Energy Storage for Greenhouse Gas Emissions Reduction

July 30, 2024

A Presentation of the Energy Storage Technology Advancement Partnership (ESTAP)

Webinar Logistics

We are using the newly updated version of GoToWebinar!
Thank you for your patience as we get used to this new platform. We encourage you to provide feedback in the post-webinar survey or via email.

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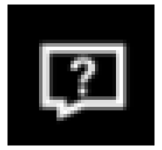
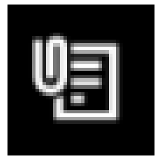
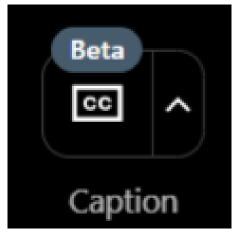
Submit questions and comments via the Questions panel 

Speaker bios available in the “Materials” section 

Automated **captions** are available 

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Celebrating 20 Years of State Leadership

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The Clean Energy States Alliance (CESA) is a national, nonprofit coalition of public agencies and organizations working together to advance clean energy.

CESA members—mostly state agencies—include many of the most innovative, successful, and influential public funders of clean energy initiatives in the country.

Clean Energy States Alliance

www.cesa.org

State of California Energy Commission

Connecticut Green Bank

Department of Energy & Environment

Energy Trust of Oregon

IPA Illinois Power Agency

Maine Governor's Energy Office

State of New Hampshire Department of Energy

Massachusetts Clean Energy Center

Maryland Energy Administration

EGLE Michigan Department of Environment, Great Lakes, and Energy

BPU New Jersey Board of Public Utilities

New Jersey's cleanenergy program — njcleanenergy.com

New Mexico emnrd Energy, Minerals and Natural Resources Department

New York State NYSERDA

mn Commerce Department

SMUD Powering forward. Together.

State of Rhode Island Office of Energy Resources

Vermont Department of Public Service Clean Energy Development Fund

Virginia Energy

Rhode Island Commerce Corporation

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Illinois Commerce Commission ICC

OEI Wisconsin Office of Energy Innovation

Prairie Island Indian Community in the State of Minnesota

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Connecticut Energy & Environment

DOER Massachusetts Department of Energy Resources

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Colorado Energy Office CEO

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OPC-DC Office of the People's Counsel — Advocacy | Education | Protection

Energy Storage Technology Advancement Partnership (ESTAP)

Conducted under contract with Sandia National Laboratories, with funding from US DOE Office of Electricity.

- Facilitate public/private partnerships to support joint federal/state energy storage demonstration project deployment
- Support state energy storage efforts with technical, policy and program assistance
- Disseminate information to stakeholders through webinars, reports, case studies and conference presentations

www.cesa.org/ESTAP

Thank You!

Dr. Imre Gyuk

Director, Energy Storage Research,
U.S. Department of Energy

Waylon Clark

Energy Storage Program Demonstration Team Lead,
Sandia National Laboratories

Webinar Speakers

Imre Gyuk
US Department of Energy Office of Electricity

Brian McAuley
Verdant Associates

Stephan Wollenburg
Sustainable Energy Advantage

Todd Olinsky-Paul
Clean Energy States Alliance

U.S. DEPARTMENT OF ENERGY

Sandia National Laboratories

Clean Energy States Alliance

Clean Energy States Alliance

todd@cleanegroup.org

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California's Flexible Demand Appliance Standards for Pool Controls Program – Employing Load Shifting to Lower Peak Demand and Avoid Emissions (8/15)

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ENERGY STORAGE FOR GHG EMISSIONS REDUCTIONS

Brian McAuley, Verdant Associates

CESA Webinar, 7/30/2024

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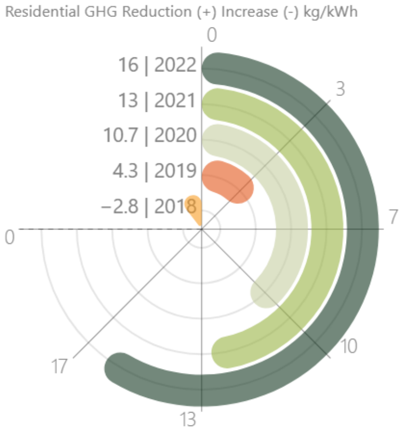
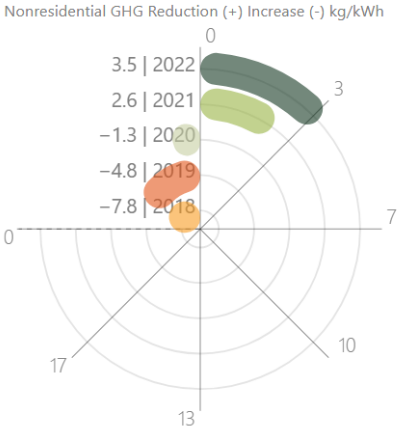
INTRODUCTION

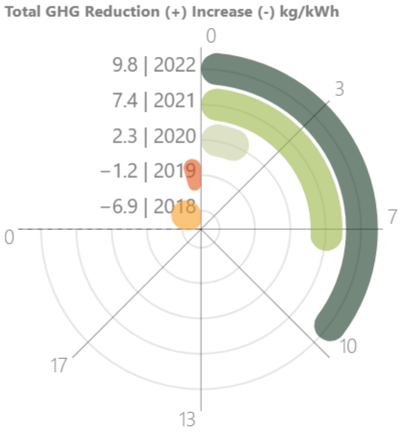
- Brief history of the SGIP and M&E objectives
- Results from recently completed SGIP Impacts Evaluation for 2021 and 2022
  - BTM energy storage receiving SGIP equipment incentives
- Explore different ways energy storage technologies are utilized
  - How does that behavior/utilization impact GHG emissions
- Observed impacts compared to optimal dispatch of storage
  - With perfect foresight, how could storage be dispatched to maximize GHG reductions?
- Conclusions and program design improvement strategies

ENERGY STORAGE GHG IMPACTS (2018-2022)

Tracking Per Unit Impacts over time (kg/kWh or MT/MWh)







- Significant improvement in GHG emissions reductions in 2021-2022
- Third consecutive evaluation with program-level reductions
- Nonresidential sector fleet reduced emissions for first time in 2021 → 2022
- Continued reductions in residential sector since 2019

TIMELINE OF ENERGY STORAGE IN THE SGIP

2001

SGIP Created

2010

BTM storage eligibility

- Standalone storage becomes eligible

2011

CA Senate Bill 412

- Modified the primary purpose of SGIP from peak load reduction to GHG emissions reductions

2016

SGIP re-funded

- 75% of budget to energy storage
- $0.50 to $0.15 / Wh incentives

2017

Equity Budget established

- $0.85 / Wh incentive

2019

GHG Working Group Established

- Create a GHG Signal
- Compliance/operational requirements address storage GHG impacts

Equity Resiliency Budget established

- $1.00 / Wh incentive
- Significant uptake in participation

2020

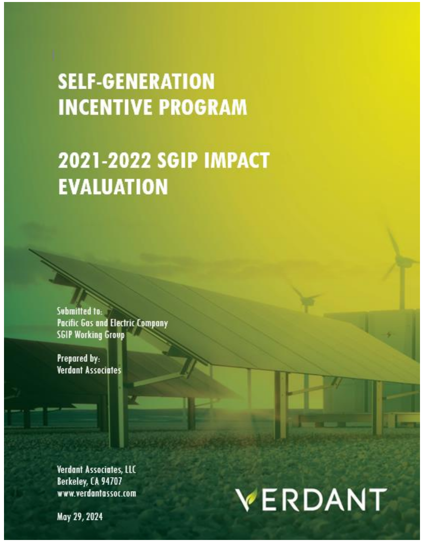
SGIP funding from 2020-2024

- 88% of incentive budget to storage

MEASUREMENT AND EVALUATION

Ongoing evaluation reports assess SGIP's effectiveness and ability to meet its goals

- System performance – utilization and efficiency
- Grid impacts and Utility Avoided Costs
- **Environmental impacts – GHG emissions reductions**
- Customer resiliency and bill impacts
- Track storage costs and market characteristics over time
- Optimization modeling
- Quantification of SGIP population impacts

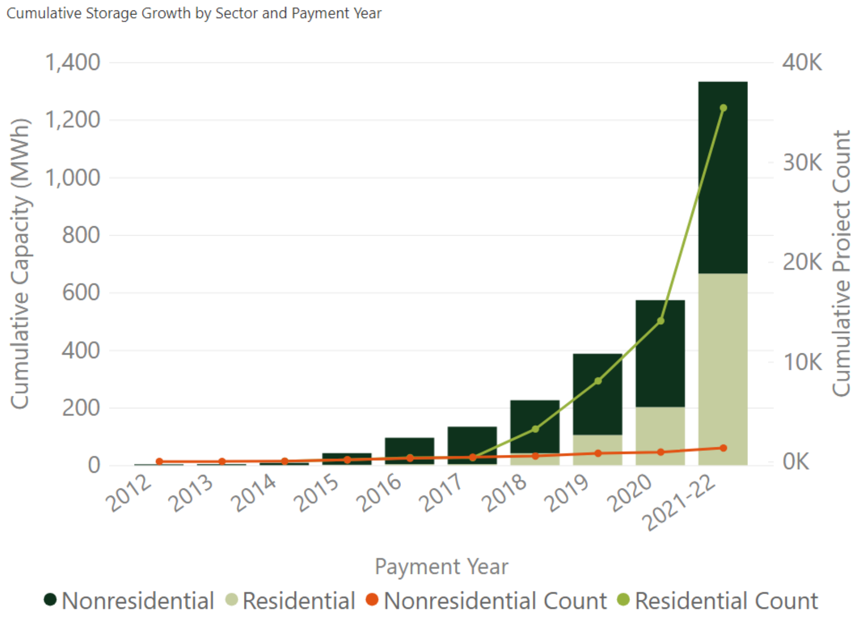


https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/self-generation-incentive-program/sgip-2021-2022-impact-evaluation.pdf

EVALUATION POPULATION

- SGIP population by end of 2022*
  - ~37,000 systems paid incentives
  - ~1,300 MWh
- Project Count
  - Residential 95% of program
- Program Capacity
  - Residential – 666 MWh | 276 MW
  - Nonresidential – 667 MWh | 294 MW

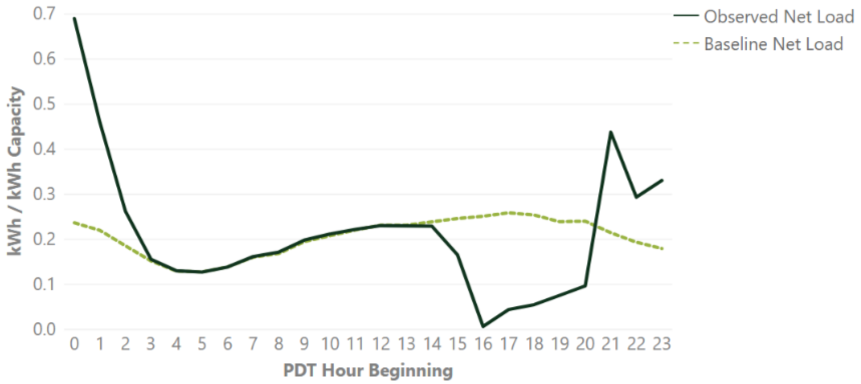
*** By 7/30/2024 the SGIP has incentivized over 45,000 systems and over 2,000 MWh of capacity**



EVALUATION APPROACH

Observed Impacts and Unobservable Baselines

- **Metered storage charge/discharge**
  - Actual system characteristics calculated from metered data – RTE, CF, Annual cycles
- **Consumption at the meter in the absence of the SGIP technology**
  - Unobservable counterfactual to measure impact of program intervention
    - System could provide GHG emissions reductions relative to counterfactual if → emissions avoided during discharge are greater than emissions increases during charging



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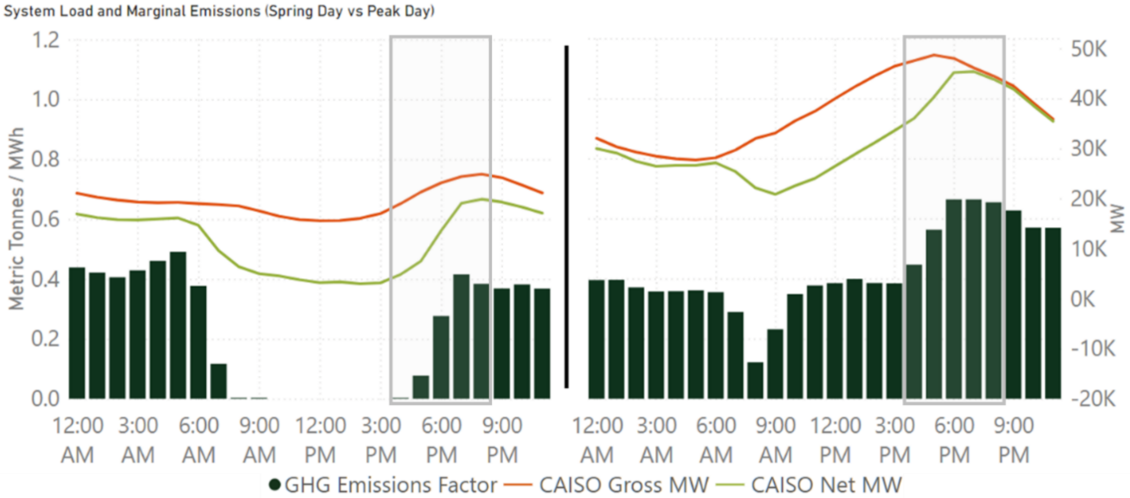
WHY TIMING AND MAGNITUDE OF DISCHARGE MATTERS

Relationship between Grid Emissions and System Load

- » Greater magnitude of system load on Peak day
- » Marginal emissions zero during several morning/midday hours on Spring day
- » Emissions ramp as Net load ramps
- » Emissions greatest from 6 pm – 9 pm on Peak Day

To optimize GHG reductions, charge during lowest emissions hours and discharge during highest emissions hours

Typical Sunday Spring Day (5/1/2022) **Peak CAISO Day (9/6/2022)**



* SGIP GHG emissions factors developed by Wattime
is a heat rate-based calculation to estimate generator efficiency based on LMP

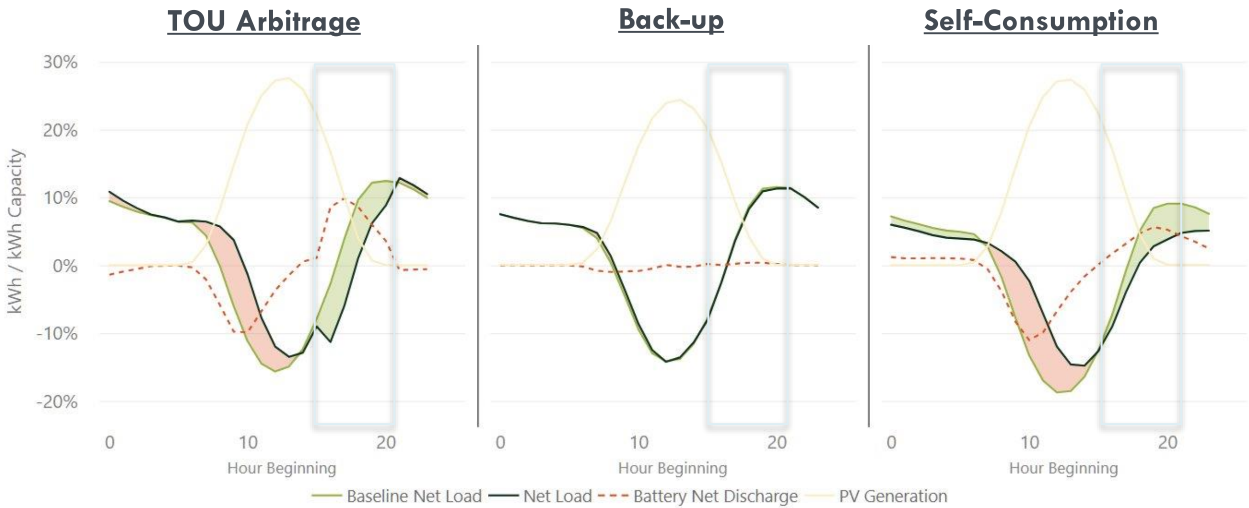
SGIP CHARACTERISTICS

Residential Energy Storage Dispatch Behavior

- **97% of residential storage paired with Solar PV**
  - Charging from early morning on-site PV
  - Discharging for:
    - Self-consumption – zero out imported load
    - TOU arbitrage w/out export
    - TOU arbitrage with export – regularly or during specific events (DR)
    - Under-utilization or backup (not allowed in SGIP)
- **3% are standalone systems**
  - Discharging on-peak (arbitrage) and charging overnight

KEY EVALUATION FINDINGS

Typical Residential Energy Storage Operating Modes



Shaded red = an increase in customer load

Shaded green = a decrease in customer load

Light blue box = 4pm to 9pm on-peak

TOU Arbitrage
- With and without export
- Discharge exclusively on-peak

Back-up
- Not allowed in SGIP
- Observed infrequently

Self-Consumption
- Discharge to zero out imported load
- Discharge continues outside on-peak

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ENERGY STORAGE DISCHARGE PATTERNS

Residential Hourly Utilization

- » PV paired systems charging almost exclusively from solar (some exceptions in 2022)
- » Max avg hourly discharge ~6-7% of kWh capacity
  - ~45% of system capacity discharged daily in summer months
- » Standalone systems exhibit similar discharge pattern (lower magnitude)
- » Charging occurs overnight

Charge from on-site PV (hours 8–13) — **Discharge mostly on-peak** (hours 16–20)

PV Paired	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
January	1%	0%	0%	0%	0%	0%	0%	-0%	-2%	-5%	-6%	-6%	-5%	-3%	-1%	0%	3%	4%	5%	4%	3%	1%	1%	1%
February	1%	1%	0%	0%	0%	0%	1%	-1%	-4%	-7%	-8%	-7%	-5%	-3%	-1%	0%	2%	4%	5%	5%	4%	2%	2%	1%
March	1%	1%	1%	1%	1%	1%	1%	-0%	-4%	-7%	-9%	-8%	-6%	-4%	-1%	-0%	2%	4%	5%	5%	4%	3%	2%	2%
April	2%	1%	1%	1%	1%	1%	1%	-1%	-4%	-8%	-10%	-8%	-5%	-3%	-1%	0%	2%	3%	5%	5%	4%	3%	3%	2%
May	2%	1%	1%	1%	1%	1%	1%	-1%	-5%	-9%	-10%	-8%	-5%	-3%	-1%	0%	2%	3%	5%	5%	5%	3%	3%	2%
June	1%	1%	1%	1%	1%	1%	0%	-2%	-6%	-10%	-10%	-8%	-5%	-3%	-1%	1%	3%	5%	6%	6%	5%	3%	3%	2%
July	1%	1%	1%	1%	1%	1%	0%	-1%	-5%	-9%	-10%	-9%	-6%	-3%	-1%	0%	3%	5%	6%	6%	5%	3%	2%	2%
August	1%	1%	1%	1%	1%	1%	0%	-1%	-4%	-8%	-11%	-9%	-7%	-4%	-1%	1%	4%	6%	7%	6%	5%	3%	2%	1%
September	1%	0%	0%	0%	1%	1%	1%	-0%	-3%	-7%	-10%	-9%	-7%	-4%	-1%	0%	4%	5%	7%	6%	4%	2%	2%	1%
October	1%	1%	1%	1%	1%	1%	1%	0%	-2%	-6%	-9%	-9%	-7%	-5%	-2%	-0%	3%	5%	6%	5%	4%	2%	2%	1%
November	0%	0%	0%	0%	0%	0%	0%	-1%	-4%	-6%	-8%	-7%	-5%	-3%	-1%	1%	4%	5%	5%	4%	3%	2%	1%	1%
December	-0%	-0%	-0%	0%	0%	0%	0%	-0%	-2%	-5%	-6%	-6%	-5%	-3%	-1%	1%	4%	5%	5%	3%	2%	1%	1%	0%

No PV	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
January	-3%	-2%	-1%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	0%	1%	1%	1%	2%	2%	1%	-1%	-1%	-1%
February	-4%	-2%	-1%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	0%	1%	1%	1%	2%	2%	1%	-1%	-1%	-1%
March	-5%	-2%	-1%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	0%	1%	1%	1%	1%	2%	2%	-1%	-0%	-2%
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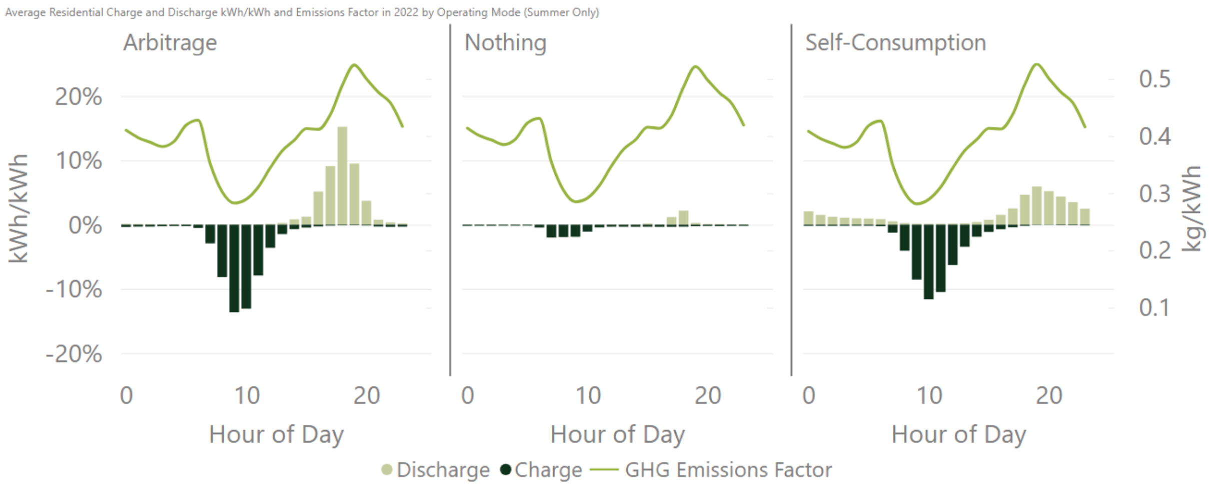
May	-6%	-3%	-1%	-0%	-0%	-0%	0%	-0%	0%	0%	-0%	-0%	-0%	-0%	0%	1%	2%	2%	2%	2%	2%	-1%	-0%	-1%
June	-7%	-4%	-2%	-0%	-0%	-0%	-0%	0%	-0%	-0%	-0%	-0%	-0%	-0%	0%	2%	3%	3%	2%	2%	2%	-1%	-1%	-1%
July	-7%	-5%	-2%	-0%	-0%	-0%	0%	0%	-0%	-0%	-0%	-0%	-0%	-0%	0%	1%	3%	3%	3%	2%	2%	-1%	-1%	-1%
August	-9%	-6%	-3%	-0%	-0%	-0%	-0%	0%	-0%	-0%	-0%	-0%	-0%	-0%	0%	1%	4%	4%	4%	3%	3%	-0%	-1%	-1%
September	-10%	-6%	-3%	-0%	-0%	-0%	0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	0%	1%	4%	4%	4%	3%	3%	-0%	-0%	-1%
October	-10%	-5%	-2%	-0%	-0%	-0%	-0%	0%	-0%	-0%	-0%	-0%	-0%	0%	0%	1%	3%	3%	3%	3%	2%	-0%	0%	-1%
November	-10%	-6%	-3%	-0%	-0%	-0%	0%	-0%	-0%	-0%	-0%	-0%	-0%	0%	0%	1%	3%	3%	3%	3%	3%	0%	0%	-1%
December	-11%	-8%	-4%	-0%	-0%	-0%	0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	0%	1%	4%	4%	4%	4%	3%	-0%	0%	-1%

Charge mostly overnight (hours 0–2, September–December) — **Discharge exclusively on-peak**

ENERGY STORAGE GHG EMISSIONS

Residential by Operating Mode

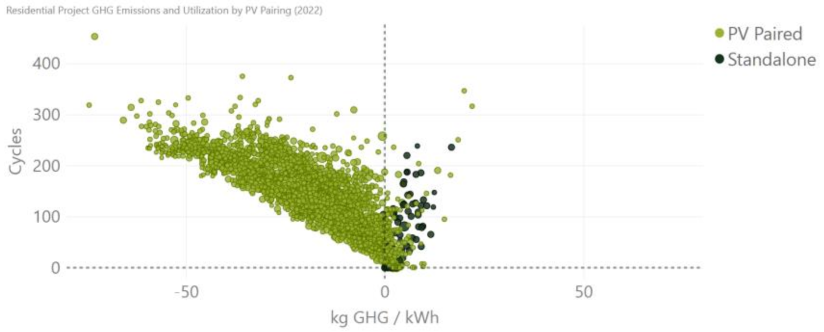


- » ~4% of residential systems idle or under-utilized in 2022 (“Nothing” above)
- » Discharging extends outside peak hours with self-consumption

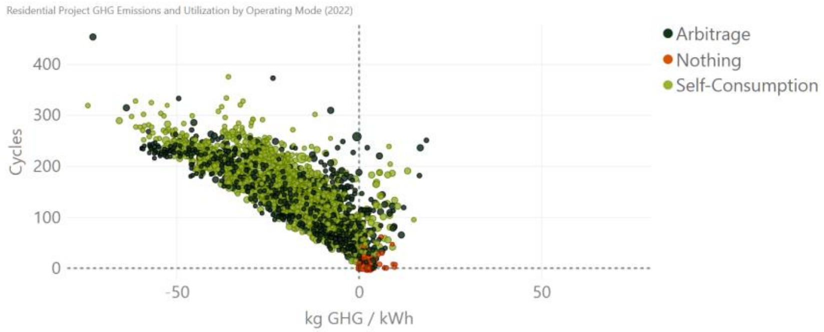
ENERGY STORAGE GHG EMISSIONS

Residential Project Emissions by PV Pairing and Operating Mode

Project Emissions – PV Paired versus Standalone Systems



Project Emissions – by Operating Mode



- Correlation between GHG emissions reductions and greater utilization
- Standalone storage charges overnight and increases emissions slightly
- **Solar PV charging critical to emissions reductions**
- Idle systems contribute to emissions increases

IS THERE VALUE BEING LEFT ON THE TABLE?

Comparing actual dispatch to optimal dispatch using Wattime GHG emissions signal

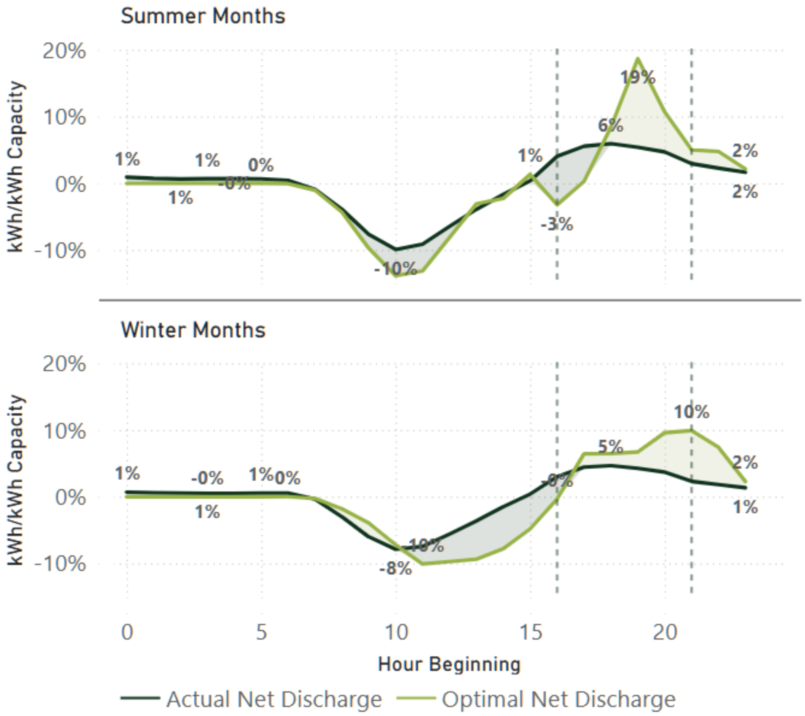
» Optimal dispatch suggests…Yes!

» **17 kg/kWh observed GHG reduction**

- Average across residential fleet

» **54 kg/kWh optimal reduction**

- 3x improvement in GHG when optimized for it



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RESIDENTIAL OPTIMIZATION

Heatmaps of Charge (-) Discharge (+) by Month and Hour

- » Actual hourly discharge follows on-peak TOU periods →
  - Discharge generally limited to underlying customer load (no export)
- » Significant hourly differences with perfect foresight →

Actual Hourly Discharge (+) Charge (-) kWh / kWh Capacity

month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	0%	0%	0%	0%	0%	0%	0%	-0%	-2%	-4%	-6%	-6%	-5%	-4%	-2%	0%	3%	4%	4%	3%	3%	2%	1%	1%
2	1%	1%	1%	0%	0%	0%	1%	-0%	-3%	-7%	-8%	-8%	-5%	-3%	-1%	0%	3%	5%	5%	4%	4%	2%	2%	1%
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5	1%	1%	1%	1%	1%	1%	1%	-1%	-5%	-8%	-10%	-8%	-5%	-3%	-1%	0%	3%	4%	4%	5%	5%	3%	3%	2%
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8	1%	1%	1%	1%	1%	1%	0%	-1%	-4%	-7%	-10%	-10%	-7%	-4%	-2%	0%	5%	6%	6%	6%	5%	3%	2%	2%
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10	1%	0%	0%	1%	1%	1%	1%	0%	-2%	-5%	-8%	-9%	-7%	-5%	-2%	0%	3%	5%	6%	5%	4%	2%	2%	1%
11	0%	0%	0%	0%	0%	0%	0%	-1%	-3%	-6%	-7%	-7%	-5%	-3%	-1%	1%	4%	5%	5%	4%	3%	2%	1%	1%
12	-1%	-0%	-0%	0%	0%	0%	0%	-0%	-2%	-4%	-6%	-6%	-5%	-3%	-1%	1%	4%	5%	4%	3%	2%	1%	1%	0%

ghg

month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	-0%	-0%	-0%	-0%	-0%	-0%	0%	-0%	-1%	-3%	-6%	-9%	-11%	-10%	-5%	-3%	4%	11%	9%	3%	7%	5%	3%	-0%
2	-0%	-0%	-0%	-0%	-0%	-0%	0%	-0%	-2%	-5%	-5%	-9%	-12%	-13%	-11%	-7%	1%	12%	8%	1%	9%	16%	8%	1%
3	-0%	-0%	-0%	-0%	-0%	-0%	0%	-0%	-1%	-1%	-5%	-9%	-11%	-12%	-9%	-7%	-5%	4%	5%	8%	5%	13%	15%	5%
4	-0%	-0%	-0%	-0%	-0%	-0%	0%	-0%	-1%	-4%	-8%	-10%	-8%	-9%	-11%	-9%	-5%	-1%	5%	15%	9%	6%	17%	7%
5	-0%	-0%	-0%	-0%	-0%	0%	-0%	-1%	-4%	-7%	-11%	-13%	-6%	-2%	-5%	-4%	-8%	-3%	1%	19%	20%	11%	4%	2%
6	-0%	-0%	-0%	-0%	-0%	0%	-0%	-2%	-6%	-11%	-15%	-14%	-5%	2%	-5%	-1%	-2%	-1%	4%	22%	18%	3%	2%	2%
7	-0%	-0%	-0%	-0%	-0%	0%	-0%	-1%	-4%	-10%	-14%	-12%	-10%	-5%	-3%	3%	-5%	1%	3%	22%	10%	7%	7%	5%
8	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-1%	-5%	-10%	-14%	-14%	-9%	-5%	1%	4%	-2%	-1%	12%	23%	9%	3%	2%	0%
9	-0%	-0%	-0%	-0%	-0%	-0%	0%	-0%	-3%	-7%	-12%	-13%	-9%	-4%	-2%	-1%	-4%	3%	15%	8%	6%	7%	9%	1%
10	-0%	-0%	-0%	-0%	-0%	-0%	0%	0%	-1%	-4%	-9%	-14%	-11%	-10%	-7%	-5%	5%	15%	11%	0%	6%	9%	6%	2%
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12	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-0%	-1%	-3%	-6%	-7%	-9%	-8%	-5%	-1%	3%	6%	3%	3%	14%	7%	0%	-0%

CONCLUSIONS & PROGRAM DESIGN IMPROVEMENTS

- **SGIP BTM energy storage is providing GHG emissions reductions more recently** – 1) minimum cycling requirements, 2) high-differential on-peak TOU rates, 3) battery operating modes, 4) DR participation, 5) digitally accessible GHG signal are guiding this behavior.
- Residential and nonresidential systems are not discharging the total capacity of the system regularly and many residential customers are limiting discharge to maintain net zero load rather than exporting
  - **Program improvements that encourage additional battery utilization – 1) increase cycling minimums to better capture actual behavior, 2) enrollment in virtual power plants (VPP), 3) utility control of storage, 4) participation in real-time rates, or 5) other mechanisms.**
- Solar PV paired residential storage discharges roughly 45% of system kWh capacity daily throughout summer weekdays, and standalone systems discharge about 22% of available capacity
  - **Encourage more targeted dispatch that emphasizes the importance of discharging batteries (and reducing load) during on-peak hours rather than daily self-consumption.**

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CONCLUSIONS & PROGRAM DESIGN IMPROVEMENTS

- **BTM storage paired with on-site PV charges from early on-site PV generation**
  - Clean energy being discharged/exported to the grid
  - Charging occurs during lower grid-scale emissions hours
- GHG emissions differentials between charging overnight and discharging on-peak are not sufficient to realize emissions reductions like observed with PV paired systems charging from on-site PV
  - **Standalone systems can achieve GHG reductions with the appropriate signal, such as the SGIP GHG signal or real-time pricing signals.**
- Optimization modeling revealed that the average actual avoided emissions of 17 kg of GHG per kWh of capacity would triple if optimized for GHG reductions
  - **Create ambitious GHG reduction targets that reflect improvements in technology to maximize its potential.**

THANK YOU

Brian McAuley
brian@verdantassoc.com

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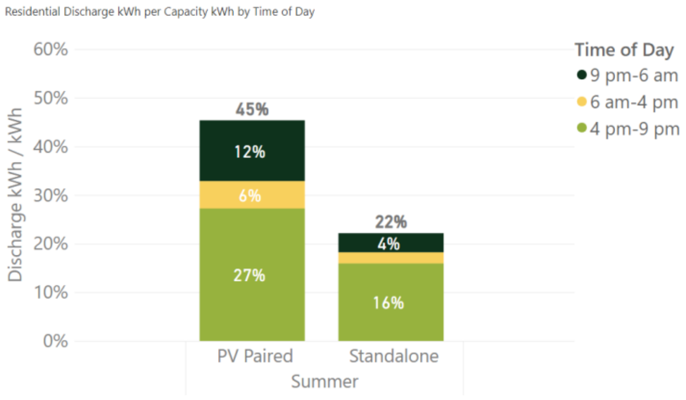
ADDITIONAL SLIDES

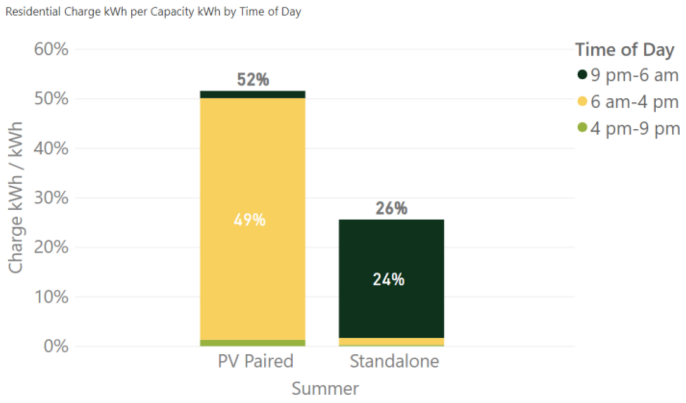
KEY EVALUATION FINDINGS

Residential Energy Storage Daily kWh Utilization

Discharge kWh per Capacity kWh



Charge kWh per Capacity kWh



- PV Paired utilized ~45% of battery capacity daily
- Most discharge comes between 4pm-9pm
- Standalone utilized ~22%

- PV paired early morning solar charging
- Standalone system overnight charging

SGIP CHARACTERISTICS

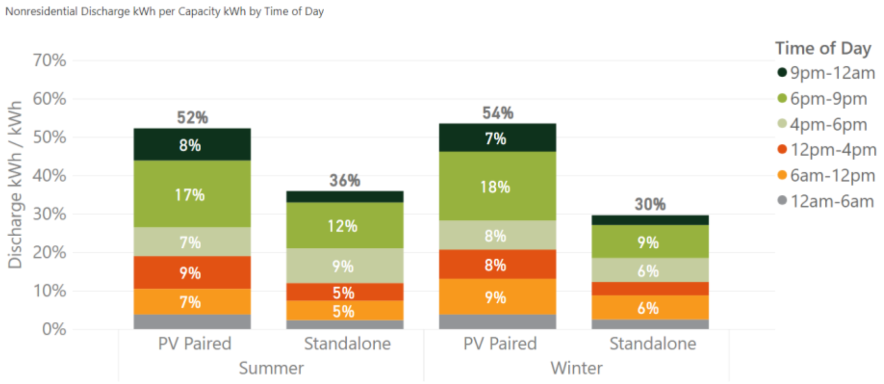
Nonresidential Energy Storage Dispatch Behavior

- **34% of nonresidential storage paired with Solar PV**
  - Charging from early morning on-site PV
  - Discharging for:
    - Self-consumption & TOU arbitrage
    - Demand charge reduction (non-coincident and on-peak)
- **66% are standalone systems**
  - TOU arbitrage and demand charge reduction
  - Cycling

KEY EVALUATION FINDINGS

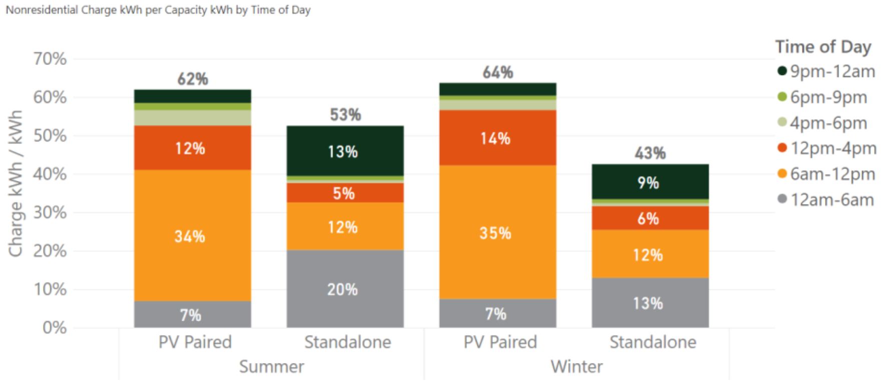
Nonresidential Energy Storage Daily kWh Utilization

Discharge kWh per Capacity kWh



- PV Paired utilized ~52% of battery capacity daily in Summer
- Discharging occurs across hours

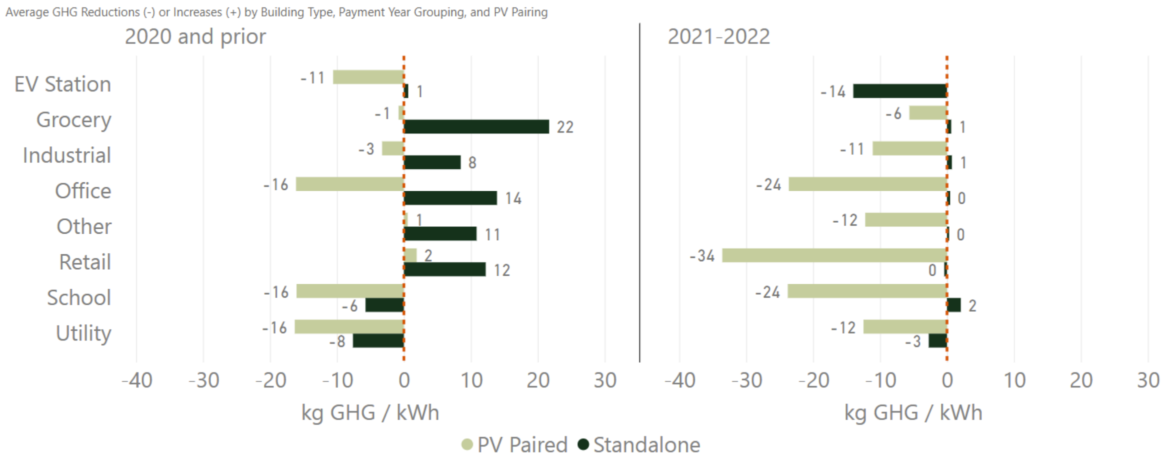
Charge kWh per Capacity kWh



- More heterogeneity in charge timing
- Most PV paired charging from on-site solar

ENERGY STORAGE GHG EMISSIONS

Nonresidential by Facility Type, PV Pairing, and Upfront Payment Year



- » PV paired segments decreased emissions in 2022
- » More recent (2021-2022) standalone installations reducing emissions

ENERGY STORAGE GHG IMPACTS

Charging from on-site solar critical to GHG reductions in the energy storage sector

- **Residential energy storage sector**
  - PV paired average **GHG reductions** of 17 kg per kWh capacity
  - **Standalone systems increase emissions** by almost 4 kg per kWh capacity
  - Idle/under-utilized systems increase emissions slightly
- **Nonresidential energy storage sector**
  - PV paired average **GHG reductions** of 10 kg per kWh capacity
  - **Standalone systems increased emissions** by 1 kg per kWh capacity
    - Reduced emissions increases from previous years
    - Medium duration batteries and more targeted discharge

Sustainable Energy Advantage, LLC

How Clean is the MA Clean Peak Standard?

Energy Storage Technology Advancement Partnership

July 30, 2024

Sustainable Energy Advantage, LLC

Consulting & advisory firm helping clients build renewable energy business, markets, policies and projects through analysis, strategy & implementation since 1998.

Markets	Policies
Objective Analysis Modeling Forecasting Transaction Facilitation	Tracking & Analysis Development Implementation Multi-Stakeholder Support
Strategy	**Projects**
Insight Intelligence Negotiation Support Action	Financial Models & Analysis Due Diligence & Feasibility

CPMO
CLEAN PEAK MARKET OUTLOOK

- Policy and market analysis specific to MA Clean Peak Energy Standard
- Supply, demand, price projections
- Resource modeling and case studies
- Collaboration of Sustainable Energy Advantage and Customized Energy Solutions

CleanPeakMarketOutlook.com

Our Subscription Service Suite

New England Renewable Energy Market Outlook (REMO)

- Detailed REC market fundamentals analysis, briefings, providing actionable information on New England's complex REC markets to support informed business decisions. Delivered 3x per year
- Since 2005

Northeast Eyes & Ears

- ***We track it…now you can too.***
- Renewable Energy Regulatory Policy & Legislative Tracking & Analysis Service
- Extending & enhancing subscribers' busy users' government affairs / market intelligence functions
- New England: since 2007. New York: Since 2017.

New York Renewable Energy Market Outlook (REMO)

- Bulletins, Topical Webinars, and detailed REC Market Fundamentals Analysis, providing subscribers with comprehensive & timely insight into New York's rapidly expanding / evolving renewables market.

PJM… coming soon!

2016 State of Charge Report

*"Over the last three years from 2013 – 2015 on average, the **top 1% most expensive hours accounted for 8%** ($680 million) of Massachusetts ratepayers' annual spend on electricity. The top 10% of hours during these years, on average, accounted for 40% of annual electricity spend, over $3 billion."*

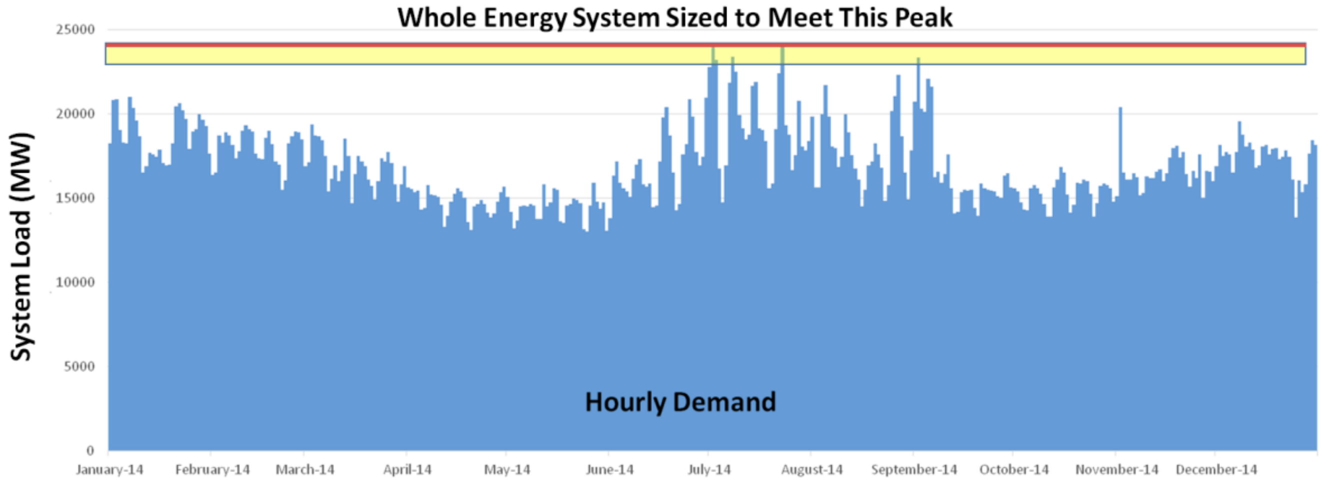


Figure 2: The whole electricity system is sized to meet peak demand

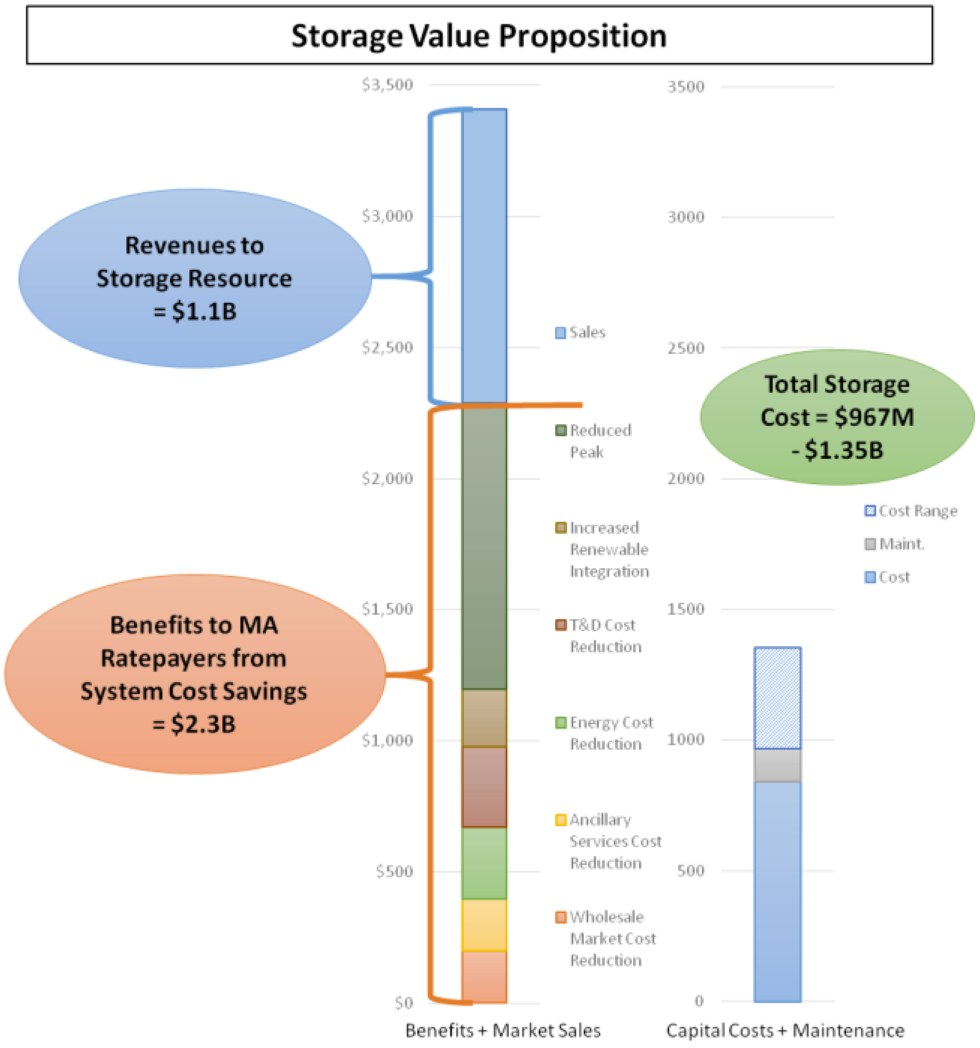


Figure 12: Storage Value Proposition

Primary conclusions include:

1. System peaks drive costs and emissions
2. Storage can help and is cost effective

State of Charge Report (2016)

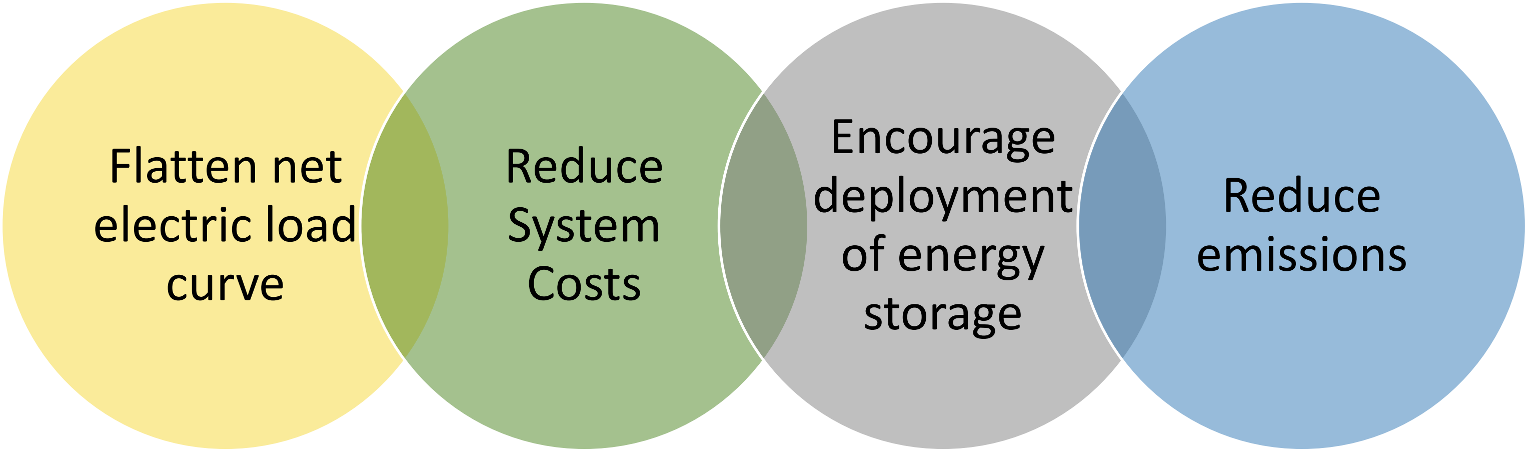
Clean Peak Energy Standard Background

PRESS RELEASE 8/04/2020

Baker-Polito Administration Launches First-in-the-Nation Clean Peak Energy Standard

Program Will Promote Use of Clean Energy When Costly Electricity Demand is Highest

- 2018 – enabling legislation passes
- Policy goes into effect in 2020
- CPS Objectives from MA Department of Energy Resources (DOER) straw proposal:

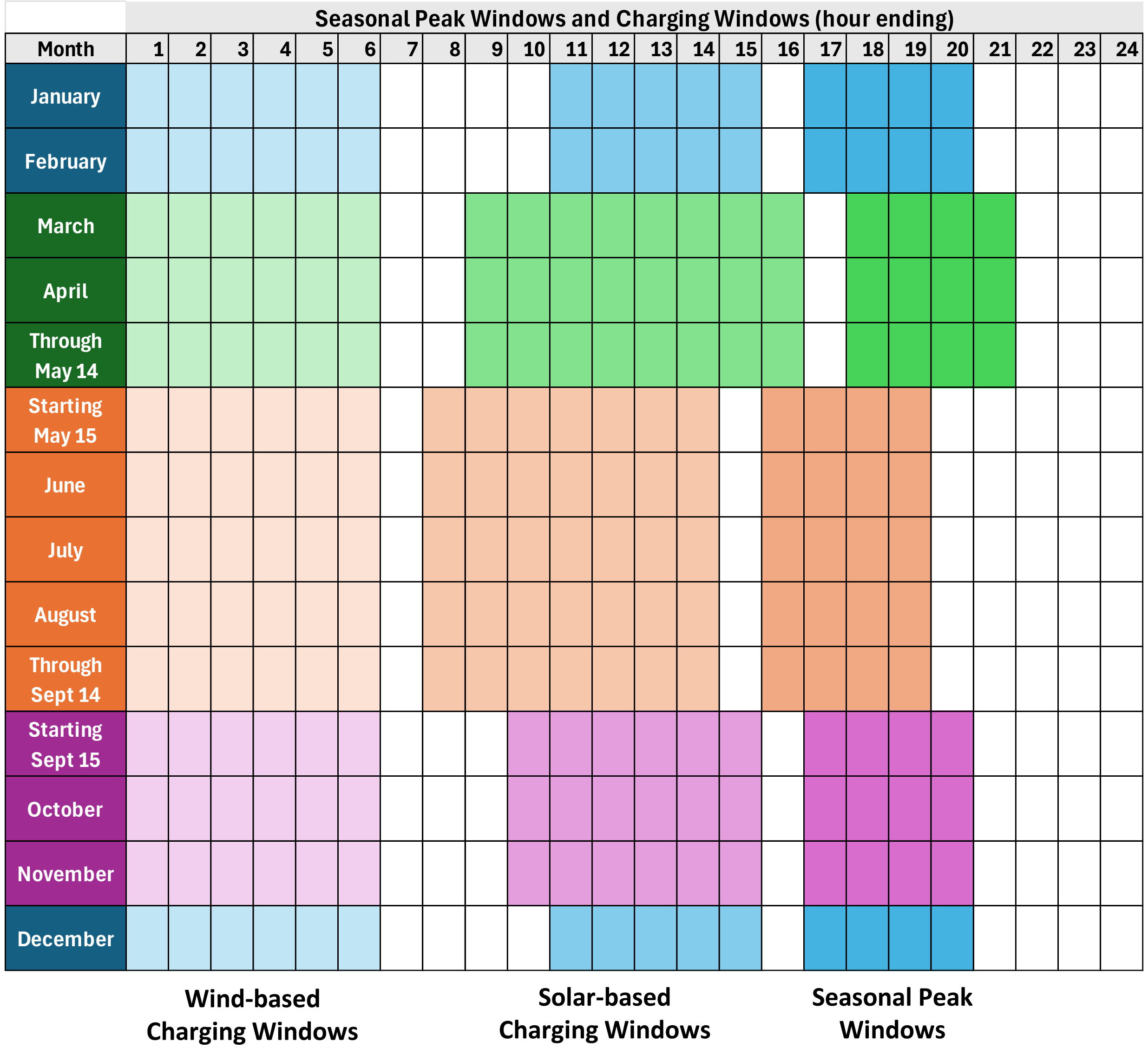


What is CPS? (1)

Like an RPS but, more complicated. It has…

…Seasonal Peak Windows and Charging Windows!!!

- Hours that define when Clean Peak Energy Certificates (CPECs) can be generated
- Alternatively, resources can i) physically or ii) through bilaterial contracts charge from renewables



Applies only to Business Days and non-state/federal holidays

What is CPS? (2)

Like an RPS but, more complicated. It has…

…Multipliers!

- Which increase or decrease CPEC production based on resource- or time-specific criteria.

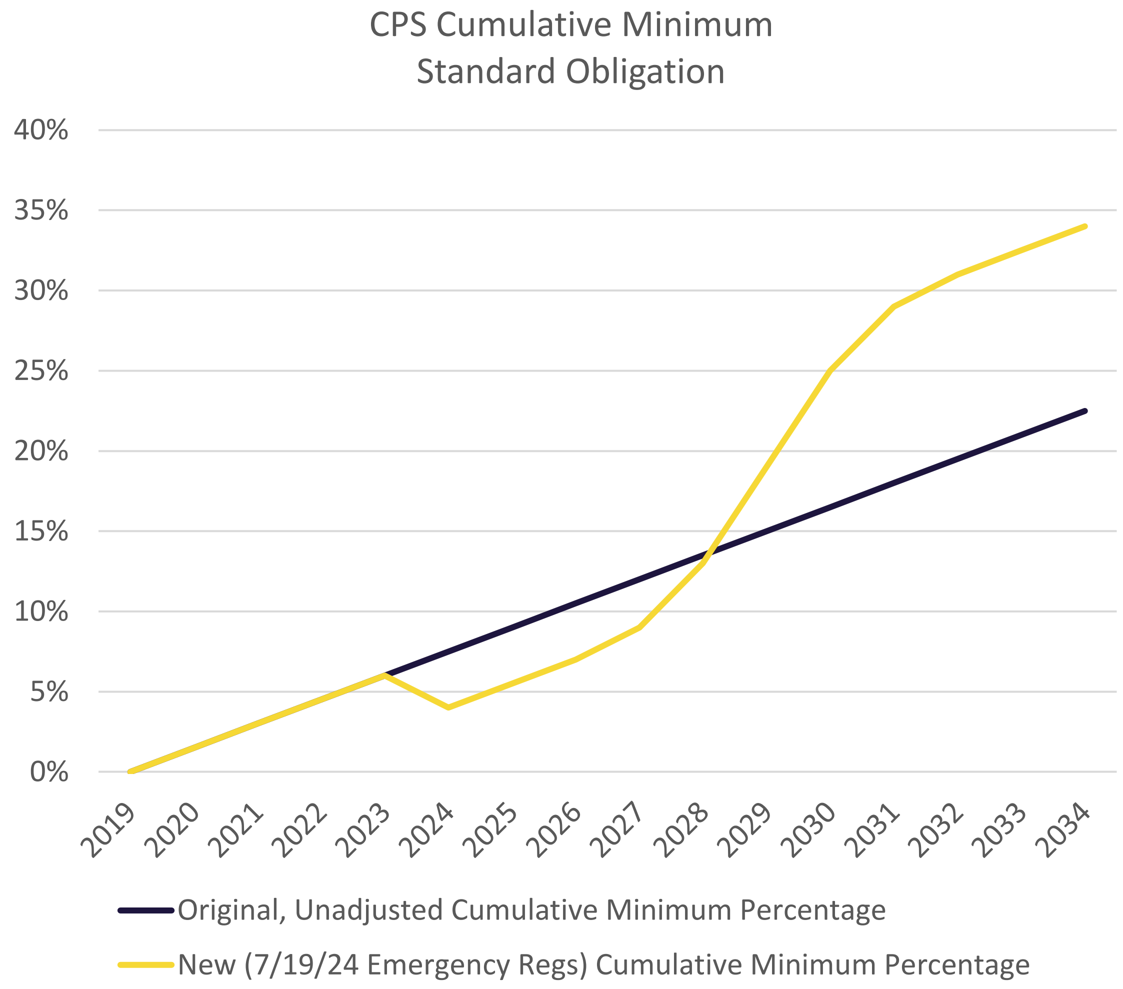
Multiplier Type	Multiplier Amount
Seasonal	Spring & Fall = 1X Summer & Winter = 4X
Monthly Peak Hour	25X
Existing (pre 2019) Resources	0.1X
Resources with Policy-Driven Long-Term Contracts	0.01X
Resources Providing Resilience	1.5X
SMART Energy Storage	0.3X
Resources on Highly Loaded Distribution Circuits (“Distribution Circuit Multiplier”)	2X first 10 years
New! Distribution-Connected Standalone Storage Online by end of 2026 (“Near-Term Resource Multiplier”)	2X first 10 years

What is CPS? (3)

Like an RPS but, more complicated. It has…

…other cool features!

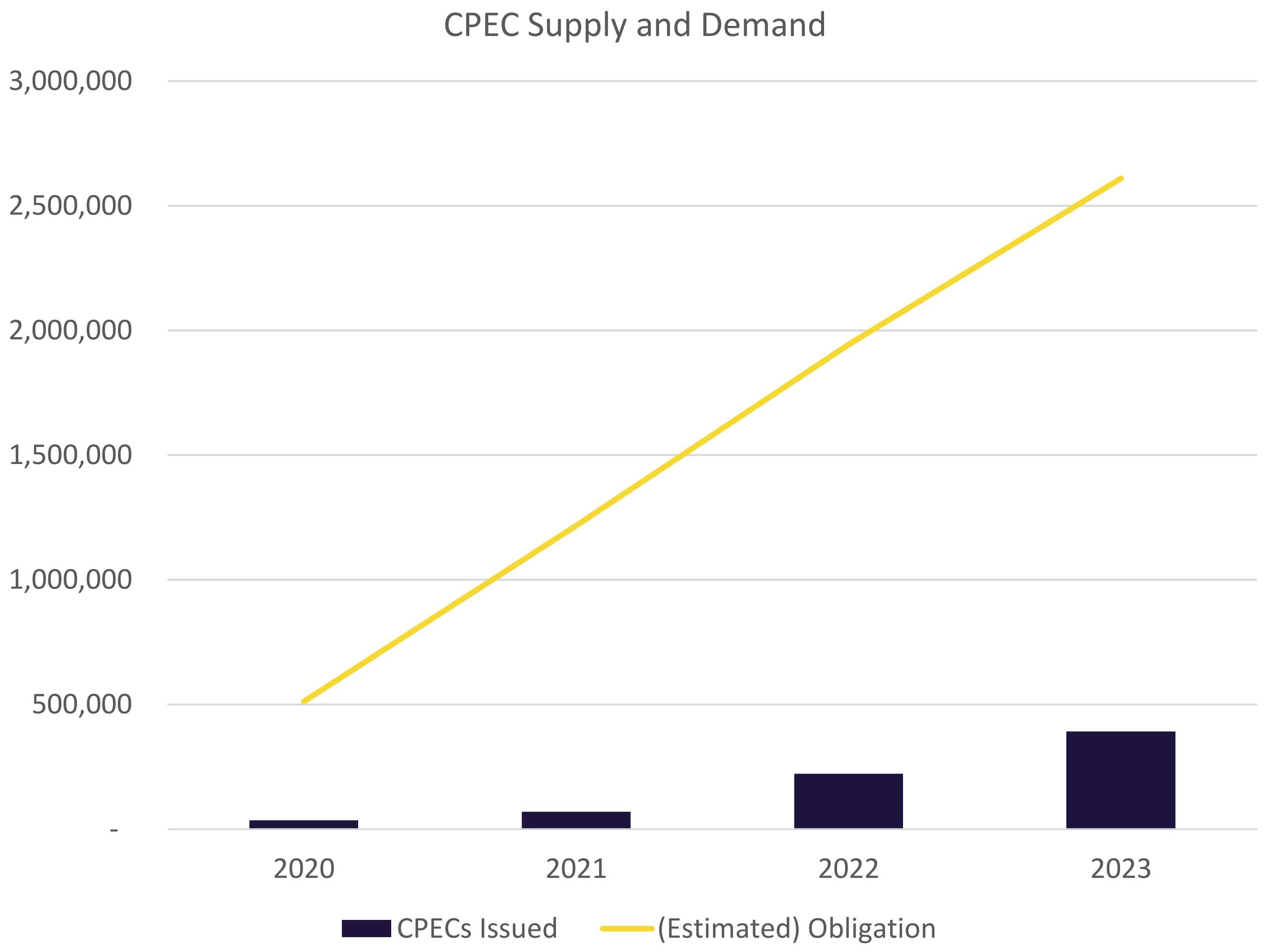
- **Variety of eligible technologies** including renewables and demand response, though most supply likely to come from storage
- A **declining ACP** rate that falls faster in response to oversupply
- **Long-term procurements of CPECs**, though this element of the policy has not yet been implemented
- **Emergency regulations and Program Reviews**, most recently resulting in a change in the Minimum Standard (% requirement for CPECs) and introducing a new multiplier



How Has CPS Been Working?

- A little slowly.

- Nonetheless, the market is expected to get more interesting (supply will catch demand), especially with recent changes to Minimum Standard



Is CPS Reducing Emissions?

- Probably not much. Yet.

"However, today, New England does not have sufficient penetration of renewables to support meaningful arbitrage between low-emitting, low-price renewable generation and high-emitting "peaking" oil and gas generation when storage losses are considered."

2023 Charging Forward: Energy Storage in a Net Zero Commonwealth

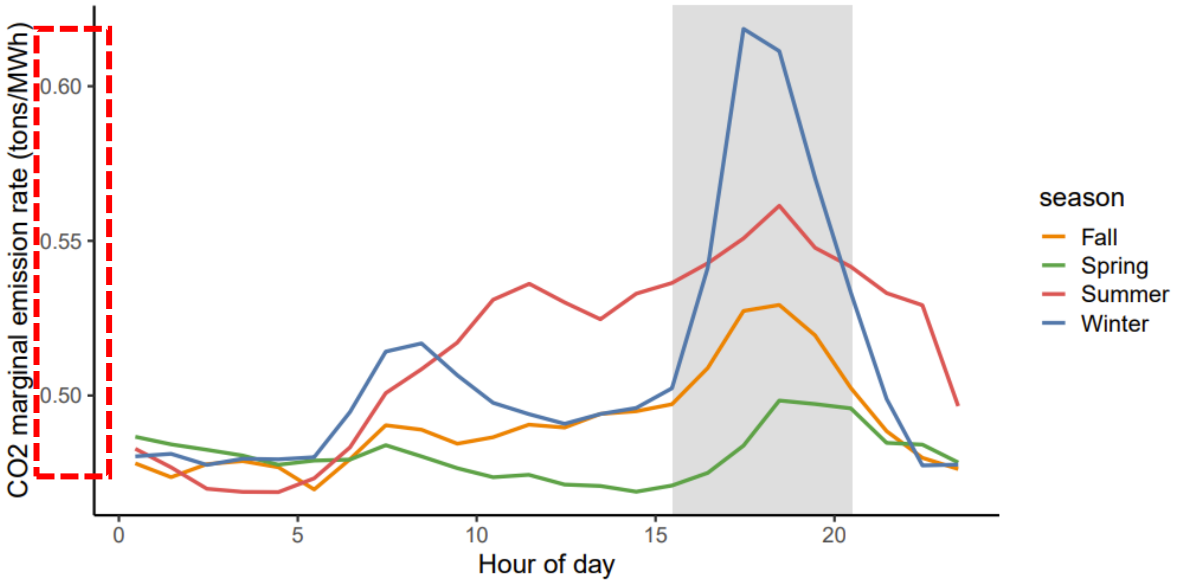
"We show that the policy is largely ineffective at achieving this emissions reduction goal."

2019 (Not So) Clean Energy Standards

Why Not? 1: Flat(ish) Marginal Emissions Rates

- Historically, marginal emissions rates in New England have been fairly flat
- With round-trip efficiency losses, cycling storage can increase emissions
- Zero emissions resources (solar & wind) rarely the marginal resources
- Natural gas almost always the marginal unit, though, in winter, more common for oil to be marginal unit
- This will change over time

Figure 1: Marginal Operating Emission Rates



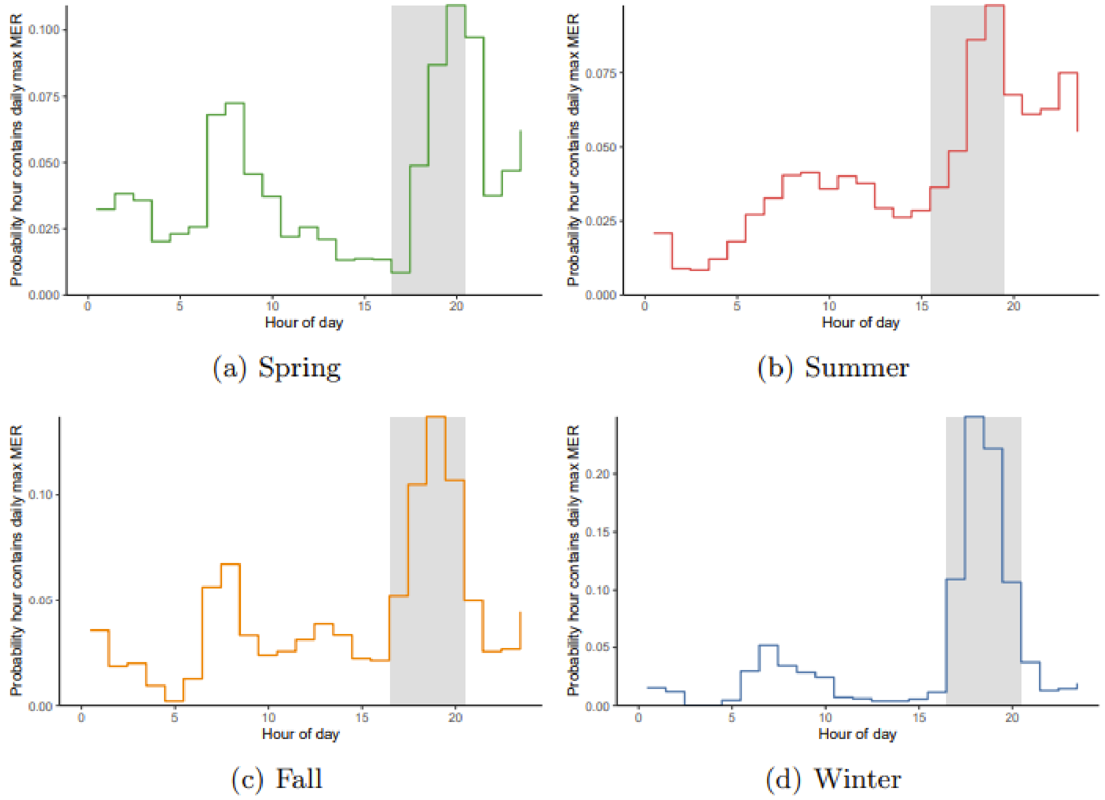
Notes: The figure shows marginal operating emissions rates (MOERs) in tons of CO_2 per MWh, averaged by season and hour of day over the sample period. The gray bar shows the Clean Peak window across all seasons.

2019 (Not So) Clean Energy Standards; “sample period” = 2018-2019

Why Not? 2: CPS Design

- CPS design (defined discharge windows) intended to provide simplicity and predictability
- Flip side – peak emissions for a day may not always fall within defined windows
- DOER has authority to adjust CPS windows as needed
- Charging hours primarily driven by wholesale prices – strong alignment with marginal emissions, but not perfect

Figure 5: When Do Peak Emissions Occur?



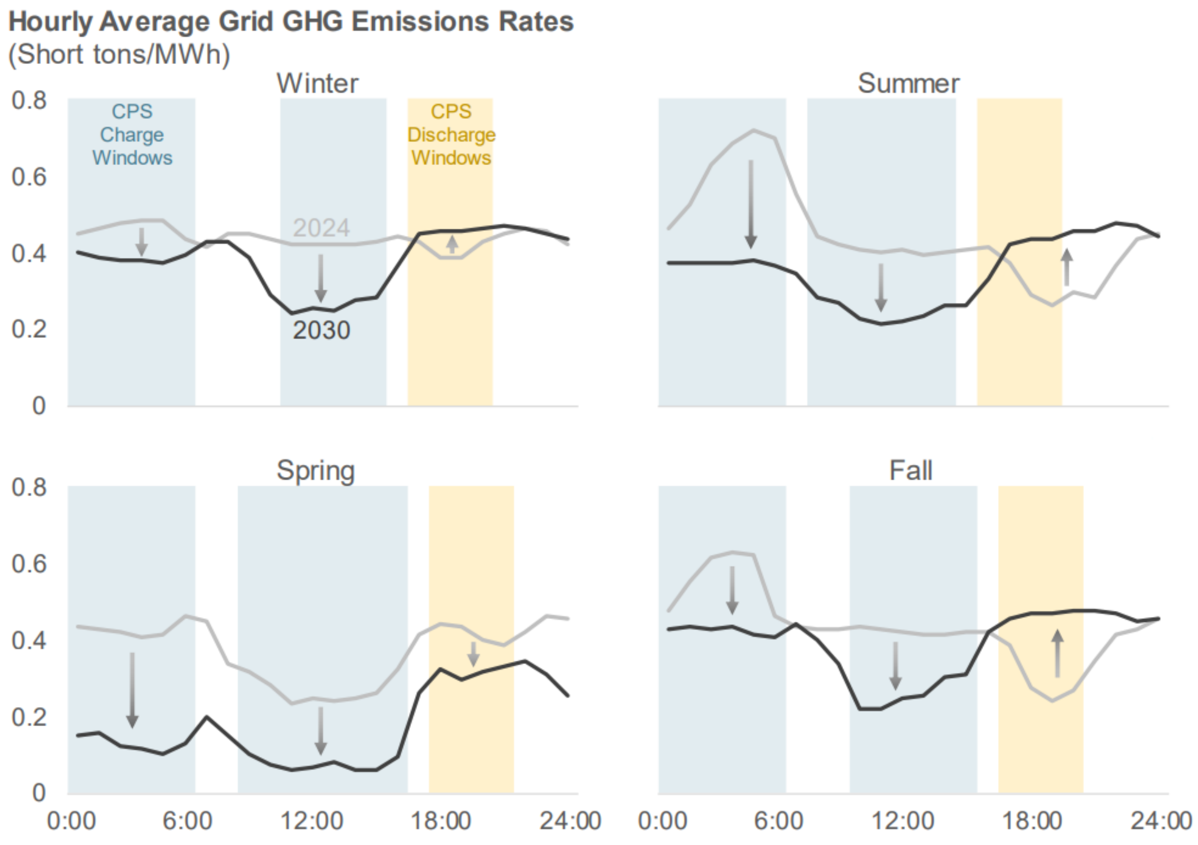
Notes: The figures show the probability of a day's peak emissions occurring within any given hour of the day in the baseline scenario. Each panel shows a different Clean Peak season. The gray bars are the Clean Peak windows based on average peak demand.

2019 (Not So) Clean Energy Standards

Will Emissions Impact Improve in the Future?

- Almost certainly yes
- As more renewables come online, likely to result in higher price and emissions volatility – CPS can amplify this signal and provide revenue boost needed for storage to come online

Figure 2-8. AESC grid emissions factors by season and hour



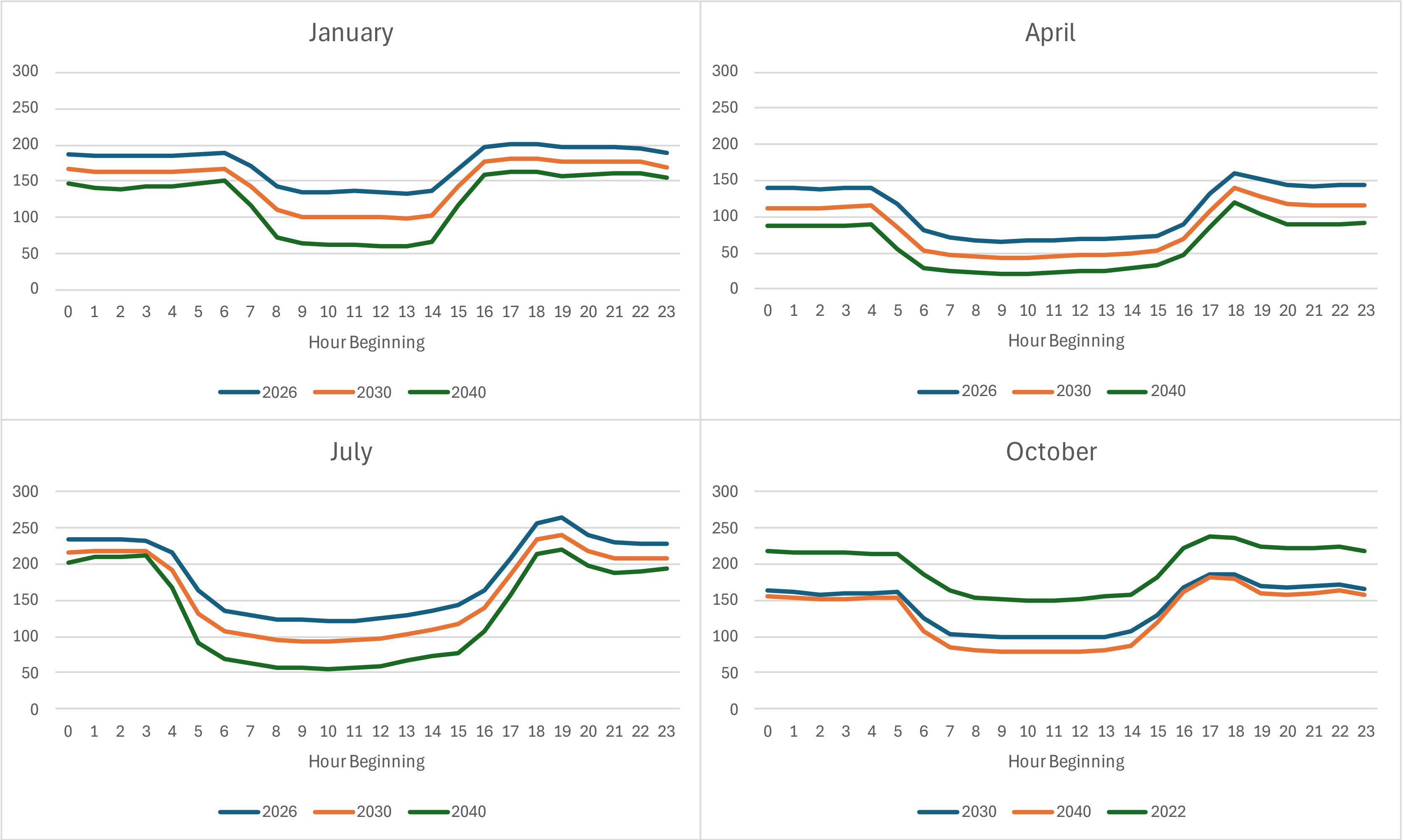
[2023 Charging Forward: Energy Storage in a Net Zero Commonwealth]

More Projections on Marginal Emissions

- Most marginal emissions estimates are short-run – assume only *operational* changes (e.g., one unit runs more or less)
- NREL's Cambium datasets include long-run marginal emissions rates (LRMER) estimates, intended to capture emissions impacts while also accounting for structural changes to the grid (transmission buildout, new/retired generators)
- Using LRMER, storage operating in CPS is delivering emissions reductions

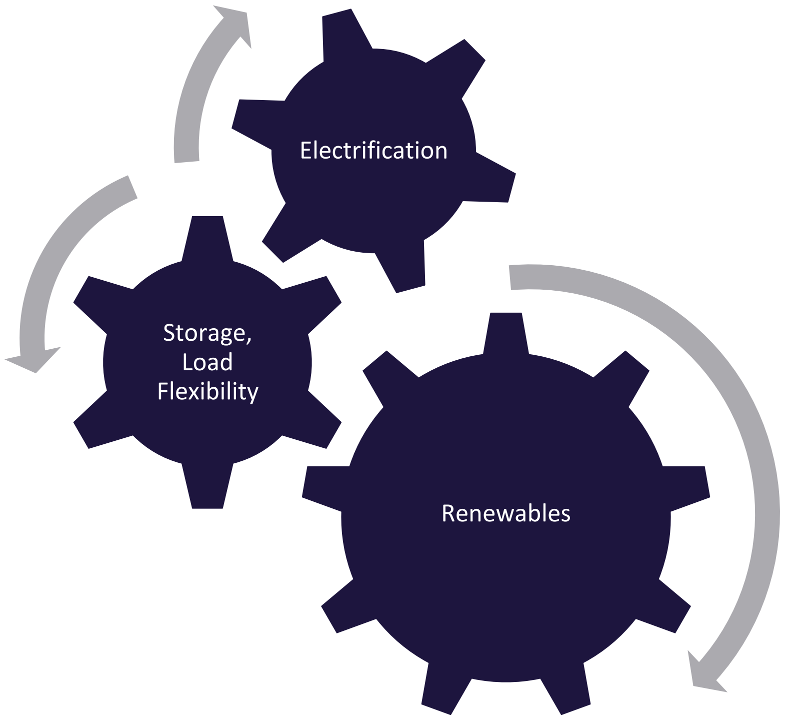
Long-Run Marginal Emissions (NREL Cambium)

Kg per MWh, Mid-Case



Looking at the Larger Picture

- Short-term, direct emissions reduction is an important metric for evaluating storage policies, but not the only one
- **Longer-term view of impact on emissions** may be more relevant, especially as building storage (both as an industry and individual projects) takes time. If allowing a small increase in emissions in the near-term is necessary (it may not be) to scale industry so that storage can deploy at scale when greater emissions arbitrage is available, may be better long-term outcome.
- **Achieving MA's GHG and clean energy mandates will necessitate storage (and load flexibility) → CPS incentivizes both**
  - *Financial* benefits: e.g., storage increases the capacity value (and reduces out of market compensation requirements) of renewables
  - *Physical* need: e.g., need storage to keep the lights on (and power heat pumps)
- **Downward pressure on electric rates can help drive electrification**
  - Storage can help manage rates through deferred/avoided T&D investments
  - Lower rates can help spur electrification – indirect emissions benefits



Ultimately, cost-efficiently meeting GHG goals requires storage.

Sustainable Energy Advantage, LLC

Thanks!

Stephan Wollenburg, Director

Lead – Energy Storage Practice

swollenburg@seadvantage.com