Form Energy Comments on Long-Duration Energy Storage Study Stakeholder Session #1 Presentation

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Tom Ferguson, Ph.D.
Energy Storage Programs Manager
Massachusetts Department of Energy Resources
100 Cambridge Street, 9th Floor
Boston, MA 02114
Submitted via email: thomas.ferguson@mass.gov

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Dear Dr. Ferguson

Form Energy appreciates the opportunity to comment on the study that the Massachusetts Department of Energy Resources (DOER) and the Massachusetts Clean Energy Center (MassCEC) will perform on how to optimize the cost-effective deployment and utilization of both new and existing mid-duration and long-duration energy storage to inform the design of solicitations and procurement in compliance with Section 80 of Chapter 179 of the Acts of 2022, *An Act Driving Climate Policy Forward* (Section 80). These comments focus on the proposed study approach presented at Stakeholder Session #1 on June 7, 2023 (Stakeholder Session #1 Presentation).[1]

Summary Recommendations

Our primary recommendation is that the study must include as its foundation a cost-minimizing capacity expansion optimization that evaluates mid-duration and long-duration energy storage needs to meet the state's greenhouse gas emissions limits. This optimization is required by Section 80 and will inform DOER's decision about how best to exercise its authority to require solicitations and procurements for energy storage. We additionally recommend scenarios, data sources, and assumptions to include in this cost-minimizing optimization so that the results produce reasonable evidence of the benefits of mid-duration and long-duration energy storage, inclusive of the multi-day energy storage class like Form Energy's 100-hour iron-air batteries.

[1] The State of Energy Storage and its Future Role in the Commonwealth, Stakeholder Session #1: Study Overview, Approach and Early Insights, June 7, 2023.

About Form Energy

Form Energy is a Somerville, MA based company that is commercializing and manufacturing a new class of multi-day energy storage systems to enable a fully renewable electric grid that is reliable and cost-effective year-round, even in the face of multi-day weather events. Our first commercial product is a rechargeable iron-air battery capable of continuously discharging electricity for 100 hours at a system cost less than 1/10th the total installed cost, per unit energy, of lithium-ion battery technology. Form Energy has over 3 GWh of projects under contract and development, with our first project expected to come online in 2024 with utility Great River Energy in Minnesota. With over 500 employees, Form Energy also has offices in the San Francisco Bay Area and the Greater Pittsburgh Area. Our first commercial manufacturing facility is under construction in Weirton, West Virginia, and will employ more than 750 people and have an annual production capacity of 500 megawatts when operating at full capacity.

Recommendations

1. **Section 80 Requires the DOER to Conduct a Least-Cost Capacity Expansion Optimization**

Section 80 includes many requirements, but first and chief among them is a requirement that DOER conduct a study of "how to optimize the cost-effective deployment and utilization of both new and existing mid-duration and long-duration energy storage systems."[2] The plain reading of this language indicates that DOER's study should include a least-cost resource optimization, generally referred to as a capacity expansion optimization, to identify the optimal long-term needs for mid-duration and long-duration energy storage that minimize system costs and achieve the state's greenhouse gas goals.

The primary purpose of this study is to support DOER in fulfilling its obligation both to "require solicitations and procurements [of mid-duration and long-duration energy storage] in accordance with the study recommendations"[3] if the study finds it beneficial to the Commonwealth, and to ensure that procurements contribute to greenhouse gas emission reductions, promote the integration of offshore wind and other renewables, transport energy from periods of low energy demand to periods of high demand, enhance electric reliability, and minimize ratepayer costs.[4] Unfortunately, the Stakeholder Session #1 Presentation does not reflect these requirements or clarify how the proposed study will evaluate appropriate energy storage deployment targets.

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[2] See St. 2022, c. 179, §§ 80(a) (Section 80)

[3] Section 80(c)

[4] *Id*

Fortunately, E3 has the expertise to conduct a least-cost capacity expansion optimization,[5] and it is possible to efficiently structure such a study to fulfill many Section 80 requirements and build upon the 2050 Clean Energy and Climate Plan (CECP) modeling.[6]

2. **The Study Should Conduct a New Least-Cost Capacity Expansion Optimization that Improves on Learnings and Limitations of the 2050 Clean Energy and Climate Plan**

E3 proposes to take the least-cost Phased Scenario portfolio results from the 2050 CECP as a fixed starting point for the study, rather than conduct a new optimization that improves upon CECP modeling. We recommend that E3 conduct a new capacity optimization due to several limitations of the 2050 CECP modeling that understate the needs for and benefits of long-duration energy storage, even though the 2050 CECP results are relatively favorable to 100-hour energy storage compared to other long-duration energy storage resources:

- Intent of the 2050 CECP was to inform economy-wide planning not electric procurement: The 2050 CECP 2050 was intended to explore the balance of emissions reductions expected from different economic sectors (e.g. electric vs transportation sectors); it was not designed to inform electric resource planning and procurement decisions
- Limited representation of energy storage resources:
    - The CECP only modeled two simplified energy storage resource types: lithium-ion storage with a duration from 0 to 12 hours, and a generic long-duration storage resource with a duration of 24 to 100 hours
    - DOER provided Form Energy with spreadsheets of energy storage modeling inputs and outputs in the 2050 CECP, which indicated that the optimal 2050 New England portfolio included 11.3 GW of lithium-ion storage with 119.6 GWh of energy capacity (an implied average fleet duration of 10.6 hours), and 7.2 GW of long-duration storage with 716.5 GWh of energy capacity (an implied average fleet duration of 99.4 hours).
    - Although these energy storage needs roughly align with our own modeling of the CECP Phased Scenario, the total 2050 CECP portfolio includes vastly more solar resources than we identified in our own modeling. This raises concerns that the 2050 CECP portfolio may significantly understate energy storage benefits, inaccurately represent energy storage operational profiles, and result in mischaracterizations about the reliability benefits of energy storage.
- Lack of transparent inputs and results: The detailed energy storage assumptions and results referenced above were not included in the public 2050 CECP report or made

[5] E3 and Form Energy are currently collaborating on a study funded by the California Energy Commission, *Assessing the Value of Long Duration Energy Storage*. This study included a least-cost optimization of diverse energy storage archetypes in California. [Final workshop results presented on May 15, 2023](#).
[6] Available at https://www.mass.gov/doc/2050-clean-energy-and-climate-plan/download

available on DOER's website as far as Form Energy has been able to identify. This has prevented robust participation from the storage industry and other stakeholders about how best to represent diverse long-duration energy storage resources for the purposes of developing deployment targets and procurement programs required by Section 80.

- Limited electric sector technology or portfolio scenarios: the 2050 CECP did not include multiple technology sensitivities or electric sector emissions or weather scenarios that could help identify the benefits of long-duration energy storage to the Commonwealth to support the design of procurement programs.

- Additional concerns:

  - Wind limits: It appears that the 2050 CECP may have imposed limits on offshore wind resource build, which may have led the model to select higher amounts of solar energy and short-duration energy storage, relative to long-duration storage, than it would have otherwise.

  - Reliability simplifications: CECP modeling of the reliability contributions of storage also appears to have awarded reliability value based on the amount that energy storage discharges in a given hour, rather than the amount of energy in MWh that an energy storage resource has stored in reserve, which could also impact optimal portfolio results. This means that a 100-hour battery and a 4-hour battery are likely given the same reliability value, an interplay that could further complicate E3's proposed reliability analysis based on CECP results.

If DOER concludes that it does not have sufficient time or resources to conduct a new least-cost optimization, 2050 CECP results could inform initial or interim recommendations about energy storage procurement targets; however, we caution that the best approach would be to conduct a least-cost optimization purpose built to inform the design of energy storage deployment targets and procurement programs pursuant to Section 80.

3. Recommended Capacity Expansion Optimization Study Approach and Assumptions

We recommend that E3 reorient its proposed study around a capacity expansion optimization that explores the least-cost portfolio of new and existing mid and long-duration storage, as well as other existing and new generation resources, to meet the Commonwealth's policy goals. This kind of analysis can enable E3 to address other requirements in Section 80 pertaining to:

- Helping increase the utilization of energy storage systems
- Evaluating the state of energy storage systems in development
- Reviewing existing energy storage technologies and projects in New England
- Exploring the cost-effectiveness of providing incentives to storage
- Evaluating the location of energy storage in use
- Exploring opportunities to expand storage deployment
- Considering barriers to the deployment of energy storage

To improve upon 2050 CECP modeling results, we recommend the following practices for modeling energy storage in a capacity optimization and valuation exercise:

Storage Technology Classifications

We recommend modeling broad energy storage resource classes in a technology-neutral manner. Various long-duration storage technologies are still in early stages of development. These early generation technologies are subject to substantial cost uncertainty, presenting a challenge for resource planners seeking to quantify the need for and value of energy storage technologies with different durations.

One effective way to present technology-neutral modeling results is to group energy storage technologies into resource classes. In this way, a capacity optimization can model realistic technologies and technology attributes, while also presenting results in a manner that shows class needs, not technology needs. For example, the model should have the option to select multiple kinds of flow battery technologies and compressed-air energy storage, but when presenting overall results it should represent the GW and GWh of total energy storage needs for all technologies within the 10-24-hr duration category. This approach will help distinguish the different roles that these resource classes play in the grid, without picking individual technology winners.

For the purposes of this study and Section 80 definitions, we recommend the following classes:

Class Name	**Relation to Section 80**	**Example Technologies**[7]
>4 to 10 hour storage	Mid-duration storage	Lithium-ion
>10 to 24 hour storage	Subset of long-duration storage	Flow batteries, A-CAES
>24 hour storage	Subset of long-duration storage (multi-day storage)	Iron-air batteries, thermal storage

This approach aligns with industry trends and best practices by recognizing that long-duration energy storage as a term encompasses diverse energy storage types that warrant more granular grouping by technology attributes. The U.S. Department of Energy's recent report, *Pathways to Commercial Liftoff: Long Duration Energy Storage*,[8] proposed similar but slightly different groupings: inter-day storage (10 to 36-hours of duration) and multi-day storage (>36 hours in duration). This approach is also acceptable, although we recommend a 24-hour duration as a more reasonable and intuitive definition of the multi-day storage class.

Storage Technology Specifications

[7] These are intended only for illustrative purposes. We recommend modeling a fuller set of technologies.
[8] *See* https://liftoff.energy.gov/wp-content/uploads/2023/03/20230320-Liftoff-LDES-vPUB.pdf

To represent emerging long-duration energy storage technology cost and performance attributes, we recommend that E3 use one of two resources:

- Option 1: Inputs and assumptions for E3's ongoing public analysis of long-duration energy storage for the California Energy Commission[9]
- Option 2: Long Duration Energy Storage Council report in collaboration with McKinsey & Company,[10] which surveyed technology cost and performance data and grouped technologies into two archetypes (8 to 24-hr duration, and >24-hour duration).

Scenarios

To understand the benefits of mid and long-duration energy storage, we recommend that E3 consider various scenarios that explore how least-cost optimal portfolios vary based on different assumptions. The following technology scenarios can help illustrate the benefits and utilization of multi-day storage compared to mid-duration storage, for example. The different emissions scenarios can clarify how energy storage can support the integration of renewable energy, electric grid reliability, and greenhouse gas emission reduction goals under different conditions. It is important to model true zero-carbon electric sector portfolios to show how portfolios of energy storage and renewables can substitute for legacy thermal generation and to inform future policy considerations about decarbonization and winter fuel security risks.

Technology Scenarios		
Name	Description	Rationale
All Storage	All energy storage classes are available as candidate resources	Represents the broadest view of future storage needs
No Multi-Day Storage	Multi-day energy storage is excluded as a candidate resource	Enables a direct comparison of multi-day storage to resources <24-hr in duration
Only Mid-Duration Storage	Only resources with >4 to 10-hrs in duration are available as candidate resources	Enables a direct comparison of long-duration storage to mid-duration storage
Emissions Scenarios		
Name	Description	Rationale
Base Case	Assumes existing MA climate policy reflected in the CECP. Allows existing thermal generation	Represents best-estimate of how emerging technologies compare economically to

[9] *See* E3, May 13, 2023, CEC EPC-19-056: Assessing the Value of Long Duration Energy Storage (E3 CEC Study)
[10] *See* LDES Council. November 2021. *Net-zero power: Long duration energy storage for a renewable grid*.

	to be economically retired in the optimization	existing resources
No Fossil Generation	Assumes all existing fossil-fueled generation retires and no in-region electric sector GHG emissions	Represents upper-bound energy storage needs and assess alternative electric sector GHG scenarios

Weather Year Scenarios and Representation for Load and Generation

Optimal energy storage and renewable energy needs can vary significantly based on the weather year modeled. We recommend that the study evaluate how optimal resource needs may vary across multiple weather years, including years with extreme weather events.

Rather than use a proprietary "neural network regression" of ISO New England loads and different NREL data for wind and solar profiles,[11] we recommend that E3 use consistent public ISO New England data sources for both load and generation. Load profiles should be transparent, replicable, and consistent with ISO New England data. Additionally, renewable energy profiles and load profiles must be correlated to the same weather. ISO New England has produced robust stochastic historic profiles of renewable energy generation in New England,[12] which underpin ISO New England's own analysis. We recommend that E3 use this data in its modeling and not NREL's.

The choice of whether or not to use weather-correlated inputs can have significant impacts on long-duration energy storage resource adoption (portfolio results can differ more than 10x based solely on using either weather-correlated profiles or non-correlated profiles, as shown in CEC research by E3 and Form Energy and other academic studies[13]).

4. The study should avoid conducting a reliability analysis of the 2050 CECP portfolio

We are concerned that E3's proposal to conduct reliability modeling based on the 2050 CECP portfolio will not produce information that helps DOER evaluate the design and benefits of energy storage procurement programs, and that the results will produce misleading and inaccurate information about the reliability value of various energy storage resources.

We agree with the apparent intent of this effort to "characterize the reliability challenge and the role of MDES/LDES to contribute to reliability."[14] However, this goal can be best achieved via the capacity optimization modeling we recommend above, which can be used to examine optimal

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[11] In Slide 40 of the June 8, 2023 presentation, E3 indicates that it will conduct a proprietary regression of public ISO-NE and NOAA data to develop its own load forecasts.
[12] *See* Analysis of Stochastic Dataset for ISO-NE, February 2021, and data sources available at https://www.iso-ne.com/system-planning/planning-models-and-data/variable-energy-resource-data/
[13] *See* Dowling et al., 2020. Role of Long-Duration Energy Storage in Variable Renewable Electricity Systems. Joule; 4: 1907-1928, https://doi. org/10.1016/j.joule.2020.07.007.
[14] E3 Stakeholder Session #1 Presentation, slide 28

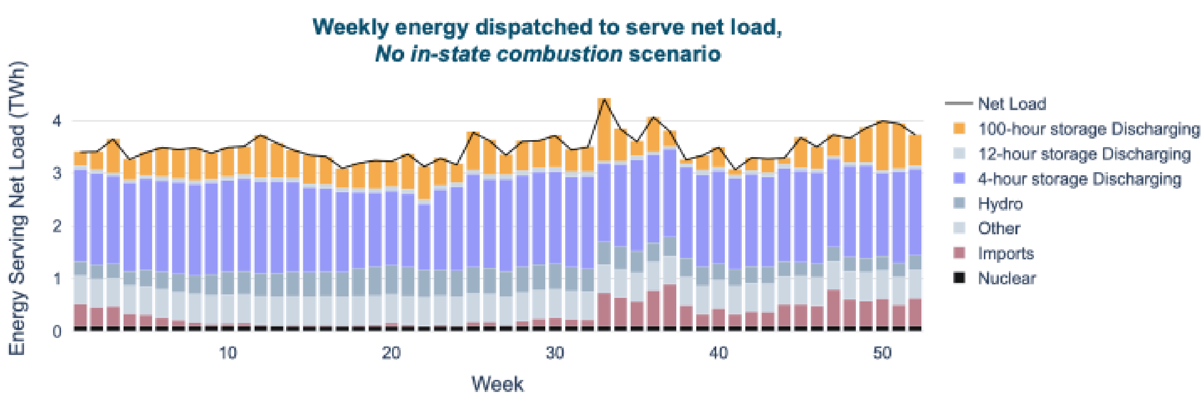
energy storage needs under various contingencies and atypical weather conditions. The long-term reliability value of energy storage is best assessed via a least-cost capacity expansion, which can be used to establish marginal effective load carrying capacity (ELCC) values. Renewables and energy storage must be optimized together, as they have interactive effects. One additional benefit of the approach we recommend is that it can generate information that can help the Commonwealth engage in ISO New England discussions about resource capacity accreditation.

As we have noted above, the 2050 CECP portfolio has significant limitations, and it would not be surprising if the portfolio identified in the 2050 CECP is not reliable under diverse weather conditions. We strongly caution against using this fixed portfolio to make determinations about the reliability value of energy. Reliability value should be an outcome of a portfolio optimization.

5. Interpretation of the Section 80 procurement cap

Section 80 appears to set a cap on the total amount of energy storage that DOER can procure, specifying energy storage system procurements of "up to 4,800 gigawatt hours of storage energy from renewable generation delivered to periods of high demand each year."[15] We recommend that DOER and E3 design the study to help evaluate whether specified energy storage procurements are within the bounds of this limit. There is a straightforward way to evaluate this via a capacity optimization model, which can be used to assess the total energy dispatched from energy storage resources in a year and shifted from periods of excess renewable energy capacity to periods of high net demand.

For example, the following chart from the joint E3/Form Energy capacity optimization analysis of California demonstrates how different classes of energy storage complement each other to meet load at varying times of the year.[16] In total, in this case short-duration storage (4-hrs) served 47% of net load, and LDES served 15% of annual net load. This analysis can easily indicate total GWh dispatched by each class and by energy storage in total. A no fossil generation scenario would provide the upper-bound of potential GWh of energy storage dispatched to compare to the Section 80 requirement.



15 Section 80(a)
16 *See* E3 CEC Study, slide 19

Conclusion

Form Energy appreciates the opportunity to provide comments and looks forward to continuing to engage with DOER, MassCEC and E3 on these important issues.

Jason Houck
Senior Manager, Policy Strategy
Form Energy
jhouck@formenergy.com