August 21, 20223

Attention:
Thomas Ferguson
Energy Storage Programs Manager, Massachusetts Depart of Energy Resources (DOER)
Thomas.Ferguson@mass.gov

RE: Comments on MA Mid- to Long-Duration Energy Storage Study

Dear Tom,

Lockheed Martin appreciates the opportunity to present stakeholder comments on the important Massachusetts Mid-to Long-Duration Energy Storage research study that is currently in progress.

About Lockheed Martin and GridStar Flow Energy Storage

Lockheed Martin, a global security and aerospace company, is commercializing a proprietary long-duration flexible redox flow battery, GridStar Flow, that could enable Massachusetts to meet its energy decarbonization goals.

- Lockheed Martin's global flow battery product engineering, development, testing and manufacturing is located in Andover, Massachusetts, at a 95,000 square foot facility, with approximately 50 Massachusetts-based employees.
- GridStar Flow is a full redox flow battery technology that enables sizing and operational flexibility. The product is designed for 8+ hour large-capacity energy storage applications, optimized for daily cycling, with the duration scalable by adding more electrolyte to the system.
- GridStar Flow is based on a novel redox flow battery chemistry, developed in Massachusetts, that consists of water-based, non-flammable engineered electrolytes made from earth abundant metals and commodity materials. The system architecture and electrolytes are designed to enable durability, flexibility, safety, and a competitive total cost of ownership.

Study Recommendations

We commend the work that Massachusetts DOER and Clean Energy Center are doing to study the status and potential role of mid and long duration energy storage to enable Massachusetts to reach the state's net zero energy goals. Lockheed Martin offers the following recommendations for the study modeling to ensure that it looks at the impact of adding technologies like redox flow batteries to the Massachusetts grid.

<u>Model Additional Classes of Duration >8 hrs, for 80% RTE Technology Class</u>

1. **Model additional duration classes of energy storage (e.g., 10, 12, 14, 16, 24 hours), with round-trip-efficiencies of 80%, as modeled for 8 hour.** The current draft modeling looks at 4, 8, and 100 hour durations, and misses a wide range of durations, that may offer value to the Massachusetts grid. The legislative language driving the study references that the study should look at 10+ hour

duration energy storage, but that duration class is not contemplated in the current modeling, other than a 100hr 50% round-trip-efficiency technology class.

Technologies, like redox flow batteries, that are modeled for the 8 hour energy storage class, can easily scale to longer durations if needed, since power and energy are decoupled and energy can be added separately than power. This technology class should be modeled at incremental duration ranges above 8 hours, up to 24 hours, with round-trip-efficiencies in the 80% range, to understand its value to the grid.

2. **Model the duration of energy storage that will be required to achieve a 100% ELCC value, under different future scenarios.** This will serve as in important signal to market participants of what energy storage durations may be required in Massachusetts under different future scenarios. For this modeling, we recommend using the 80% RTE assumption that is currently modeled for the 8 hour class.

   The duration classes modeled above 8 hours, as requested in recommendation 1, could be modeled up until the class at which 100% ELCC value is reached for a future grid mix scenario. For example if the 100% ELCC value is reached with 12 hour duration energy storage, then only 8, 10, and 12 hour duration energy storage would need to be modeled for that future grid mix scenario.

Model Storage That Can Address Both 10+ Hr AND Shorter duration uses

3. **Model 10 hour duration energy storage as ALSO able to address the shorter duration requirements.** Flow batteries have the same response times as lithium-ion systems, and are only limited in response times by the inverter. It is important to model the ability of these systems to also meet shorter duration requirements, like ancillary services and shorter peak shaving, since they could be able to do that in addition to the longer-duration uses. In fact, the lack of degradation with use that is a common characteristic of true redox flow batteries, make them well suited for frequent and high-cycling applications. While longer duration energy storage systems would not be built just for these shorter duration applications, their ability to also address them offers important operational flexibility to the grid.

Modeling Lithium-ion Degradation / Augmentation

4. **Ensure that the lithium-ion degradation and augmentation requirements are fully reflected in the model** and include these assumptions in the modeling output writeups.

Other Modeling Inputs

5. **Ensure that modeled forced outage rates are parallel for different types of energy storage** – eg 10% across all types of energy storage, not just for one class of energy storage.

Report Terminology for Different Durations

6. **Consider adjusting the study terminology to reference the actual duration of the energy storage being referenced.** The terms "short", "medium", and "long" duration energy storage are used to reference different durations of energy storage in this study in comparison to the language in the MA legistative text authorizing the study, as well as compared to federal and other state studies, leading to confusion over what is being referenced. The draft modeling slides presented in the stakeholder meeting reference 8+ hour storage as "mid" duration and 100+ as "long" duration, while the MA legislative text authorizing the study references 4-8 hour as "mid" and 10+ hour as "long." In California, long duration energy storage is defined as 8+ hours, while DOE defines it as 10+ hours. Other duration classes in other studies include definitions for "multi-day" and "seasonal". It would be therefore much clearer if the research results reference the actual duration range being studied.

Candidate Technology Table

7. **Consider updating the Aqueous Flow Battery row in the candidate technology table** as follows:
    - **Technology Readiness: Emerging / Commercial.** Companies like Lockheed Martin are deploying aqueous flow battery demonstration projects at utility scale and are well beyond the R&D stage. Other companies (e.g., vanadium systems) are currently deploying commercial units.
    - **Market Readiness: Pilot / Commercial**; See comment above.
    - **Average Round Trip Efficiency: 60% to 80% AC**

Massachusetts Energy Storage OEM List

8. **Consider including a list or overview of all of the Massachusetts based energy storage original equipment manufacturing (OEM) companies**. In addition to Lockheed Martin, there are quite a few companies based in Massachusetts and it would be informative for the report to highlight these companies, the jobs they provide and their current and future potential contribution to the Massachusetts economy.

Lockheed Martin greatly appreciates the opportunity to provide stakeholder comment on this critical study that will shed light on the important role of mid-to long-duration storage to enable the net-zero transformation of the Massachusetts grid. Thank you very much in advance for considering our recommendations. We welcome the opportunity to discuss these comments with you and the research team.

Sincerely,

Jennifer Burke, Head of Energy Storage Market Development and Market Strategy

Lockheed Martin Corporation