Charging Forward: Energy Storage Toward A Net Zero Commonwealth

MASSACHUSETTS CLEAN ENERGY CENTER

DOER Massachusetts Department of Energy Resources

Stakeholder Session #2: Study Update and Draft Results

August 16, 2023

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Energy+Environmental Economics

Agenda

- Study Background and Goals | 5 min, DOER
- Study Task 1: Energy Storage Today | 15 min, E3
- Study Task 2: MDES/LDES Cost and Use Case Outlook | 5 min, E3
- Study Task 3: Reliability Modeling | 40 min, E3
- Study Timeline and Next Steps | 5 min, DOER
- Q&A | 20 min, E3 and DOER

Session Goals

- Explain background and drivers behind energy storage study
- Share latest findings, focusing on business cases and reliability modeling
- Share key assumptions and inputs that go into analysis
- Outline next steps
- Spur continued stakeholder involvement and feedback

Today's Session Format

- During the presentation, please put your questions and comments in Zoom's Q&A feature
  - ➢ We'll answer those we can in the chatbox, and others we'll defer to the Q&A or future follow up with you
  - ➢ We also strongly encourage you to submit your written comments to DOER at thomas.ferguson@mass.gov by **Friday, September 1, 2023**
- Presentation and recording to be made available at study website

About DOER and MassCEC

DOER

The Massachusetts Department of Energy Resources ("DOER") is an agency of the Executive Office of Energy and Environmental Affairs ("EEA"). DOER's mission is to create a clean, affordable, equitable and resilient energy future for all residents, including low-income and Environmental Justice populations, businesses, communities, and institutions in the Commonwealth.

MassCEC

The Massachusetts Clean Energy Center ("MassCEC") is a state economic development agency dedicated to accelerating the growth of the clean energy sector across the Commonwealth to spur job creation, deliver statewide environmental benefits and to secure long-term economic growth for the people of Massachusetts. MassCEC's mission is to accelerate the clean energy and climate solution innovation that is critical to meeting the Commonwealth's climate goals, advancing Massachusetts' position as an international climate leader while growing the state's clean energy economy.

2022: Climate Bill, CECP, and Storage

Legislative Requirement – Approved August 11, 2022

- Section 80 of Chapter 179 of the Acts of 2022 ("An Act Driving Clean Energy and Offshore Wind") requires DOER, in consultation with MassCEC, to conduct a study on the current status of energy storage and the potential role of mid- to long-duration energy storage.

Clean Energy and Climate Plan for 2050 (CECP) – Released December 2022

- Lays out Commonwealth's Plan to achieve Net Zero in 2050 in an equitable and just manner
- Calls for collective GHG emission reductions of 85% relative to 1990 levels
  - Electric sector reduction of 93%
  - Requires 2.5x increase in electric sector load relative to 2020 and over 50 GW of solar and wind
- Storage to play a critical role in renewables integration and in meeting CECP's Net Zero goal

What specific roles will storage play? What kinds of storage will we need? How do we incentivize its deployment?

Study Outline and Outputs

- This study addresses three broad questions:
  1. What is the current state of energy storage in the Commonwealth?
     - *How much storage is deployed? What programs exist to encourage deployment? What are the costs/benefits of current use cases for energy storage?*
  2. What is the market outlook for emerging mid- and long-duration storage (LDES) technologies?
     - *What is the level of maturity for various emerging LDES technologies? How are costs projected to evolve for LDES technologies?*
  3. What are potential applications of mid- and long-duration storage?
     - *How can LDES contribute to reliability in a decarbonized system? What benefits will LDES be able to provide at the distribution level?*
- The study output will include public report, inclusive of analysis, summary of stakeholder feedback, and key findings

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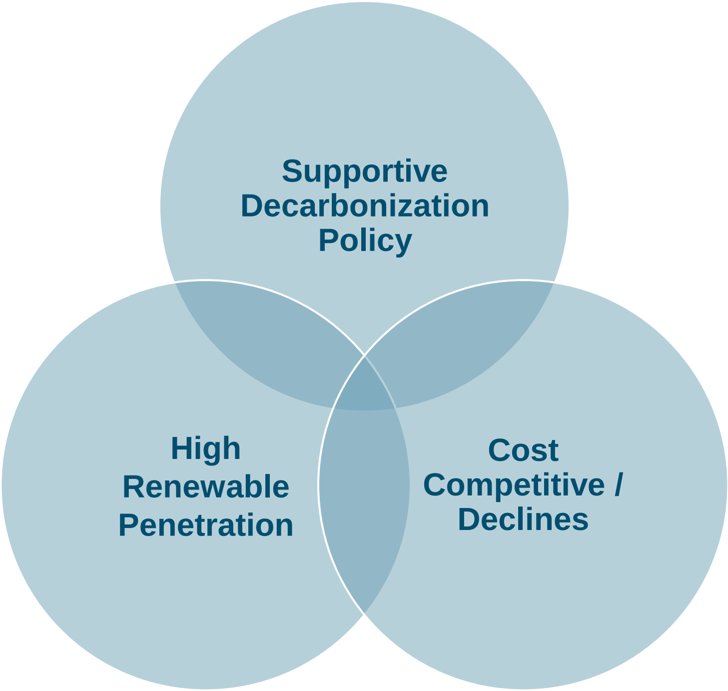
Select Emerging Study Findings

+ Today, most new storage being deployed is small (<5 MW), front-of-meter Li-Ion installations

+ Several mid-duration storage technologies (4-10 hr) are becoming available, but compete with short-duration (<4 hr, SDES); will become more valuable as new renewable energy shifts and SDES flattens net load peak beyond effectiveness of SDES

+ Long-duration storage technologies (LDES, 10+ hours) range from experimental to commercial stage (pumped hydro), and are expected to be available in the next several years (except pumped hydro, which supports state already)

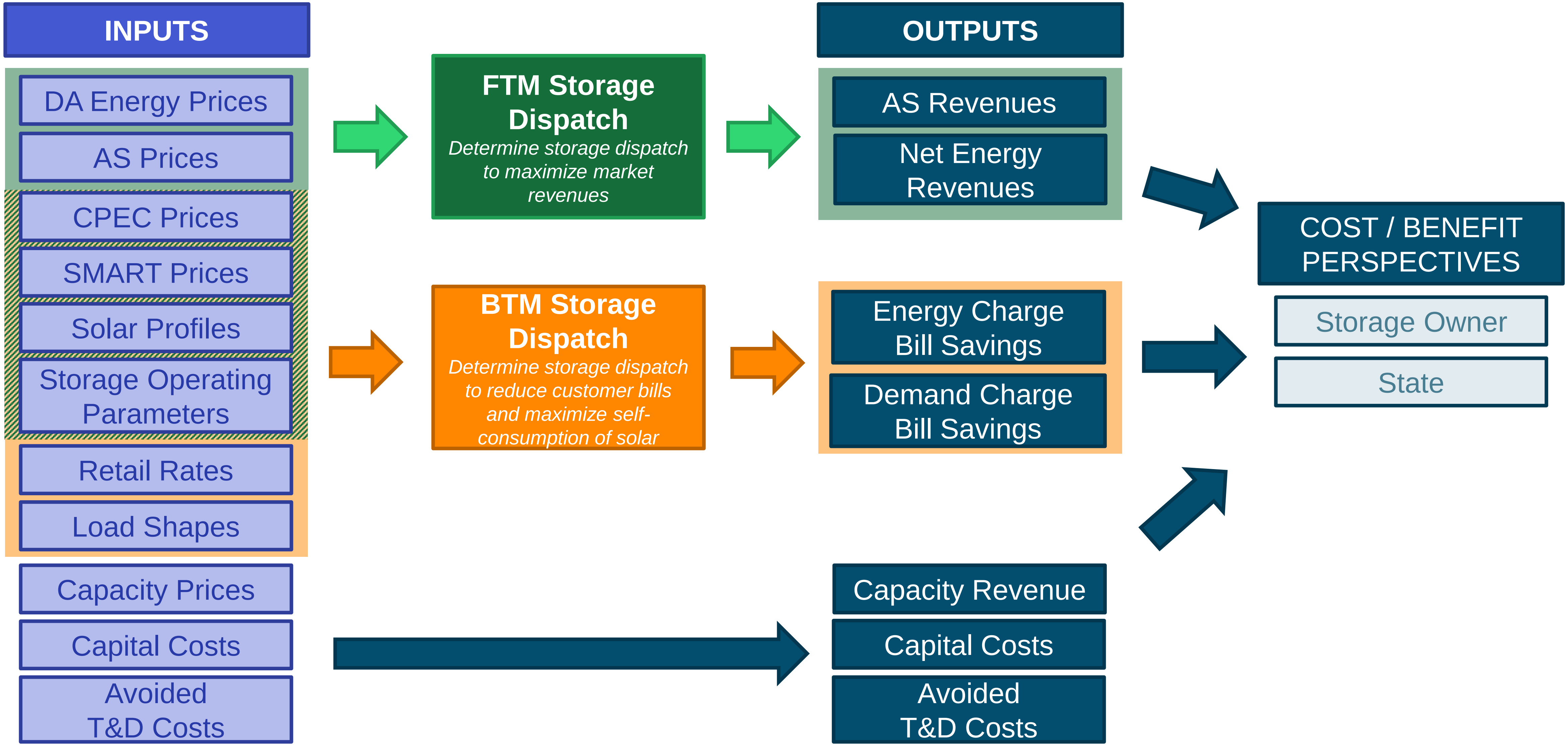
+ Storage, particularly LDES (10+ hours), can provide significant capacity value to New England



Key feedback received & responses

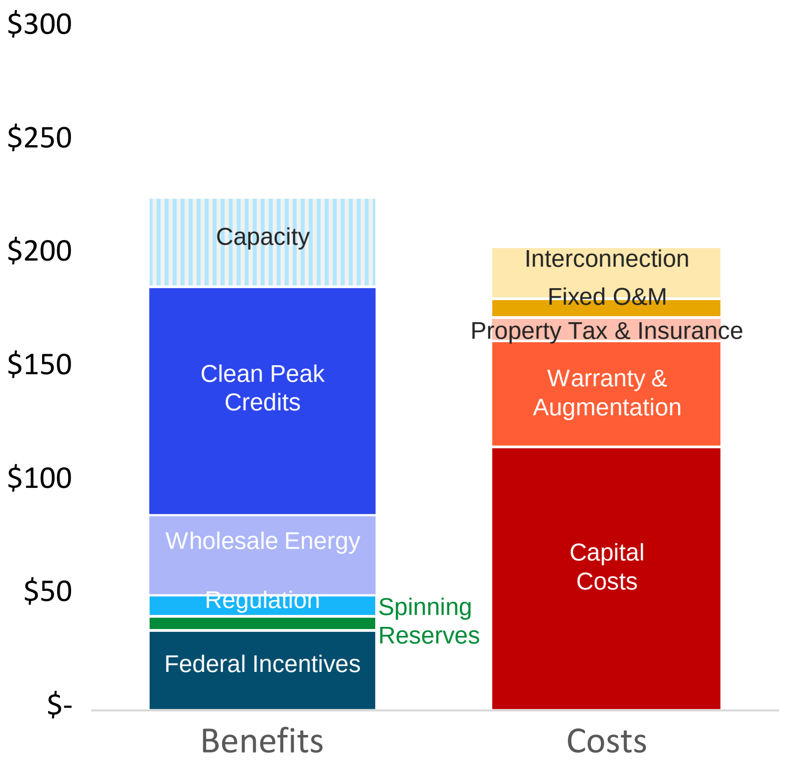
- **Information asymmetry an issue for EDCs, MLPs, developers**
  - Where would interconnection be simplest? Where would value to grid be highest? When will annual and monthly peaks occur?
  - Points to possible need for better information sharing, perhaps through coordinated planning process
- **Conservative assumptions around operations and revenue streams are barriers for interconnection and financing**
  - Lacking control of or contractual agreement dictating dispatch, distribution and transmission planners are forced to assume unrealistic “worst case” energy storage operations
  - Lack of certainty in wholesale market revenues and Clean Peak Credit price results in severe derating of potential benefits for financing considerations
- **Feedback specific to use case cost/benefit streams**
  - Interconnection costs increased to match developer experience
  - Update to distribution-connected systems charging rates
  - Typical system sizing for targeting SMART storage adder
  - Benchmarking to expectation that standalone storage requires state funding to recover costs

Reminder: Storage business case modeling compares costs to an applicable stack of benefits

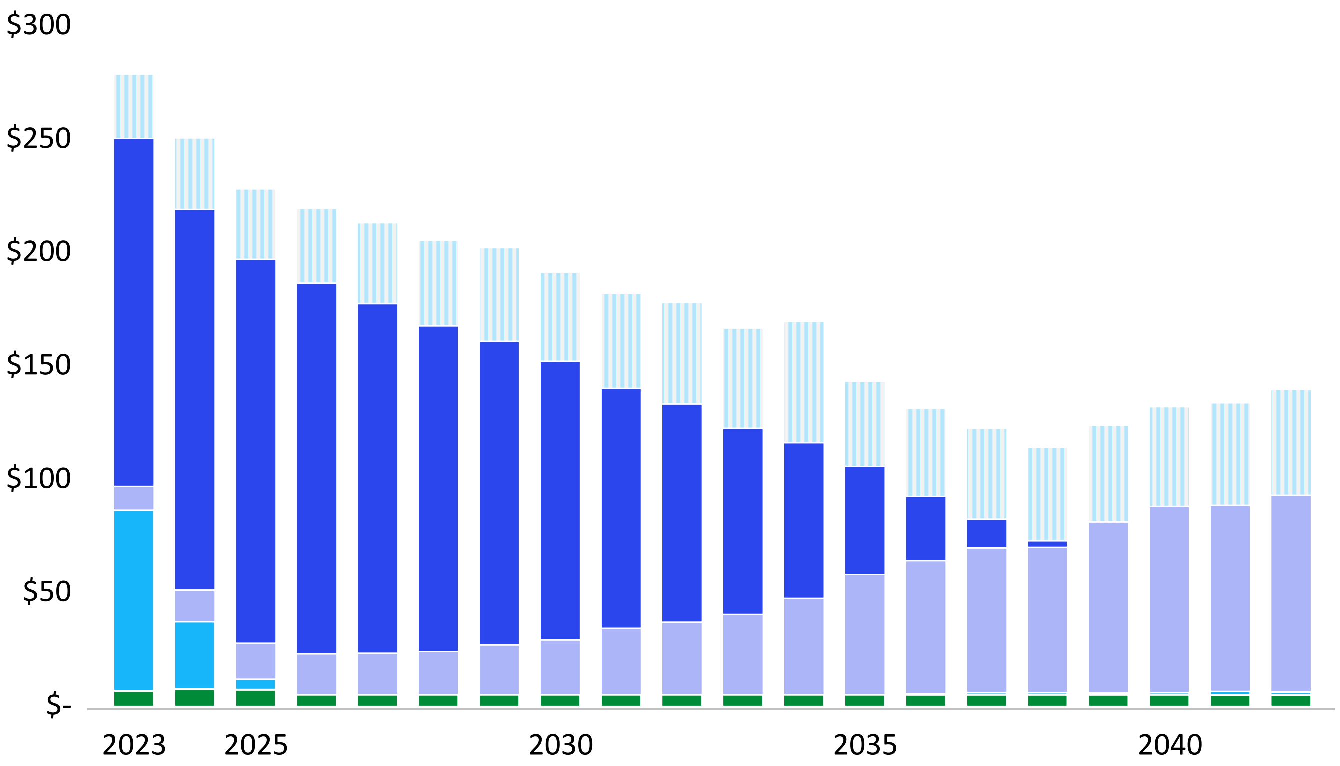


Utility-scale batteries projected to struggle to recover costs in 2023, even if multiple benefits can be realized

Levelized revenues & costs - developer view
($2022/kW-yr)



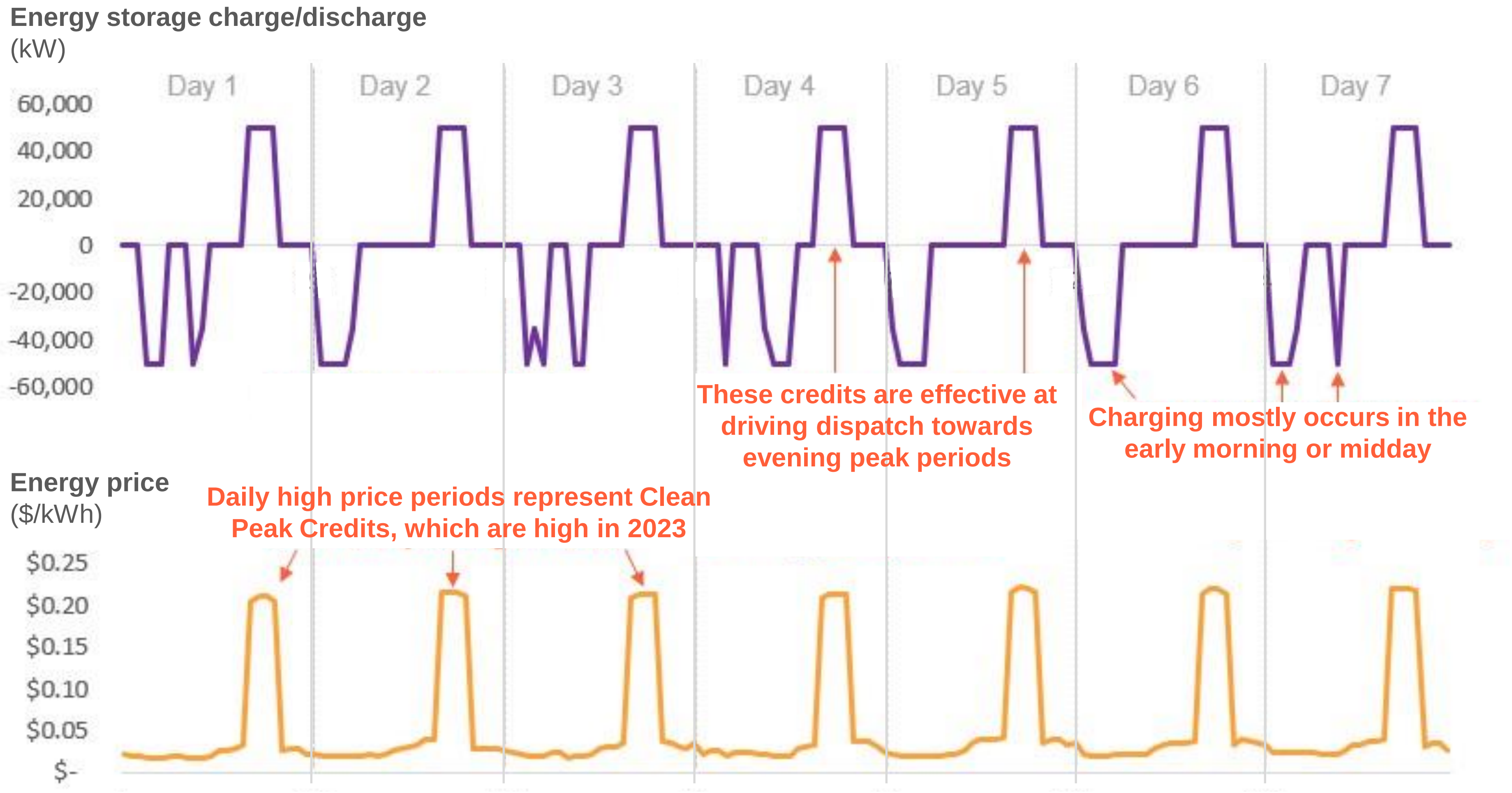
Annual revenues - developer view
($2022/kW-yr)



50 MW, 4-hr Li-Ion Battery, Standalone, Transmission connected, 2023 install year

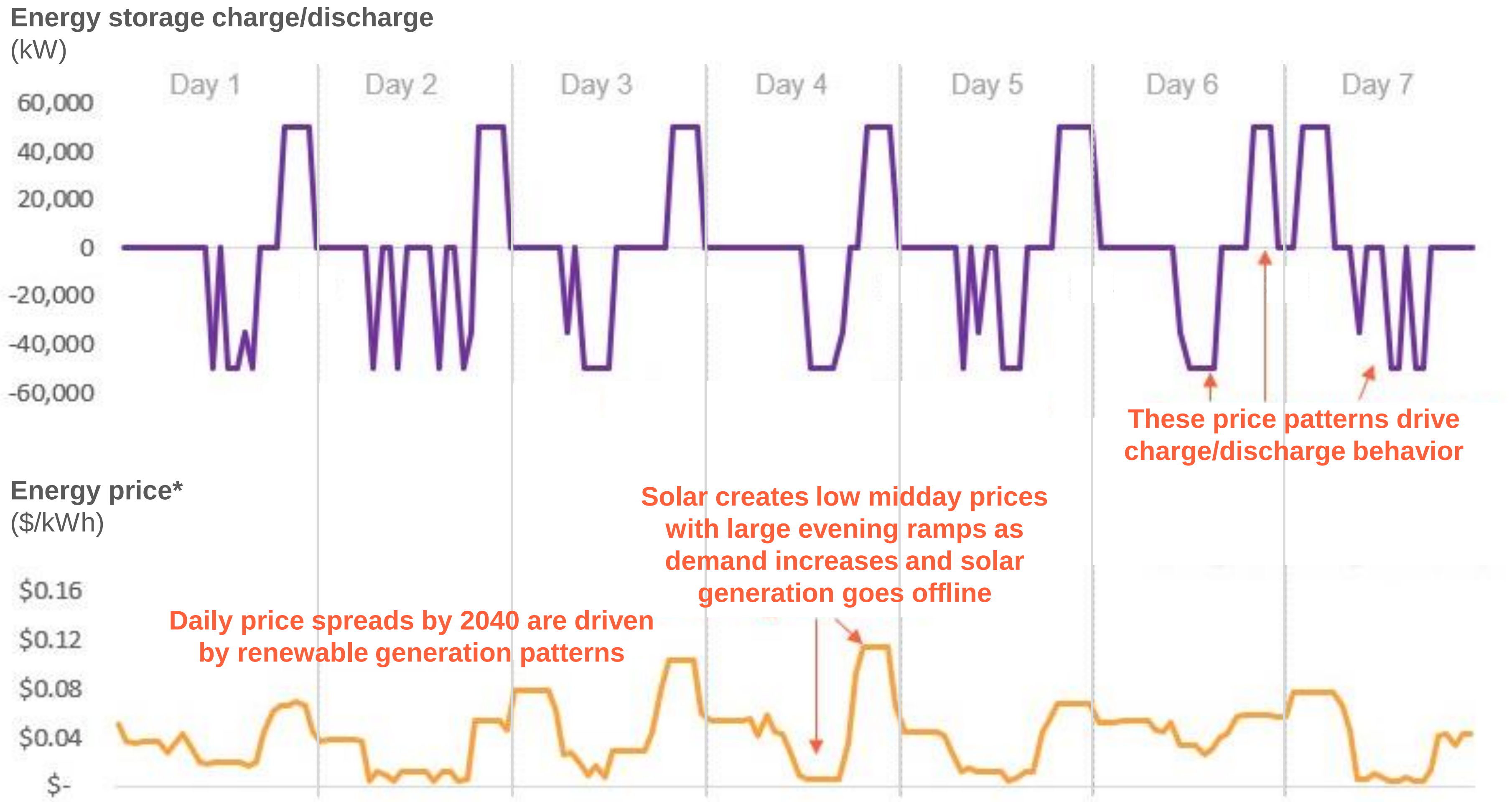
Near-term dispatch is driven by Clean Peak charge and discharge windows

2023 dispatch example



Long-term dispatch is driven by wholesale energy market spreads due to intermittent renewable output

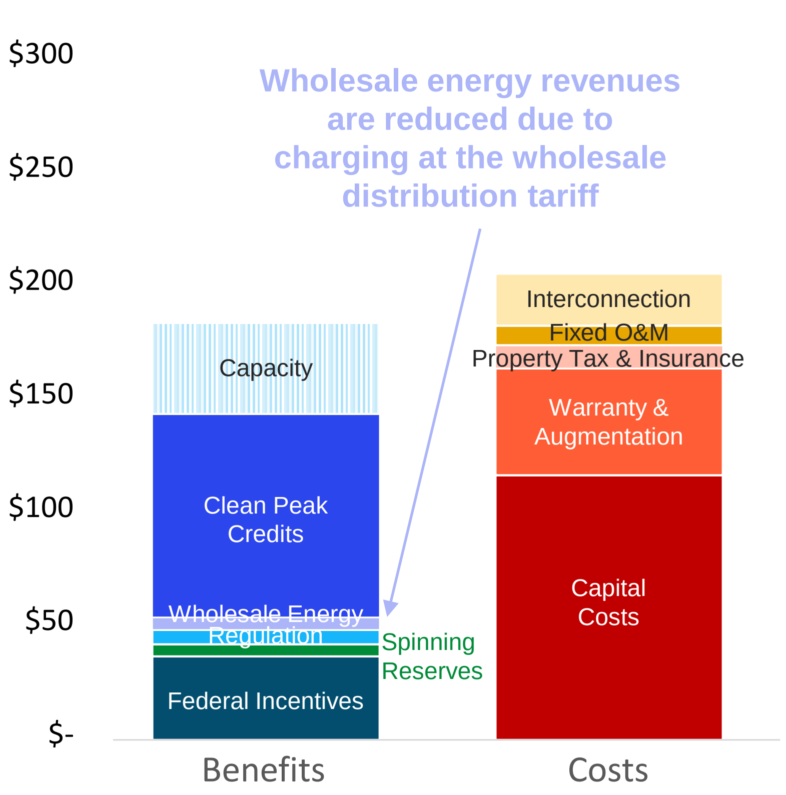
2040 dispatch example



*E3 adds hourly shape to AESC annual average energy prices based on CECP renewable builds by forecast year

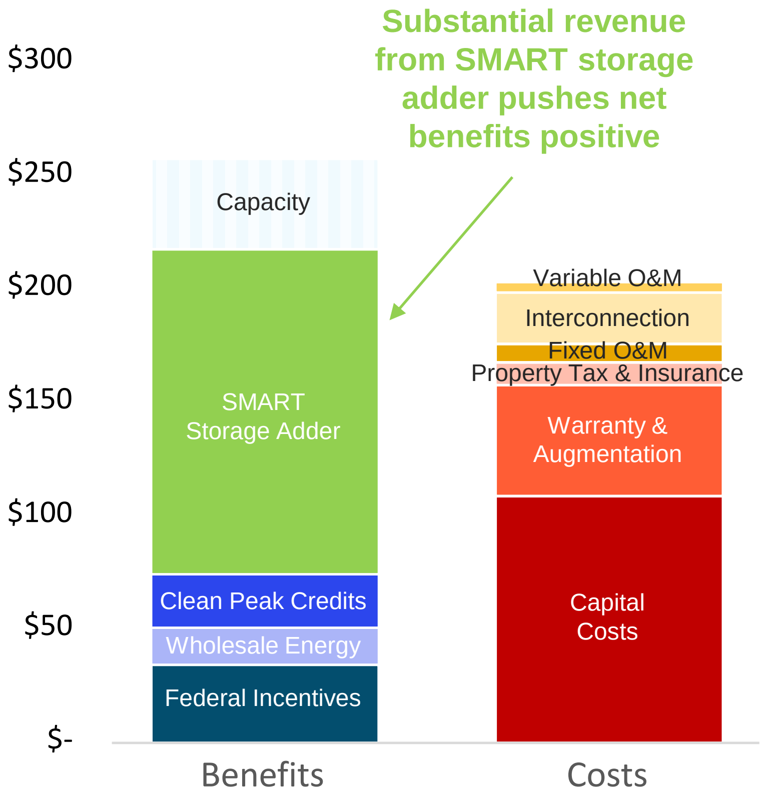
Solar-paired batteries can overcome the added barrier of high charging costs on the wholesale distribution tariff

Levelized revenues & costs - developer view
($2022/kW-yr)



*5 MW, 4-hr Li-Ion Battery, **Standalone**, Distribution connected, 2024 install year*

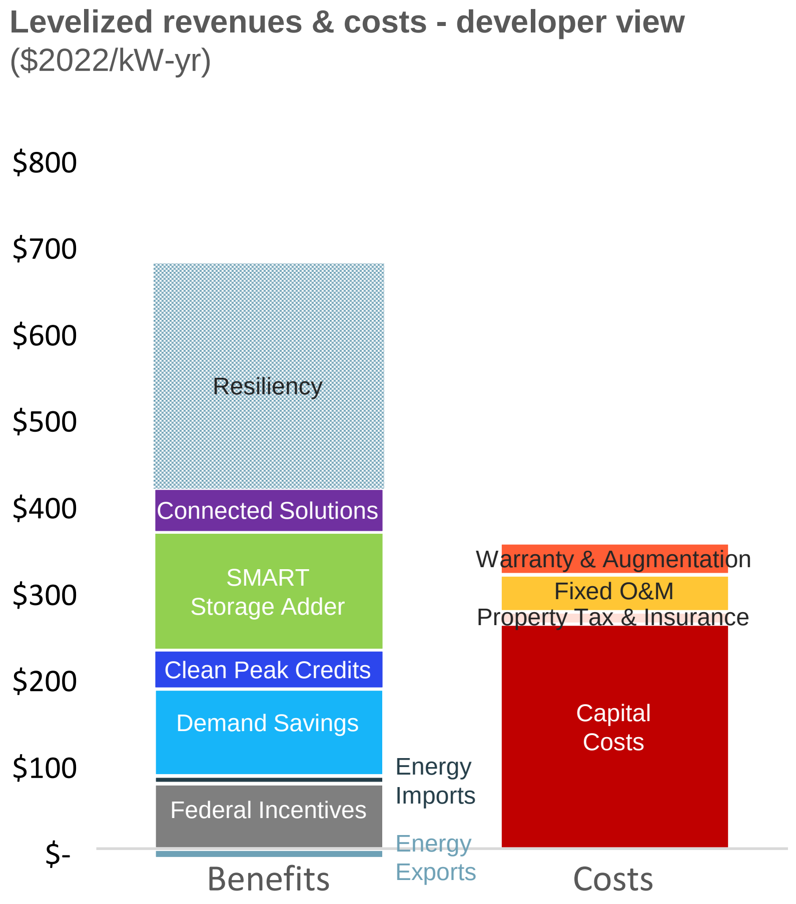
Levelized revenues & costs - developer view
($2022/kW-yr)



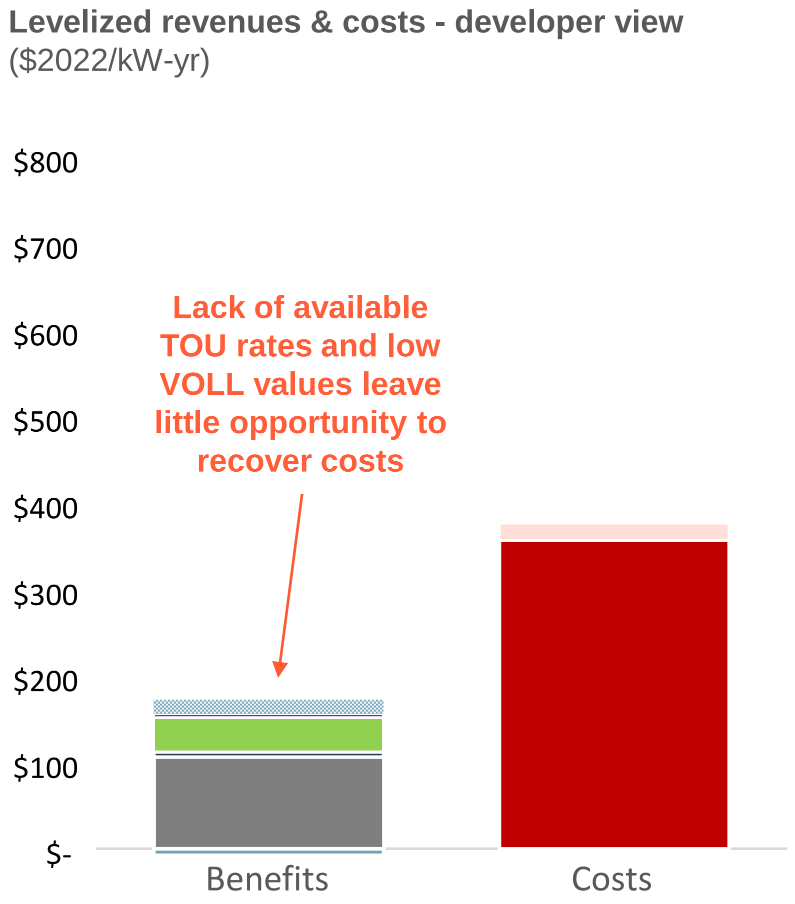
*1 MW, 4-hr Li-Ion Battery, **Paired with 4 MW solar***, *Distribution connected, 2024 install year*

*Costs/benefits shown are incremental costs/benefits of storage component of solar+storage installation

TOU rates, resiliency benefits, and state programs can combine to provide strong behind-the-meter incentives



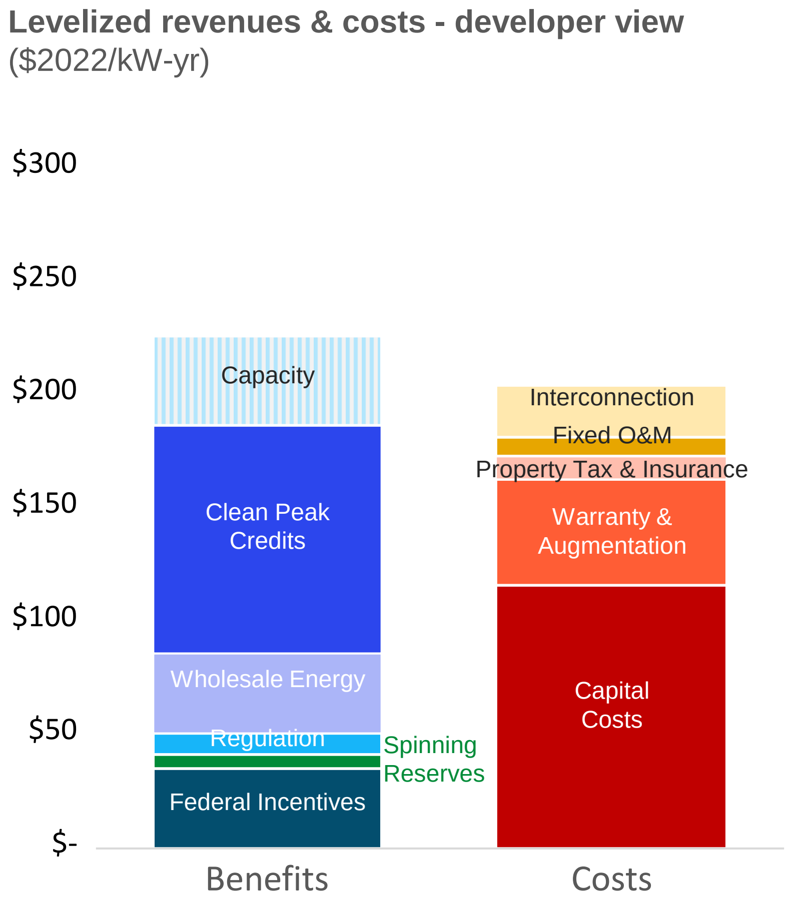
1 MW, 4-hr Li-Ion Battery, Paired with 4 MW solar, BTM at **C&I site,** 2024 install year*



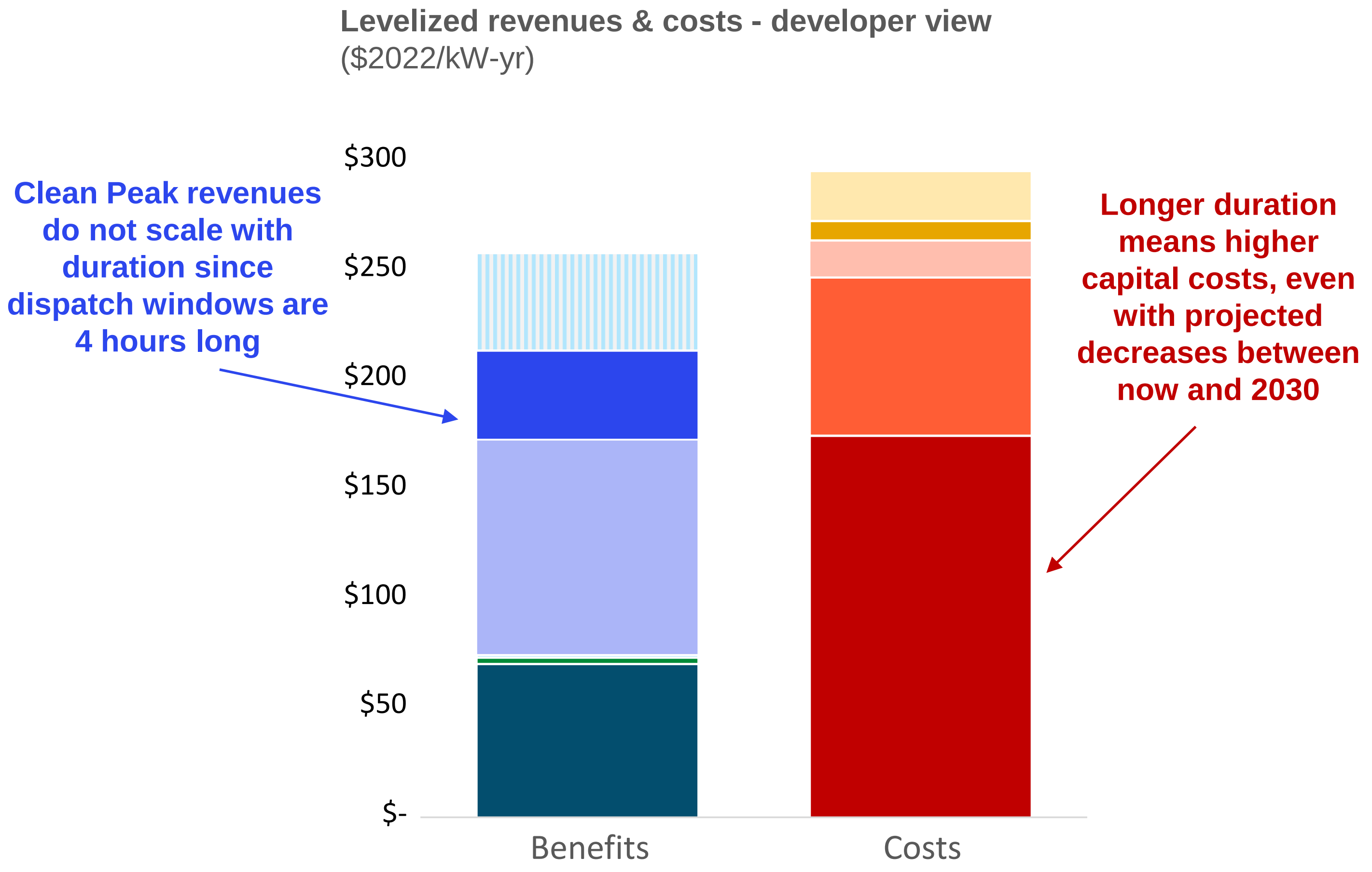
10 kW, 1-hr Li-Ion Battery, Paired with 10 kW solar, BTM at **Residential site,** 2024 install year*

*Costs/benefits shown are incremental costs/benefits of storage component of solar+storage installation

Current revenue streams are not enough to support deployment of mid-duration batteries today or in 2030



50 MW, **4-hr** Li-Ion Battery, Transmission connected, **2023 install year**



50 MW, **8-hr** Li-Ion Battery, Transmission connected, **2030 install year**

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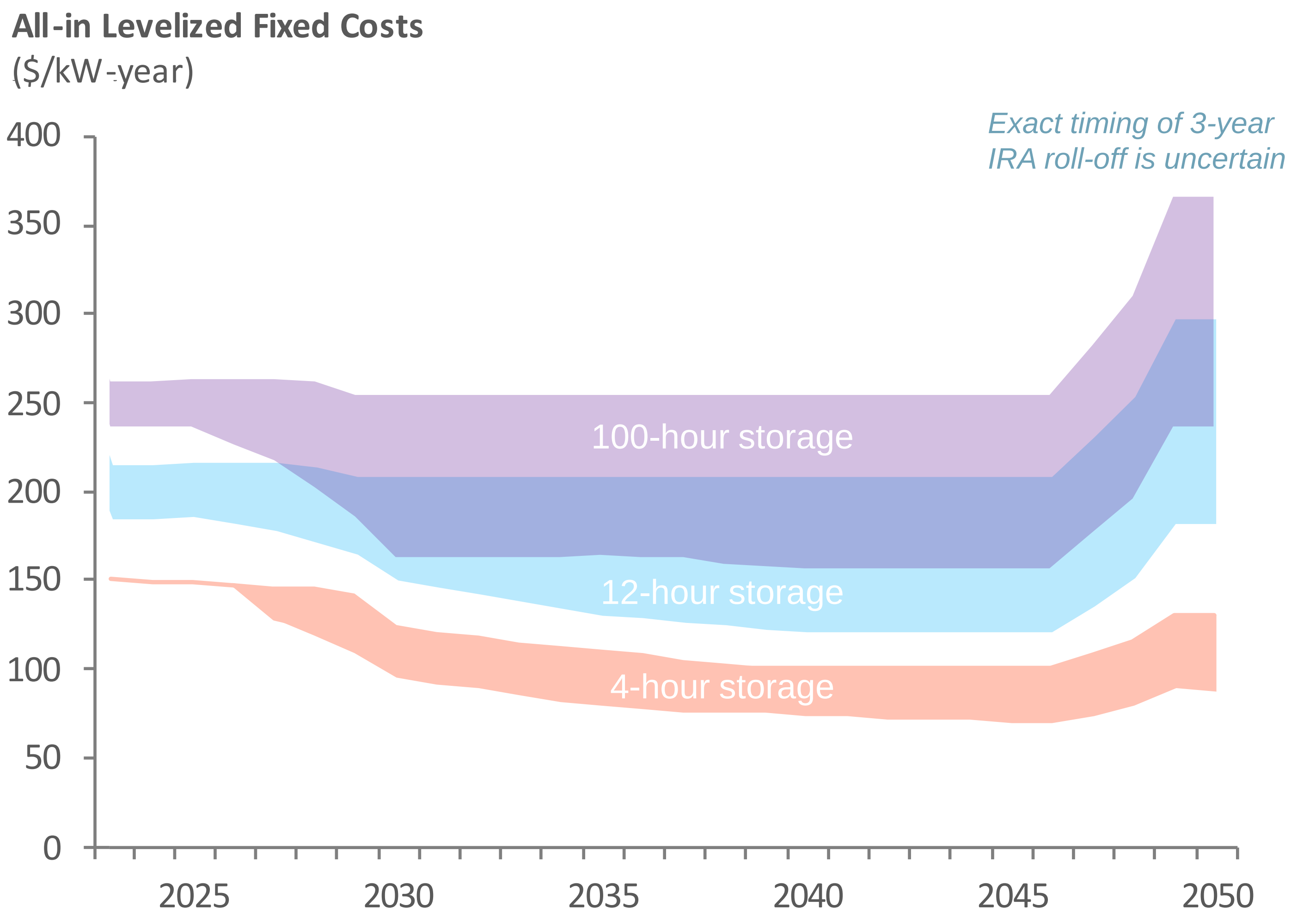
End-user applications for mid- and long-duration storage on the distribution system exist, but face significant barriers

- **Our review and analysis suggests that important use case for LDES is capacity value (covered in detail in next section)**
- **We also evaluate the feasibility of known end-user applications for mid- and long-duration energy storage on the distribution system (with partial quantification)**
  - Backup for sites with high value of lost load (VOLL) such as hospitals, lodging, and schools
  - Pairing with Fault Location, Isolation, and Service Restoration (FLISR) technology to provide backup power for disadvantaged communities (DACs) who are unable to evacuate during severe weather
  - Facilitating faster interconnection while required new infrastructure is built
  - Avoiding high demand charges for electric vehicle fleet charging
- **High technology cost and competition from other resources will likely prevent economically-driven deployment for these use cases**
  - Cost of mid- and long-duration storage are expected to remain high relative to infrequently-run fuel-based backup
  - Lack of need for significant duration in these use cases introduces competition from short-duration energy storage and vehicle-to-grid (V2G) applications of electric vehicles

Mid- and Long-duration costs expected to decline but projections are highly uncertain

+ **Mid- and Long- duration storage costs derived from November 2022 report from Long Duration Energy Storage Council**
  - Ranges represent range of technologies expected to be competitive at each duration
+ **All durations modeled as eligible for IRA tax credits**
  - Tax credits at 30% through 2045, at which point they phase down over 3 years
  - 30% assumes prevailing wage but no additional bonus credits
+ **Applications that do not require longer durations will favor lower cost and higher round trip efficiencies of shorter duration devices**



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Key questions/feedback we heard & response

+ Consider range of renewable build outs beyond Phased CEC portfolio

- *Response: Model build-outs beyond the CECP portfolio to illustrate ELCC as a function of portfolio. Today's results show lower renewable build-out and impacts of removing thermal. Report also shows results with higher levels of renewable build out and transmission outages.*

+ Consider use of a capacity expansion model

- *Response: Some stakeholders suggested running a capacity expansion model, with a range of suggestions for changes in assumptions from the CECP 2050. While we agree that the optimal storage build-out will vary as we adjust input assumptions, we rely on the CECP 2050 given that study, informed through robust stakeholder engagement, is the current basis for overall state strategies and actions. The ELCC values can inform any future capacity expansion modeling.*

+ Consider role of hydrogen

- *Response: Given the scope/timing of this study and the existing uncertainty regarding federal hydrogen policy, this is not being addressed in detail as part of this work.*

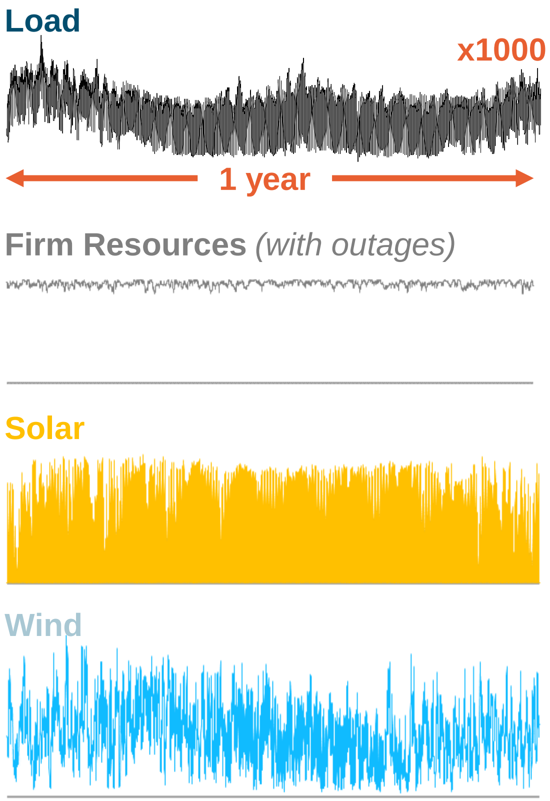
+ Consider use of ISO-NE VER data

- *Response: E3 relies on raw NREL data to ensure the underlying weather conditions assumed in the electrification load data match the renewable profile data. Both sets of data capture 8760 load and renewable output data. Renewable profiles benchmark very closely to ISO-VER data (within 1% CF for wind; NREL-derived solar CF higher given assumes tracking resource).*

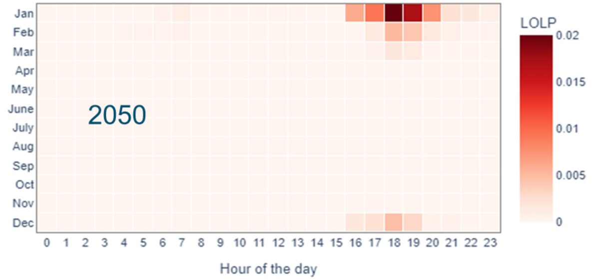
Loss-of-load probability modeling to assess storage effective capacity contributions

- **Modeling relies on Monte Carlo-based optimization model (RECAP) to evaluate the potential for storage to support electric grid reliability**
  - RECAP uses historical weather, load, solar, and wind correlations as the foundation for time-sequential simulation of the system over many potential conditions
  - Time-sequential modeling allows for tracking storage state-of-charge
- **Modeling is done on an hourly (“8760”) basis**

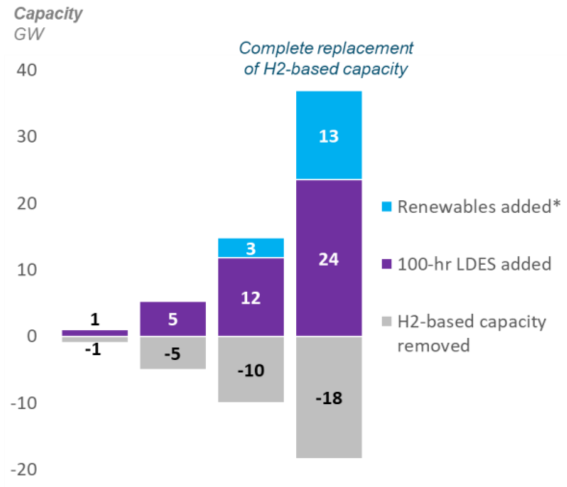
Monte Carlo Simulation of loads, renewable profiles, and generator outages used to simulate 1,000 years of plausible system conditions



Characterize the Reliability Challenge illustrate periods of high loss of load probability in 2030, 2040 and 2050 based on state’s planning portfolios



Characterize Effective Capacity Contributions for generic mid and long duration storage resources

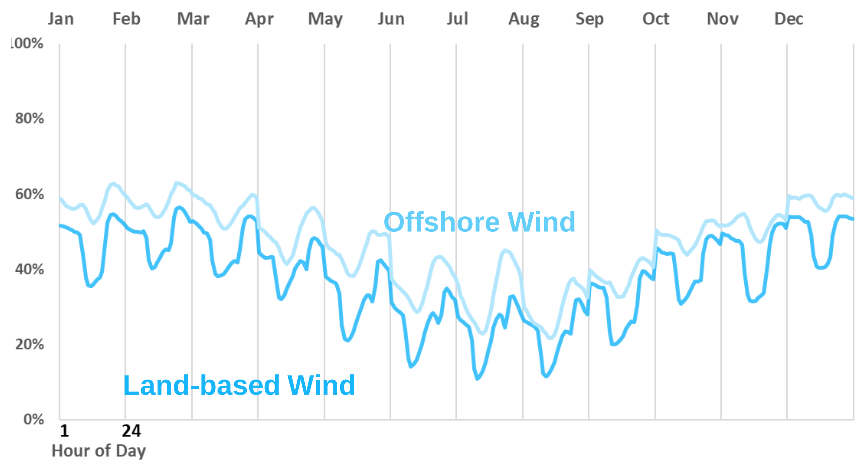


Example RECAP result from New York

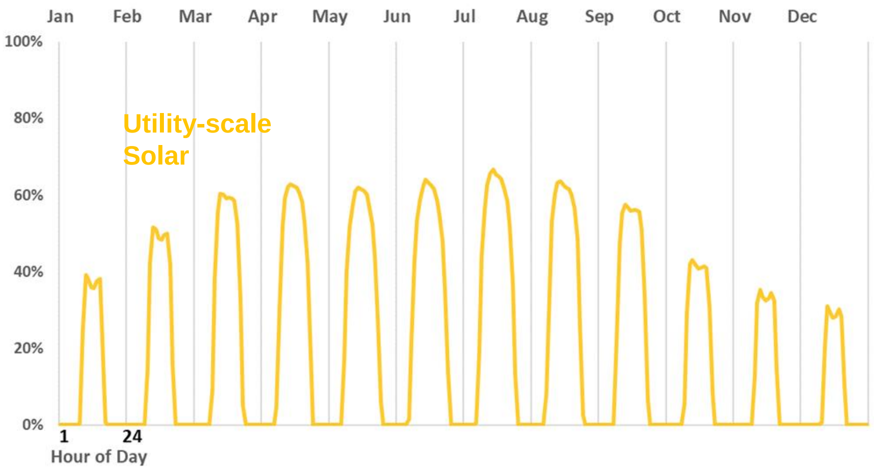
Renewable Profiles

Profile	Primary Source(s)	Weather Year Captured	Notes
Loads	**CECP study** "Phased" scenario **E3's Extended Load Profiles** 39 weather years of load profiles	1980 2019	• Annual loads through 2050 and hourly loads for weather year 2011 used from CECP • Hourly load profiles from the CECP study extended to 39 weather years based on historical loads and temperatures
Wind (Land-based & Offshore Wind)	**NREL** WIND Toolkit	2007 2012	• Profiles for **land-based wind resources** in each state simulated based on potential locations and assumed technology (e.g. hub height, power curve) • Profiles for **offshore wind resources** simulated based on North Atlantic wind quality and assumed power curve
Solar	**NREL** System Advisor Model	1998 2019	• Profiles for **utility-scale solar resources** simulated based on potential plant locations and assumed technology characteristics (tracking vs. tilt, inverter loading ratio) • Profiles for **behind-the-meter/ distributed solar** simulated for each state

Weighted-average Wind Generation Profile *(%)*



Weighted-average Solar Generation Profile *(%)*

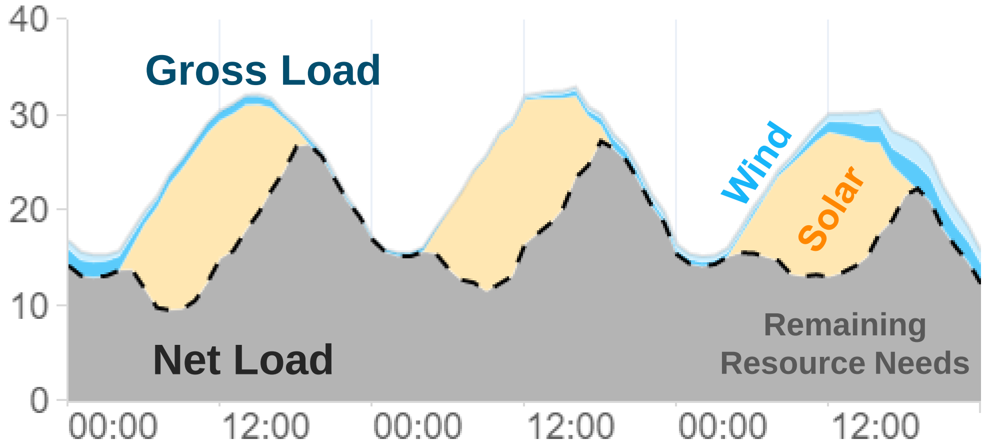


In 2030, New England renewable additions shift summer net peak into the evening

- **In 2030, median New England system peak load grows to 31+ GW but remains summer peaking**
- **Under base conditions, the New England system is assumed ~29 GW of renewables** (roughly 70% are solar), **which shift the gross peak into the evening "net peak" period**

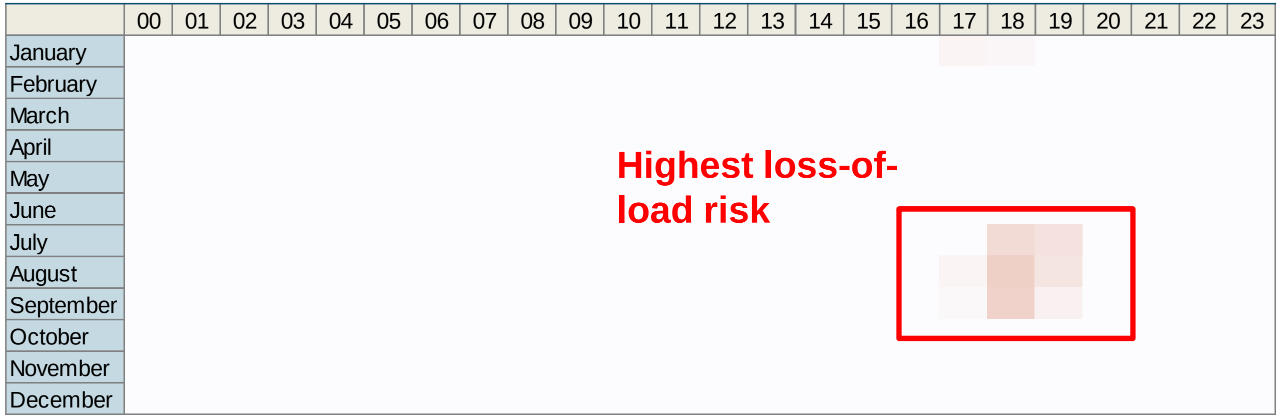
Expected renewable output in 2030 shifts net peak into the evening

Summer Week in July 2030
Renewable Output and Net Load (GW) – *Before Storage*



The greatest resource need, and loss-of-load risk, occurs from 5-7 pm in the summer months

Highest Resource Need in 2030
CECP 2030 Portfolio of Existing & Planned Resources

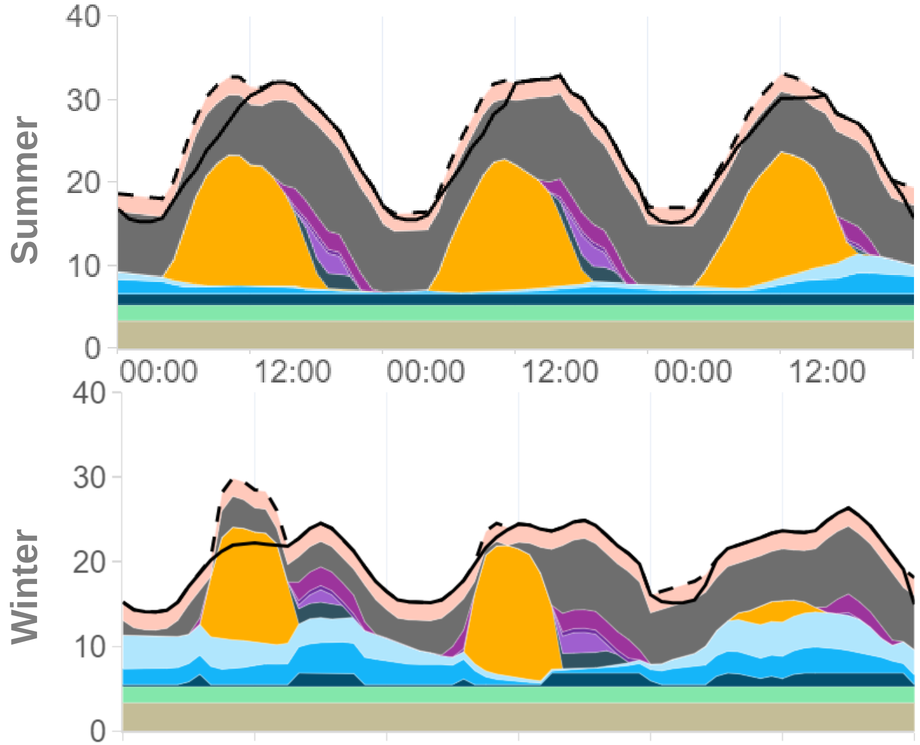


Note: All results shown today remove electrolysis loads & associated generation to serve that load

In 2030, dual peak beginning to materialize, and storage can support both winter and summer system

- **In 2030, CECP portfolios well aligned with summer load, with greater need for firm generation in winter given lower renewable output**
  - Storage can “clip” or reduce the net peak, which is a pronounced evening peak in the summer but more spread out in the winter (evening and morning)

Load and Detailed Resource Dispatch (GW)



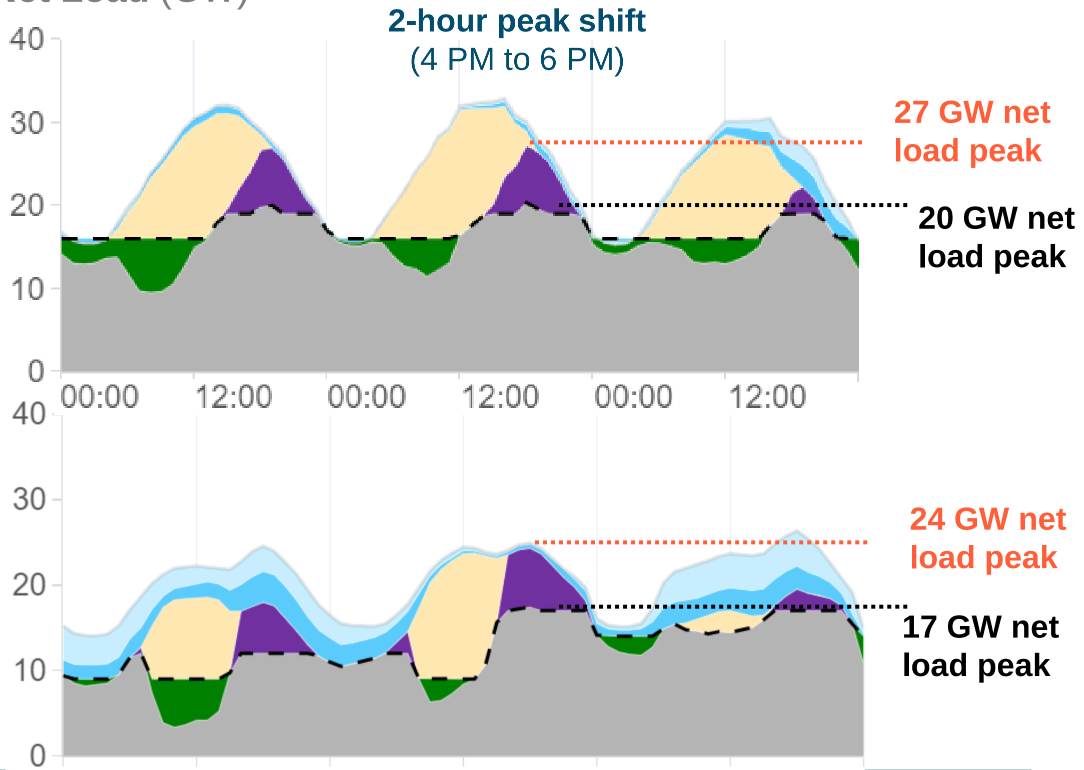
Firm Imports from NY, Atlantic Canada, and Hydro Quebec

Solar, **Offshore Wind**, and **Onshore Wind** generation well aligned with load

Biomass/Waste and **Nuclear** baseload

Large amount of **fossil thermal** generation available**,** critical in the summer and winter

Net Load (GW)



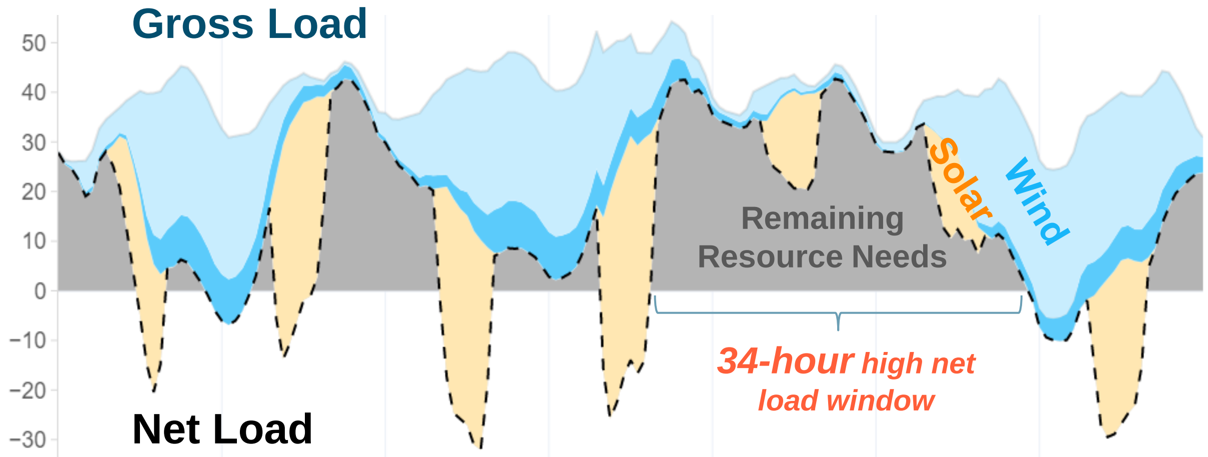
In 2050, New England is significantly winter peaking, with reliability challenge in the evenings

- **By 2050, New England system peak load grows to 50+ GW and transitions to winter peaking**
- **Driven by high electrification and heating loads, system show a dual-peaking pattern where time of high resource needs is spread over longer window and creates opportunity for long duration storage resources to discharge**

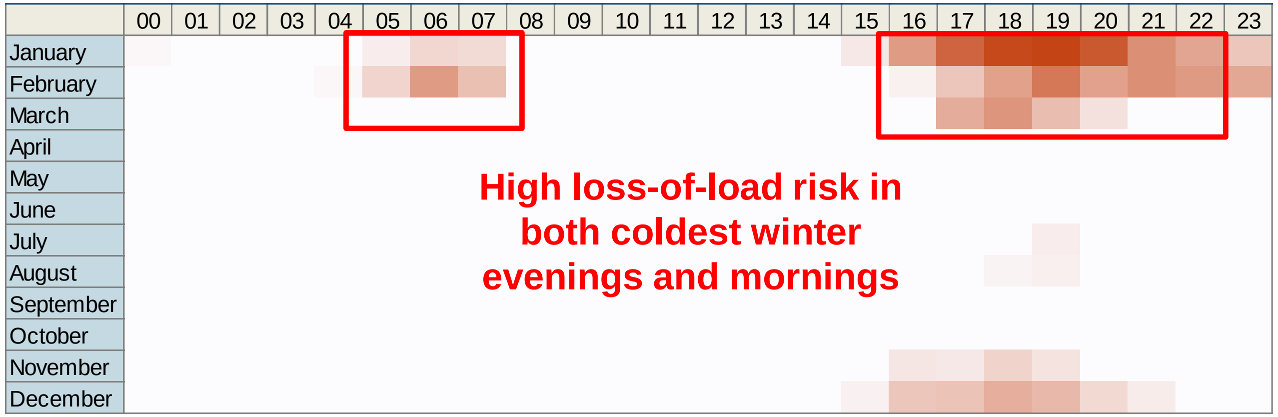
Large net load given lower renewable output on *certain* winter days (e.g., 34-hour net load)

The greatest resource need, and loss-of-load risk, has spread to 4-8 pm, and in morning

Winter Week in 2050
Renewable Output and Net Load (GW) - *Before Storage*

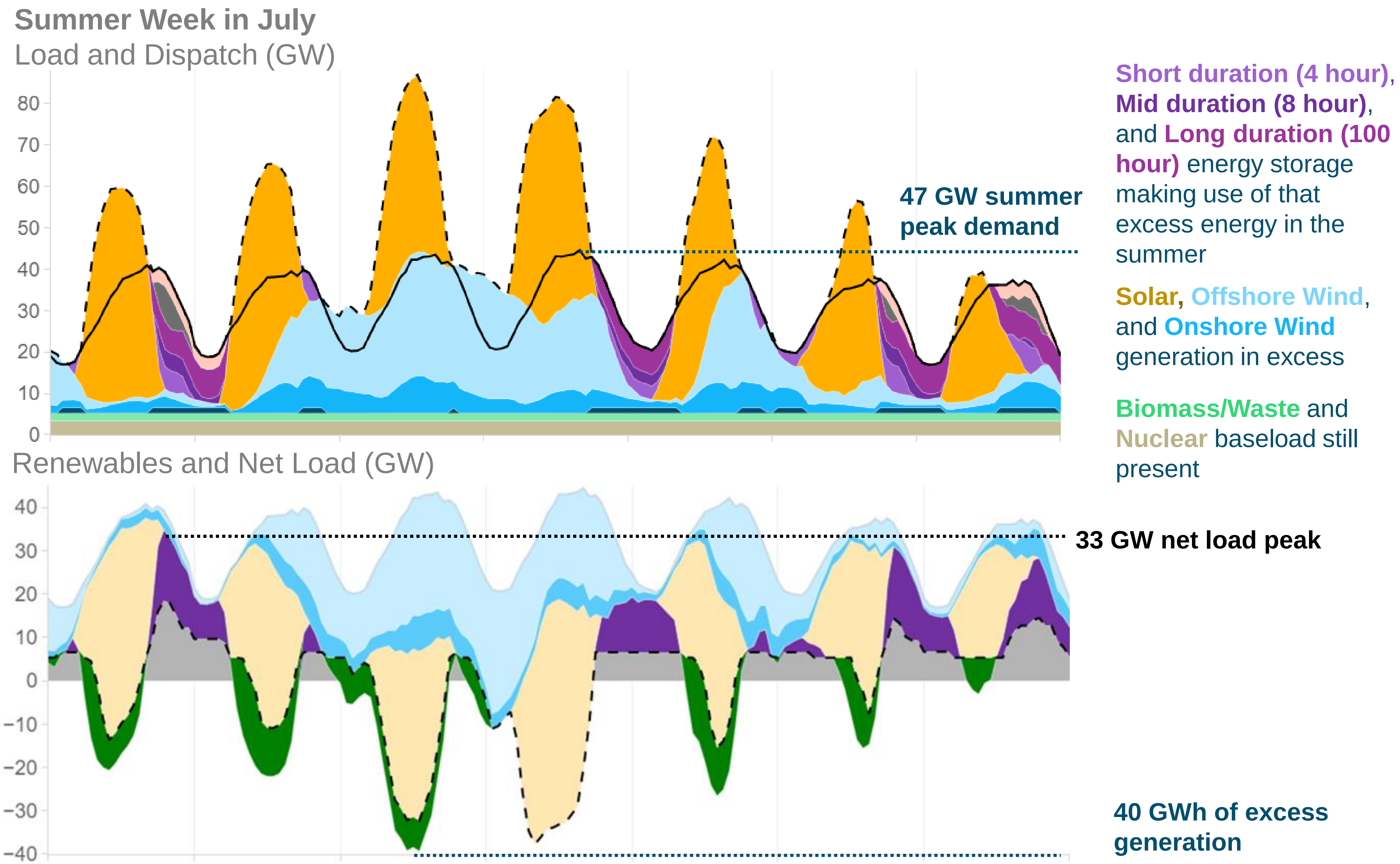


Highest Resource Need in 2050
CECP 2050 Portfolio of Existing & Planned Resources



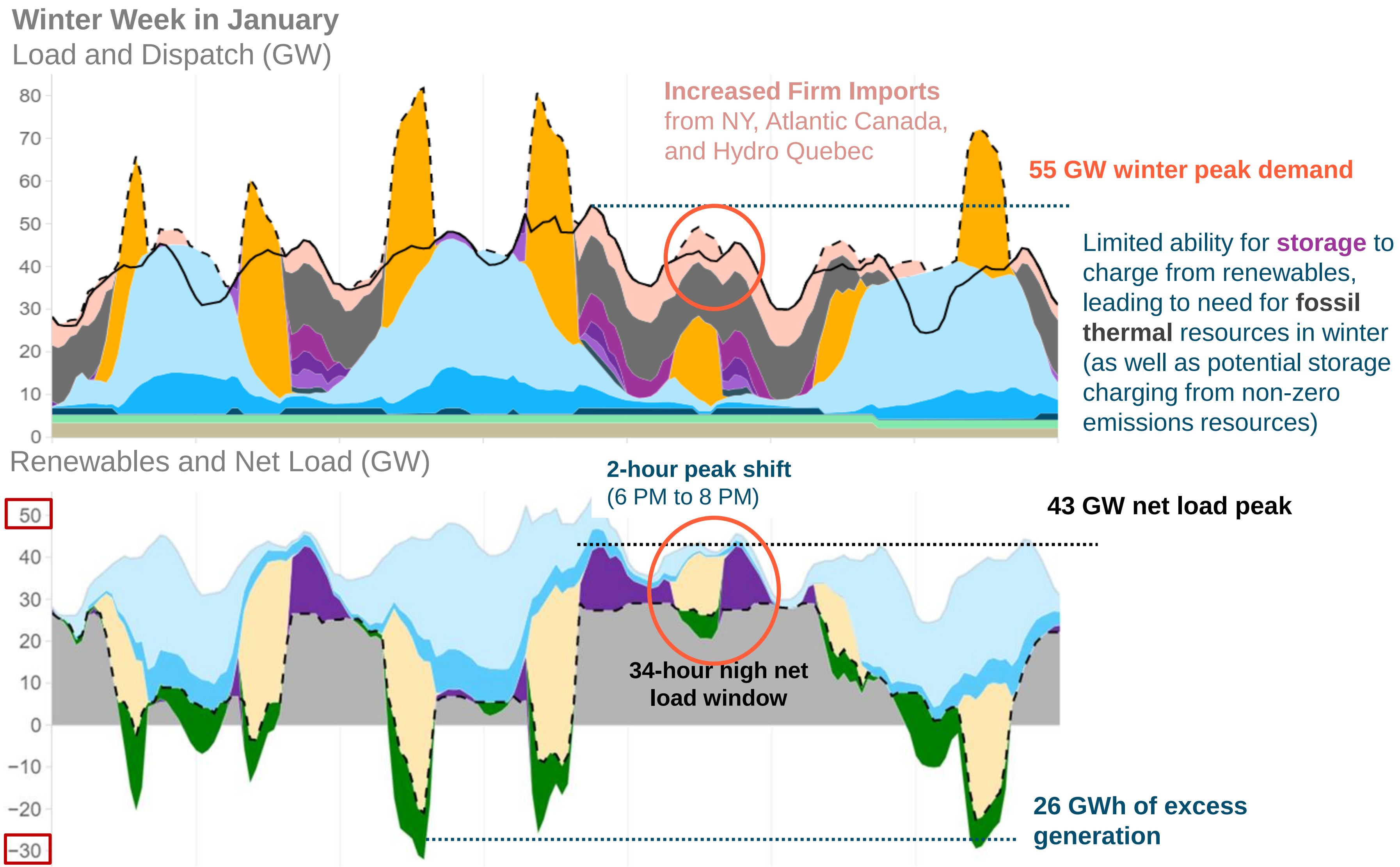
In 2050 summer, abundant renewable generation can meet gross load needs and charge storage resource in the grid

- **Excess renewable generation in the summer ensures that the system is sufficiently reliable despite high summer peak loads (relative to today)**
- **High net load periods are short given the close alignment between renewable generation and load needs**



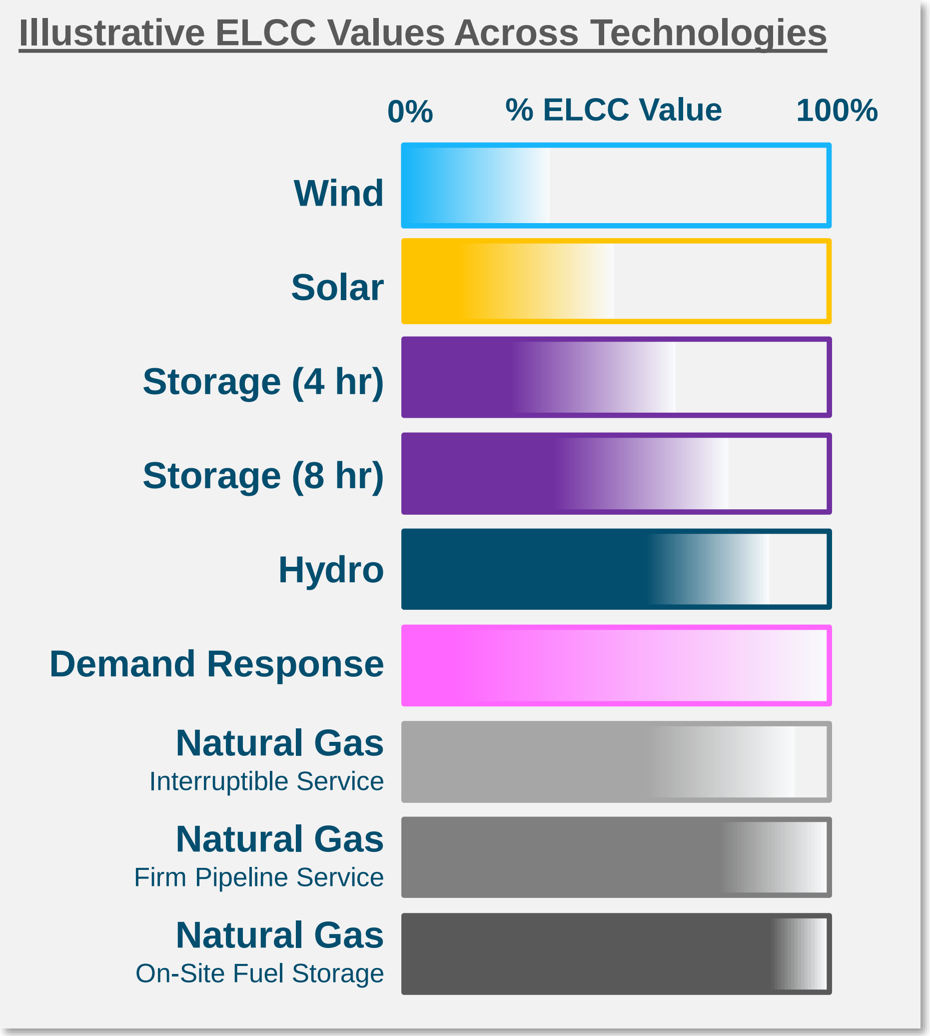
In 2050, winter grid is significantly supported by storage

- **In winter, low renewable (especially wind) periods are the periods with highest risk of loss-of-load, particularly when coupled with high later afternoon loads**
- **LDES may need to charge from thermal resources or imports given the multiple occurrences of these low renewable output/high net load events**



Measuring Effective Capacity Contributions

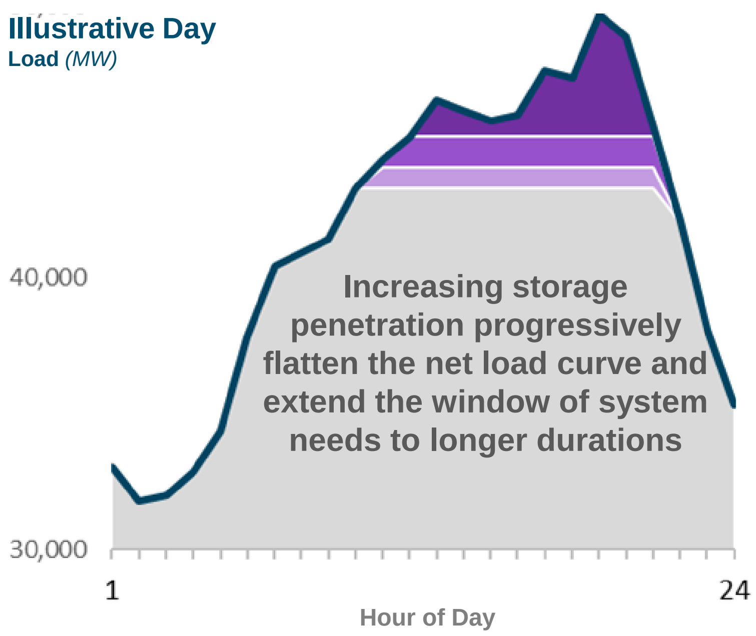
+ **Effective load carrying capability ("ELCC") measures a resource's contribution to the system's needs relative to perfect capacity, accounting for its limitations and constraint**
  - ELCC is the quantity of "perfect capacity" that could be replaced or avoided with renewables or storage while providing equivalent system reliability
  - E.g., A value of 50% means that the addition of 100 MW of that resource could displace the need for 50 MW of "perfect" capacity without compromising reliability
+ **Variable and energy-limited resources can provide significant contributions to resource adequacy**

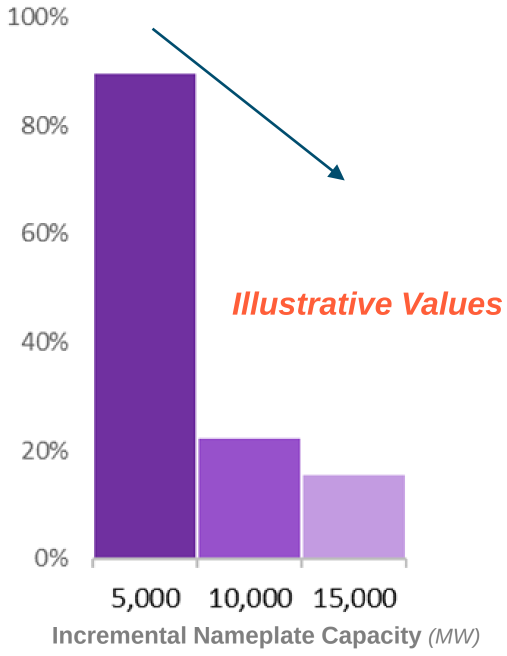


Storage ELCC is a function of penetration and duration

- Energy storage resources exhibit **saturation effect** where their capacity value to the system declines as more resources are added to the system
- Successive tranches of storage reduce peak demand but require next tranche of resource to **dispatch over a longer period** to have the same effect
- Determined by its ability to dispatch over a sustained duration before getting depleted, energy storage capacity value can decline sharply after a certain penetration

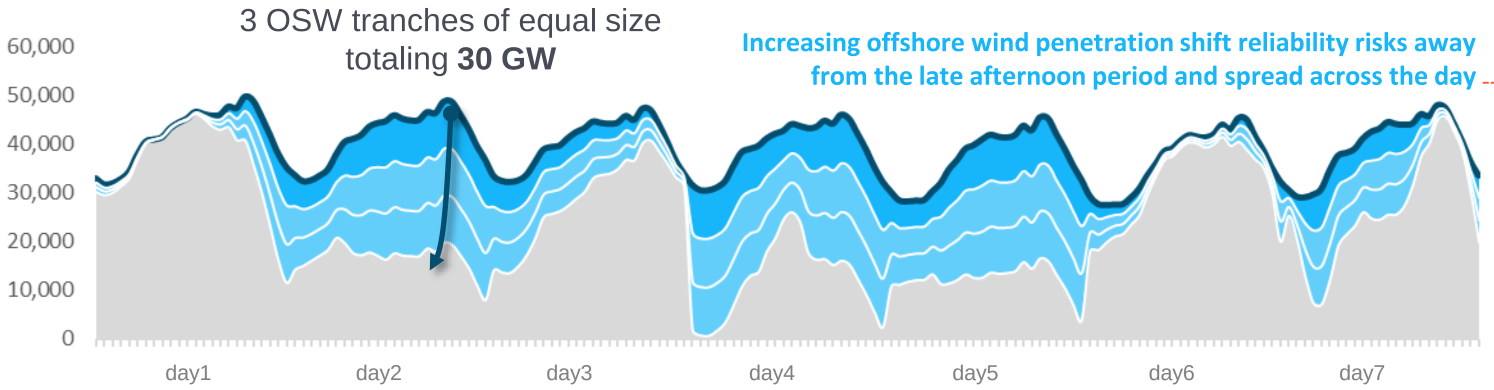
Illustration of Declining ELCC for **8-hour Energy Storage** as a function of Penetration



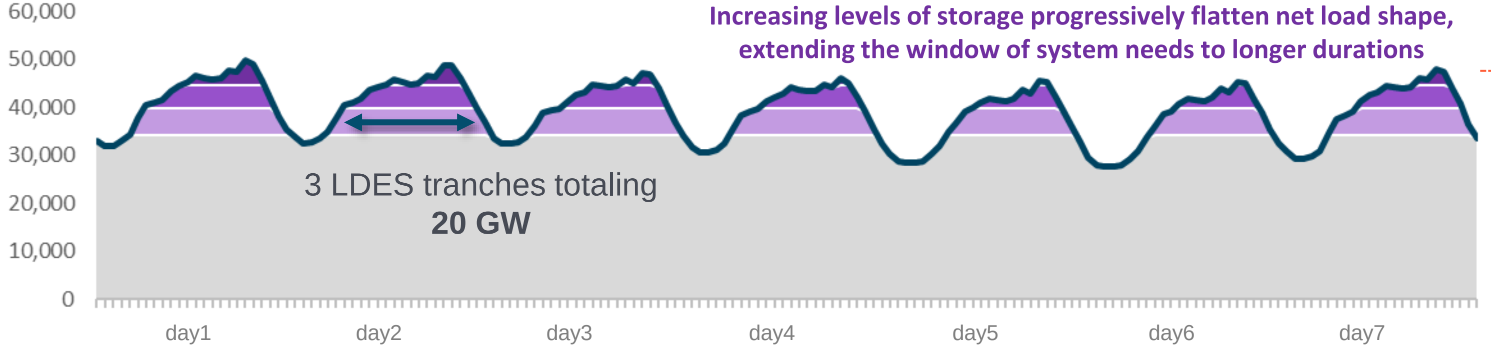


Storage ELCC is a function of rest of the portfolio, particularly offshore wind

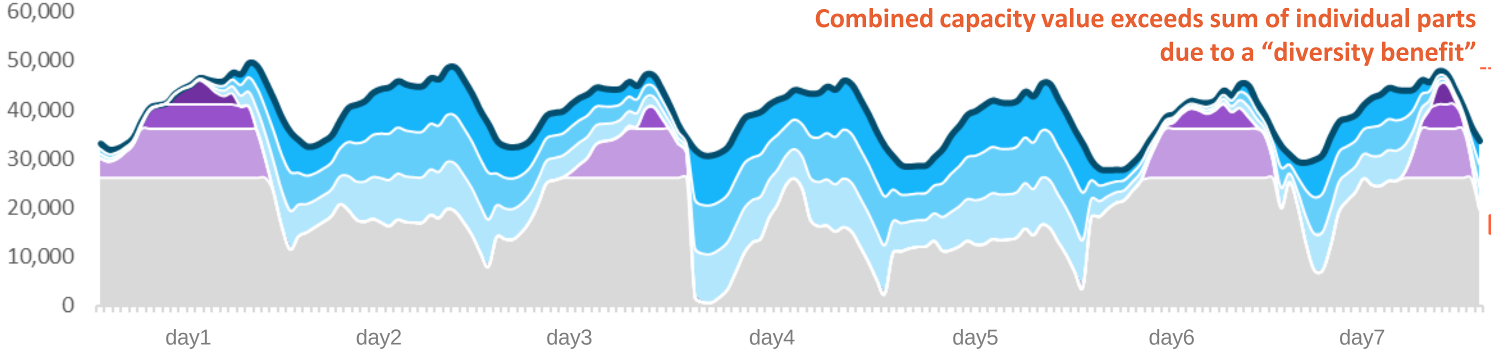
- **Storage ELCC, especially LDES is dependent on the amount of renewable builds embedded in the portfolio**
  - The **complementary interaction** between renewable and energy storage resources can create **diversity benefit** where a total ELCC is greater than the sum of its parts
- **Diversity benefit between offshore wind and LDES is a main driver of LDES ELCC, especially at high penetration**



Capacity Value: 4.0 GW



Capacity Value: 15.4 GW



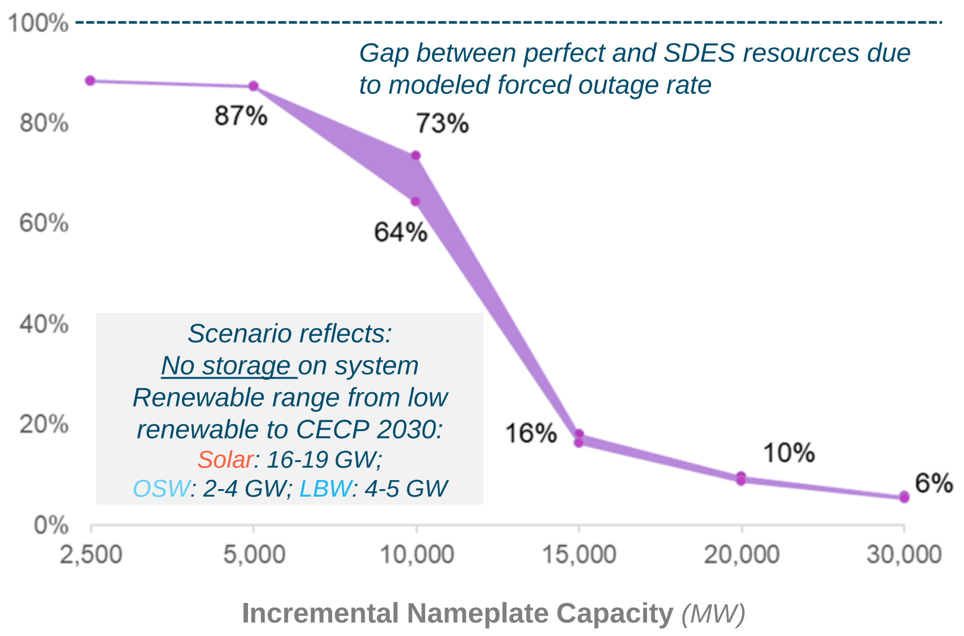
Combined Capacity Value: 23.6 GW

Diversity Benefit: 4.2 GW

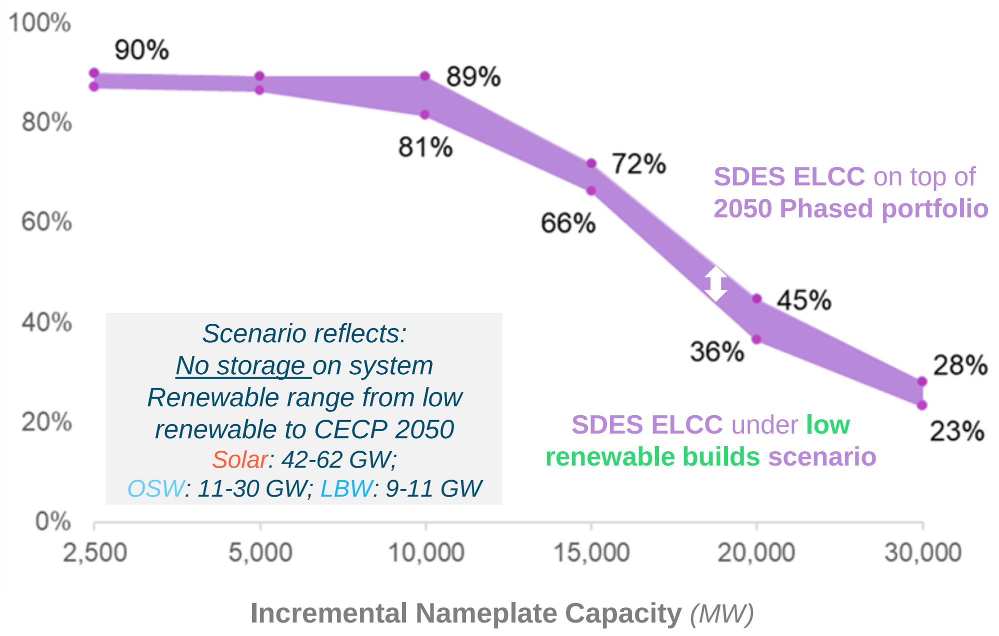
Short Duration Energy Storage ELCC in 2030 and 2050

- Short duration (4-hour) energy storage ELCC is high in first 5~10 GWs addition and then declines as the total additions increase and when saturation effects become evident
- SDES ELCC is less sensitive to amount of renewable generation in the system as it dispatches less hours each day, and thus requires less energy to recharge

Short Duration Energy Storage Incremental ELCC, 2030 *(%)*



Short Duration Energy Storage Incremental ELCC, 2050 *(%)*

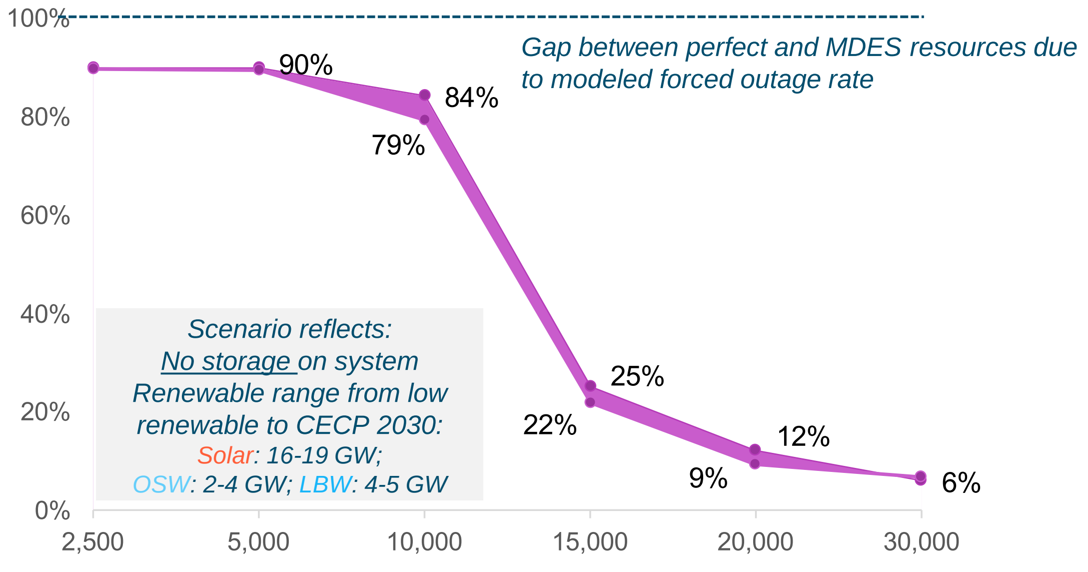


Energy+Environmental Economics

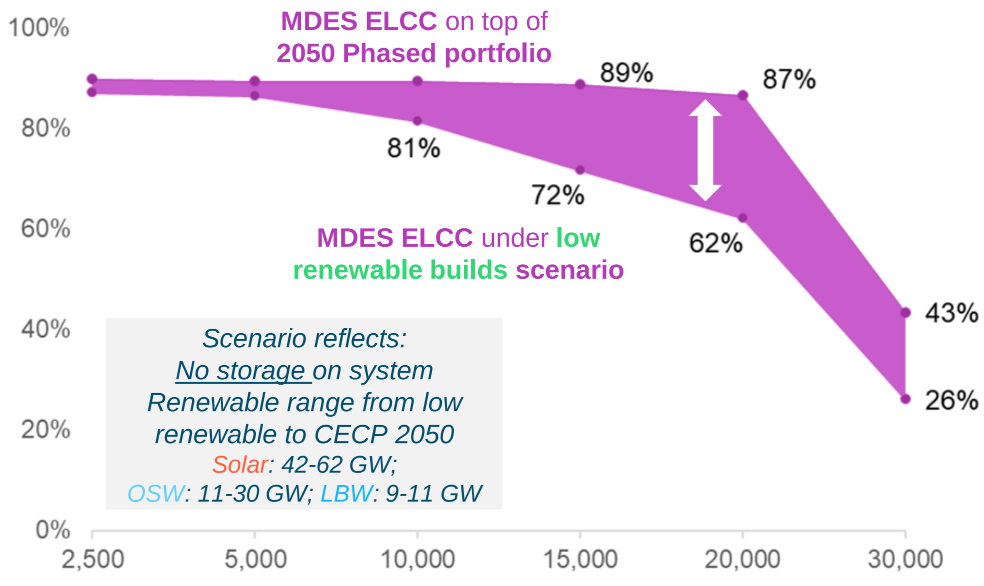
Mid Duration Energy Storage ELCC in 2030 and 2050

- **Mid duration (8-hour) energy storage ELCC is higher in 2050 when ISO-NE transitions to a winter dual-peaking system driven by growing electrification and heating loads**
- **MDES ELCC starts lower and drops more quickly in 2050 low renewable builds scenario as:**
  1. Less excess energy is available to re-charge the battery, and
  2. Net load shape becomes more volatile and creates few opportunities for MDES to dispatch and fill the gap

Mid Duration Energy Storage Incremental ELCC, 2030 *(%)*



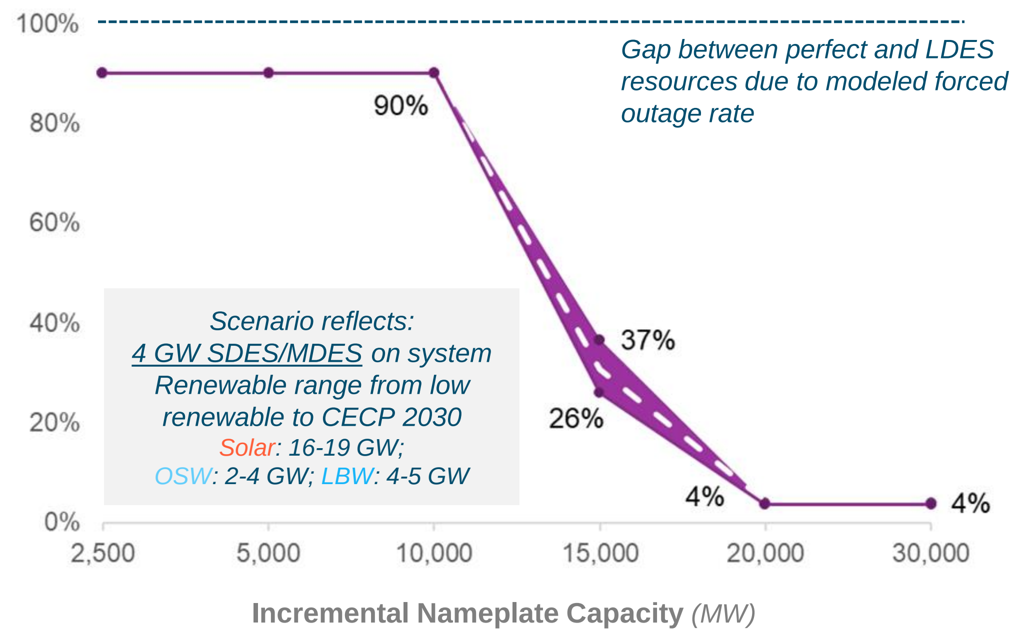
Mid Duration Energy Storage Incremental ELCC, 2050 *(%)*



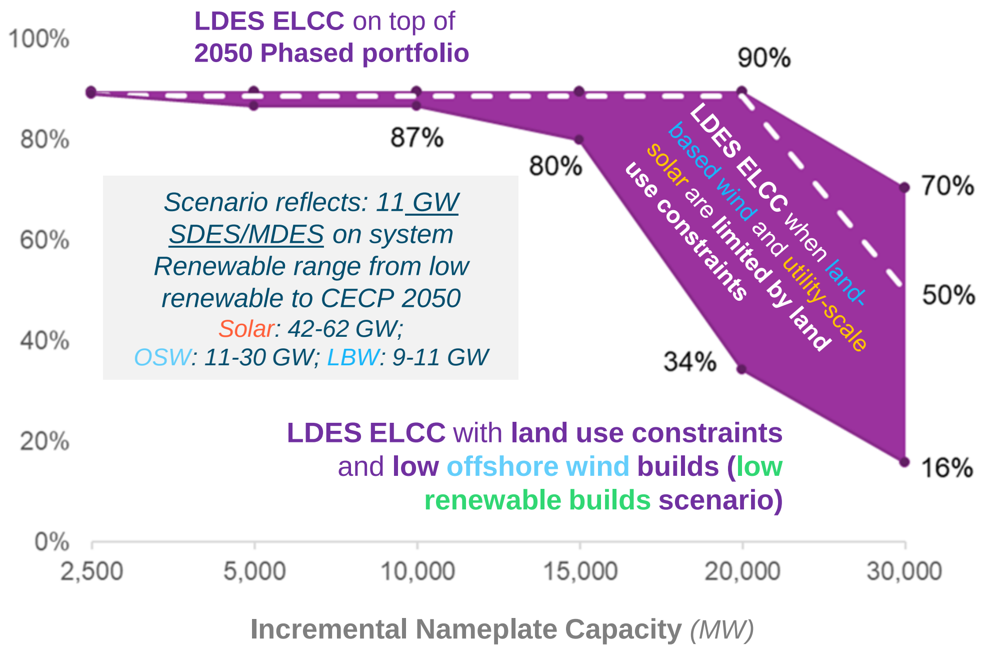
Long Duration Energy Storage ELCC in 2030 and 2050

- Long duration (100-hour) energy storage ELCC remains high in low penetrations but then declines sharply at in 2030 as total additions shave peak and flatten the net load profile
- In 2050, the difference between LDES ELCC under CECP phased portfolio and low renewable builds scenario is substantial at higher penetrations when LDES recharging capability is limited, and system requires storage to dispatch even longer for effective peak-shaving

Long Duration Energy Storage Incremental ELCC, 2030 *(%)*

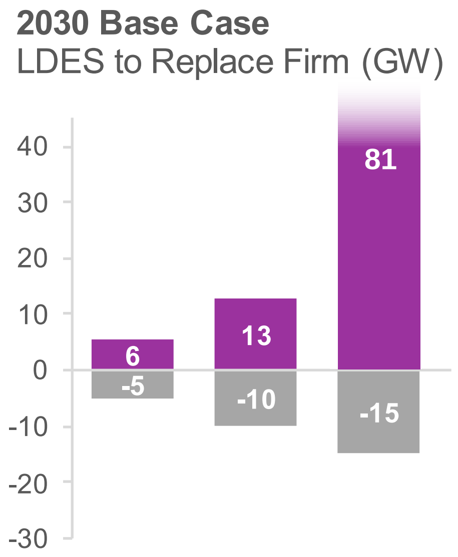


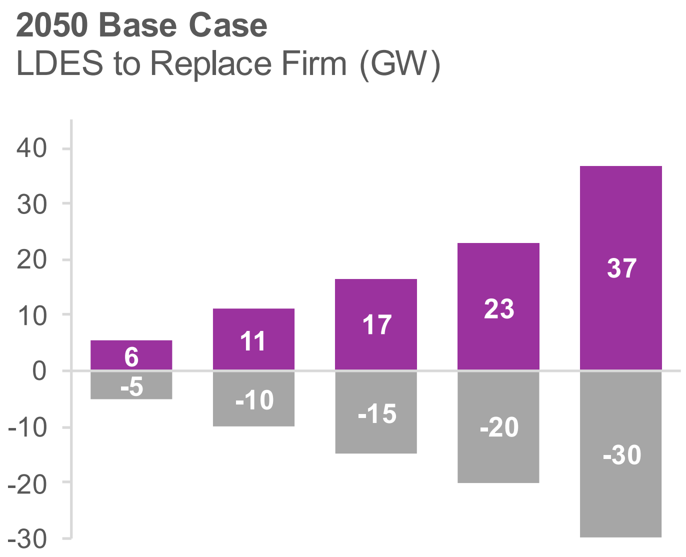
Long Duration Energy Storage Incremental ELCC, 2050 *(%)*

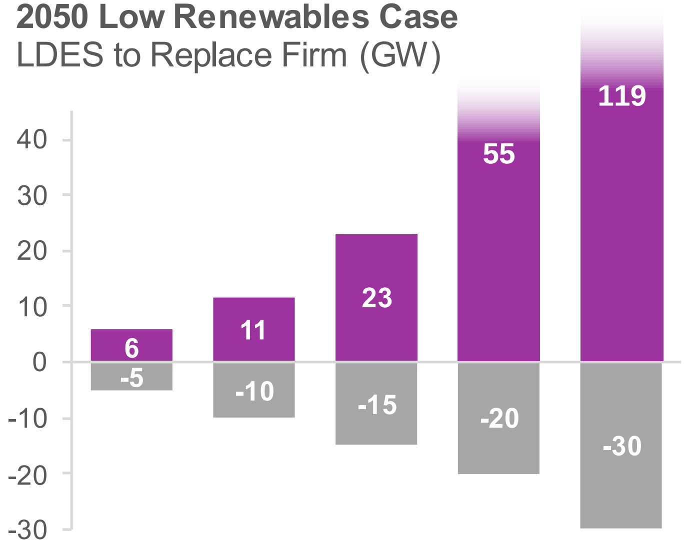


Long-duration storage can replace significant firm capacity on the New England system

+ **If New England hits renewable build-outs in line with the CECP 2050, 10-20 GW of 100-hour storage have the ability to substitute for theoretical “perfect” firm capacity on a nearly 1:1 basis**
  - Graph compares removing a “perfect” firm resource with LDES with 50% RTE







Note: Replacement value assuming no additional renewables added to the system (sensitivities with additional renewables will be in report). These maintain the same total effective capacity (or shortfall) in the initial system before NG replacement, even if system is under/over reliable

Reliability Modeling Next Steps

- **E3 is developing related scenarios, for contingencies including**
  - No imports
  - Loss of Massachusetts offshore wind (e.g., transmission outage)
  - Loss of transmission to Maine, Vermont, and New Hampshire (and associated renewable generation and loads)
  - No thermal / 100% renewable
- **Additional outputs related to system reliability, curtailment and emissions**

Agenda

- Study Background and Goals | 5 min, DOER
- Study Task 1: Energy Storage Today | 15 min, E3
- Study Task 2: MDES/LDES Cost and Use Case Outlook | 5 min, E3
- Study Task 3: Reliability Modeling | 40 min, E3
- Study Timeline and Next Steps | 5 min, DOER
- Q&A | 20 min, E3 and DOER

Study Timeline

We are here →

Task	Date
Study Kickoff	*March 29, 2023*
Stakeholder Session #1	*June 9, 2023, 9:30-11am (EDT)*
Stakeholder Modeling Feedback	*June 21, 2023*
Stakeholder Session #2	August 16, 2023, 9:30-11am (EDT)
Stakeholder Interviews	Ongoing until September 1, 2023
Stakeholder Final Feedback Due	**September 1, 2023**
E3 Results to MassCEC and DOER	October 1, 2023
DOER Report, including final study results, to Legislature	By December 31, 2023
Public comment due on DOER Report	Early 2024

Immediate Next Steps

- Seeking continued stakeholder engagement – critical to study outcomes and potential policy recommendations
  - Interviews ongoing through August – Please get in touch if interested and we haven’t yet reached out
  - Written comments – Strongly encouraged, even if you have participated in interviews. Please submit by **Friday, September 1, 2023** to: thomas.ferguson@mass.gov
- Webpage for the study: here
- Recording of today’s session will be made available and posted on the study website.

Agenda

- Study Background and Goals | 5 min, DOER
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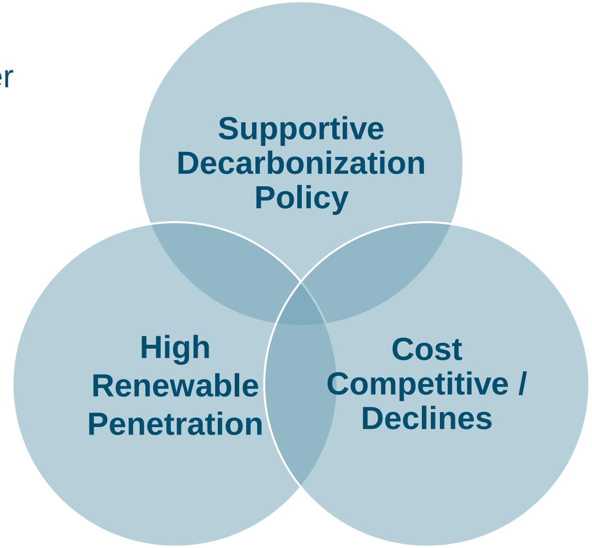
Select Emerging Study Findings

+ **Today, most new storage being deployed is small (<5 MW), front-of-meter Li-Ion installations**
  - State (and utility) programs and incentives are critical to supporting these projects, but provide little incentive to extend storage durations beyond 2-4 hours
  - Peak demand reduction is the most popular source of revenue today, which is expected to continue in the near-future
  - TOU rate availability and value of lost load play key roles in behind-the-meter installation economics
+ **Several mid-duration storage technologies (4-10 hr) are becoming available, but compete with short-duration (<4 hr, SDES); will become more valuable as new renewable energy shifts and SDES flattens net load peak beyond effectiveness of SDES**
+ **Long-duration storage technologies (LDES, 10+ hours) range from experimental to commercial stage (pumped hydro), and are expected to be available in the next several years (except pumped hydro, which supports state already)**
  - In the near term, until high levels of renewables or binding carbon targets, LDES must compete with other dispatchable technologies and short-duration storage, making the economics challenging
  - As the region decarbonizes and electrification loads materialize, LDES can provide a zero-carbon alternative to existing fossil capacity resources, if technology can become cost-competitive and scale (e.g., complete with other zero-carbon generation like H2)
  - Incremental higher capacity value of longer durations needs to outweigh higher costs of the resource (net of energy market revenues) vs. short duration storage or clean firm resources
+ **Storage, particularly LDES (10+ hours), can provide significant capacity value to New England**
  - If CECP 2050 is realized, New England portfolios will have abundant renewables, particularly offshore wind, for storage to charge from; in these portfolios, almost 20 GW LDES can replace "perfect" firm capacity without sacrificing reliability in 2050
  - The strong diversity benefit between LDES and offshore wind, driven by the availability of offshore wind to recharge LDES during challenging winter weeks, is essential to realizing high-capacity value from storage



THANK YOU!

Storage contributes significantly to the state's total effective capacity need

- **Variable resource and storage will account for an increasing share of regional resource adequacy needs**
- **Renewables provide**
  - Roughly **19%** of regional needs by 2030
  - Roughly **12%** of regional needs by 2040
  - Roughly **17%** of regional needs by 2050
- **Storage provides**
  - Roughly **13%** of regional needs by 2030
  - Roughly **20%** of regional needs by 2040
  - Roughly **29%** of regional needs by 2050

Energy Storage Share of Regional Total Resource Needs *(GW)*