsis, David, et al., “Mapping Environmental Influences on Utility Fire Threat,” February 16, 2016, Figure 10.

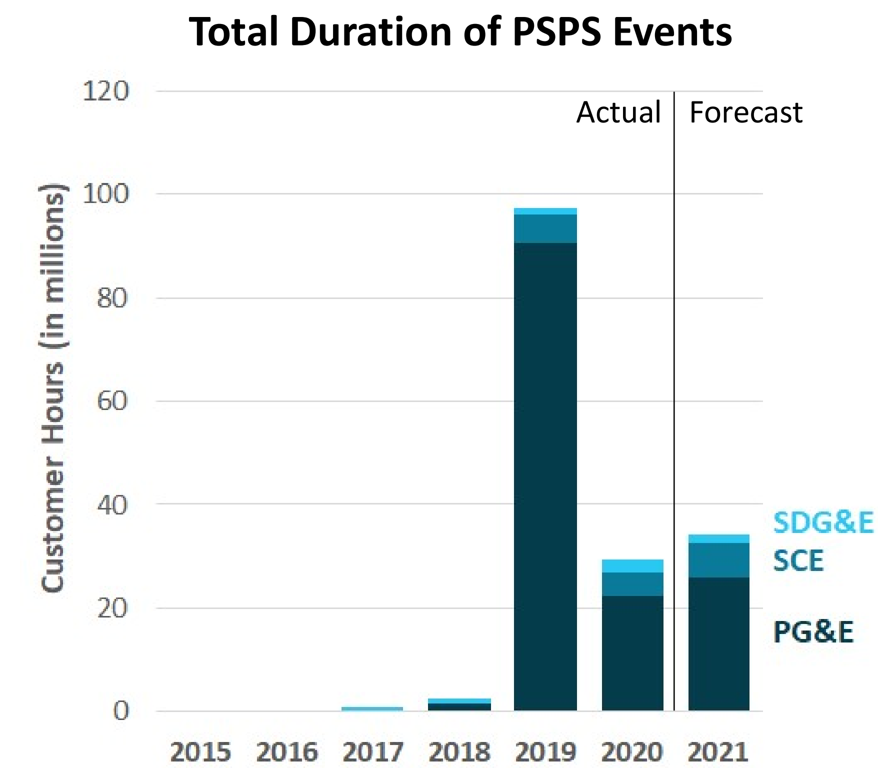
Bulk Grid Outages

The California ISO may order load interruptions under a Stage 3 Emergency due to extreme constraints on the system, as seen in August 2020.

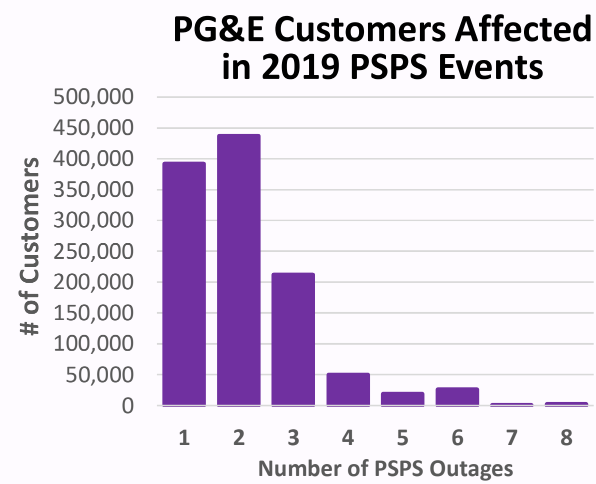
Image source: California Independent System Operator, “System Alerts, Warnings and Emergencies,” Fact Sheet, 2018.

Extended Customer Outages due to PSPS

With Public Safety Power Shutoffs (PSPS) multi-day outages has become the new normal for many customers in California



Source: Utility 2021 Wildfire Mitigation Plans.



- PG&E's 2019 PSPS events affected 1.1 million customers (20%)
- With each event taking ~2 days, these customers' service was interrupted for **4 days on average**

  (= 90 million customer hours divided by 1.1 million customers)

Source: PG&E's 2020 Wildfire Mitigation Plan.

While number of customers affected dropped in 2020 with more targeted interruptions, PSPS-related customer outages expected to remain significant in the foreseeable future

Value of Lost Load (VOLL) Estimates

- **VOLL studies traditionally focus on short-duration outages lasting less than a day**
  - An LBNL/Nexant meta-analysis of 34 VOLL studies (Sullivan et al., 2015) estimates average VOLL at $1–$3 per kWh for residential customers, $12–$22 per kWh for medium C&I customers, and >$200/kWh for small C&I customers (in 2013 dollars, for interruptions of 1–16 hours)
    - Extrapolating residential VOLL estimates for a daily outage would be ~$60/day in 2021 dollars

- **Some new work emerging, but no study currently available on VOLL to Californians**
  - Interruption Cost Estimate (ICE) Calculator is focused on short-duration outages, based on the LBNL/Nexant study that notes it does not capture the full effects of long-duration outages
  - The microgrid proceeding's RMWG highlighted the Power Outage Economic Tool (POET) under development as a "prototype extension of the ICE calculator" by LBNL/ComEd (Illinois), but it will have limitations in applicability to California until California customers are studied
  - A recent study in New England (Baik et al., 2020) found residential customers' stated willingness to pay at $2.3–$3.3/kWh, or $70–$100/day, to avoid a 10-day winter outage, but customer energy use and substitution options to meet essential needs (e.g., gas-fired heating) in New England are very different from California

Value of Lost Load (VOLL) Estimates (cont'd.)

- **Available VOLL estimates likely underestimate impact in California**
  - VOLL is tied to both $ lost and but-for kWh usage; cannot multiply a VOLL developed elsewhere against California customers' low energy consumption, well below national average
    - CA customers consume an average of 17 kWh/day residential, 173 kWh/day commercial, 767 kWh/day industrial (EIA-861 2018)
    - The New England study (Baik et al., 2020) is based on 30 kWh/day residential consumption; would need to adjust VOLL up to $4.1–$5.8 per kWh to get same $70–$100/day residential willingness-to-pay
  - Buying a $1,000 diesel generator to avoid home outages due to PSPS for the next 2–5 years roughly implies a revealed willingness-to-pay of $100–$200/day (or $6–$12/kWh) including fuel and assuming 4 outage days per year
  - Microgrid proceeding's RMWG highlighted an economic case study that implies a $140/day (or $8.3/kWh) residential outage impact
    - Half of the estimated cost is from lost income near federal poverty level—so it may underestimate costs
  - VOLL likely higher for medical baseline customers, customers reliant on A/C during life-threatening heatwaves, critical sites serving communities and providing essential infrastructure, and other vulnerable customers
  - With whole-home electrification and traditional energy substitutions phased out, VOLL will also be higher

Sample Calculation of Outage Mitigation Value Potential:

Residential Customer

Illustrative Example:

Residential Customer Experiencing Public Safety Power Shutoffs

- Outage duration: 4 days per year
- Electricity consumption: 17 kWh/day
- VOLL: $60–$200/day ($3.5–$11.8/kWh)
- Storage system size: 5 kW/13 kWh (paired w/ solar)

Estimated Customer Outage Cost:

4 days/year

× $60–200/day VOLL

= $240 to $800 per year

Outage Mitigation Value Potential for Storage:

($240 to $800)

÷ 5 kW

÷ 12 months

= **$4–$13 per kW-month**

Sample Calculation of Outage Mitigation Value Potential:

Commercial Customer

Illustrative Example:

Commercial Customer Experiencing Public Safety Power Shutoffs

- Outage duration: 4 days per year
- Electricity consumption: 300 kWh/day
- VOLL: $3,600–$6,600/day ($12–$22/kWh)
- Storage system size: 100 kW/200 kWh (paired w/ solar)

Estimated <u>Customer Outage Cost</u>:

4 days/year

× $3,600–$6,600/day VOLL

= $14,400–$26,400 per year

Outage Mitigation <u>Value Potential for Storage:</u>

($14,400 to $26,400)

÷ 100 kW

÷ 12 months

= **$12–$22 per kW-month**

Closing Remarks

Summary of Preliminary Observations

- **Improvements to data collection, retention, and centralization are crucial to understanding and evaluating cross-domain investments like energy storage**

- **California's market for energy storage development shows significant growth, cost decreases, and expansion of services available**
  - A variety of use cases have been tested and are in place (e.g., energy and ancillary services, voltage support, local and system capacity, distribution deferral, microgrid/islanding, bill management, backup power)
  - The CPUC's AB 2514 energy storage mandate is largely met (pending units under development) and it set the stage for an <u>additional</u> 5,000 MW of IRP, RPS, and RA-related procurements—half by non-IOU LSEs
  - Many storage benefits have a locational aspect and procurements tend to focus on higher-valued areas
  - Storage costs have declined across all domains, and for both third party and utility-owned projects
  - Wholesale market value is currently at an inflection point with ancillary services value declining, and energy and GHG emissions reduction value increasing
  - Avoided renewable curtailments so far are relatively small, although we see evidence that this value stream will grow over time as the state moves towards its 100% clean energy target

Summary of Preliminary Observations (cont'd)

- **The storage market has made progress with multi-use applications, but challenges remain:**
  - Many initial pilot and proof-of-concept projects necessarily focused on a narrowly-defined use case (such as distribution deferral, local distribution system stability)
  - Value-stacking is still limited in scale and barriers remain
  - Most customer-sited resources and many distribution-sited resources do not participate in the CAISO wholesale marketplace and operations are not in alignment with wholesale market signals
  - No actual specified transmission wires deferrals are observed, and distribution wires deferrals are limited
- **We observe the following situations & use cases increase GHG emissions and energy costs:**
  - Ancillary services as a primary use case—due to mileage, losses, noise-like charge/discharge profile
  - Use cases with storage mostly on standby (microgrid, local reliability, distribution deferral)—due to standby losses
  - Use cases not integrated with a wholesale market signal, such as SGIP before performance requirements (pre-2020)
- **Customer outage mitigation may be a significant resiliency benefit stream for distributed storage and vulnerable customers, but extremely limited information on Value of Lost Load makes this impact difficult to estimate**

Your Feedback

- Questionnaire will be posted on study website
  - lumenenergystrategy.com/energystorage
  - Please submit your responses by close of business **October 15, 2021**
- We seek your perspective on actual energy storage development and operating trends through 2021
  - Based on your experiences (not aspirational)
  - Response on each topic or type of evaluation metric is limited to 1,000 characters
  - A summary of the feedback we receive will be included in the next workshop

Other Communication Channels

Go to lumenenergystrategy/energystorage for information on:

- Office hours with the study team
- How to share your insights on relevant industry reports and studies
- How to track our announcements and information we share
  - If you subscribe to our emails, please add energystorage@lumenenergystrategy.com to you address book

Next Steps

- **Stakeholders to provide feedback on our preliminary observations by close of business October 15, 2021**
- **We will review and consider your feedback as we continue our analysis**
- **Workshop #3 in Q1 2022**
  - Summarize stakeholder feedback
  - Preliminary findings on energy storage project evaluations
  - Notable successes and challenges

Thank You!