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Berkeley Lab Energy Storage Comments

Attached.

Thank you!

Additional submitted attachment is included below.

BERKELEY LAB
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July 30, 2021

Chair David Hochschild
California Energy Commission
1516 Ninth Street
Sacramento, CA 95814

RE: Lawrence Berkeley National Laboratory Recommendations for the Development of the EPIC 4 Investment Plan - **Technology Advancements for Energy Storage**

Dear Chair Hochschild,

The development of robust, affordable energy storage is central to California's -- and the nation's -- clean energy future. EPIC research, together with incentives such as those provided through California's Self Generation Incentive Program, has established the state as a leader in energy storage technology and deployment, but more work remains. Lawrence Berkeley National Laboratory (Berkeley Lab) agrees with the Commission that technological advancements are needed to spur the scale-up of energy storage, including to reduce costs, simplify and streamline interconnection, extend duration and reduce supply chain constraints.[1] To better advance these objectives in connection with the development of the EPIC 4 Investment Plan, Berkeley Lab is pleased to submit these additional comments in response to the July 20 workshop on advancing energy storage technologies.

Berkeley Lab is proud of its position in history as the birthplace of lithium battery electrochemistry and it's current work since then, culminating in the announcement of the Berkeley Lab Energy Storage Center in November. Our 100+ researchers associated with the new Energy Storage Center - designed to harness and galvanize expertise, capabilities, and innovation across the entire lab to accelerate real-world energy storage solutions - are standing by to support the Commission's efforts in technology advancement for energy storage, including emphasis on workforce and energy justice.

In order to address grid storage needs, the Commission should consider funding the development of next-generation energy storage technologies and manufacturing processes to sustain U.S. leadership in energy storage science and technology and meet California and U.S. market demand in transportation and long-duration stationary applications.

In order to enable large penetration of renewable resources with flexibility to store excess power generated to be used at later times or other locations and the ability to shift power across time frames, the Commission should consider the following storage technologies:

- *Electrochemical energy storage* – Flow batteries, which decouple power from energy. Aqueous, non-aqueous, and solid state battery technologies. Electrochemical storage chemistries which address supply chain issues (e.g. cobalt, nickel, lithium, etc).

[1] See California Energy Commission, Electric Program Investment Charge 2020 Annual Report, p. 5

- *Chemical energy storage* – Cost reductions in the synthesis of hydrogen or other energy-dense carriers such as ammonia or alcohols. Advancements to reduce costs of chemical storage components and lower cost of manufacturing methods for electrolyzers used in chemical-carrier synthesis.
- *Thermal energy storage* – New concepts and technologies for thermal energy storage (including subsurface) and approaches to optimize thermal energy storage materials and designs.
- *Mechanical energy storage* – Including loosening of geographical constraints typical of compressed air energy storage systems, through advancement in porous media compressed air energy storage.

Note that a strong process to accelerate progress in this relatively new technology space is necessary, to prevent planting unnecessary seeds now that won't fit the ultimate need. By determining *a priori* the energy storage performance goals (e.g. energy, power, cycle life, calendar life, use cycles) and test plans required for different use cases, technology investments and battery development will be better aligned. Additionally, impartial assessments of technologies (e.g. independent test facilities) will be necessary.

Specifically, the Commission may wish to consider the following suggestions for developing storage technologies and approaches to securing the supply chain while strengthening California's energy storage development ecosystem.

- **New battery chemistries:** For a significant cost reduction of energy storage systems (90% reduction), new battery chemistries provide a path forward. Supply chain challenges and opportunities should be considered, especially with respect to cobalt, nickel, and lithium. For instance, Berkeley Lab has developed a new battery chemistry - DRX - that negates the need for supply chain-limited cobalt and nickel. Regarding the lithium supply chain, California's Imperial County could satisfy more than one-third of today's global lithium demand given needed technological advancements in energy-efficient lithium separations and purification, and the implications of developing a domestic lithium supply to national security, climate, and environmental justice are large. The Berkeley Lab Lithium Resource Research and Innovation Center (LiRRIC) focuses in this space.

- **Energy Storage Manufacturing Accelerator Facility:** For start-ups, national laboratories, and academic researchers, demonstrating and testing new battery chemistries and materials at a large enough scale to prove the innovation and attract funding for production is a challenge. Additionally, demonstrating novel manufacturing science is necessary in order to create new intellectual property in manufacturing processes to jumpstart U.S. battery manufacturing. An independent energy storage scaleup facility -- which includes a pilot-scale production line to scale up new innovations (physical size plus quantity to enable performance and lifetime data collection), science of manufacturing, testing, and inclusion of next-generation tools such as AI and machine learning -- would support CA's clean energy, economic, and workforce goals.

- **Recycling and securing supply chain:** End-of-life (EOL) battery recycling needs to be considered to secure the critical raw material (CRM) supply chains. Although many CRMs have high recycling potential, EOL-recovery of CRMs is generally low. For many

CRMs, sorting and recycling technologies are not available yet at competitive costs. An increasing number of different elements are being combined to improve the functionality of products. This causes difficulties in separating materials after products reach EOL and hence lower the recovery efficiency. E.g., although lithium, manganese, and copper are technically nearly 100% recyclable, because of current battery designs they are hard to separate from other metals without using expensive organic reagents for solvent extraction. The Commission should consider investing in applied research efforts aimed at design-for-recycling to not only secure the CRMs needed for large-scale energy storage deployment, but to also manage the massive battery end-of-life waste challenge that looms.

- **Storage for grid reliability:** Energy storage presents significant opportunities for improved local energy reliability, particularly when accounting for the increased risk and stresses on the current grid from climate change. EPIC funding has supported a number of microgrid projects incorporating storage and could further Commission initiatives into improving the climate resilience of energy infrastructure by closely assessing how energy storage systems can be aligned with CPUC and investor-owned utility climate adaptation planning. This is especially true for aligning with CPUC requirements for incorporating the needs of disadvantaged communities into vulnerability studies and adaptation planning. The Commission could consider assessing the projected vulnerabilities and adaptation needs in energy reliability for these communities, and how energy storage can act as an effective adaptation measure in reducing risks.

- **Integration of different types and scales for storage:** Different types of energy storage technology have their pros and cons and specific use cases. At the district scale, the optimal storage system is an integration of various types of technologies including chilled water storage, short and long term electric storage to take advantage of time varying value (economic or carbon) of grid electricity. Research is required to develop prototype design and operation strategies for integrated storage systems serving different types of districts (residential, commercial, mixed-use) to optimize performance as well as to support optimal level of on-site renewable energy generation. The integration of various types of storage technologies, including thermal energy storage (chilled water), short term and long term electric battery, is key to optimize overall performance of a district scale energy system to improve energy performance and demand flexibility, which benefits the grid decarbonization and resilience. It also improves community thermal resilience under extreme weather events (cold snaps, heatwaves) or grid power outage.

- **Subsurface energy storage:** Solutions that involve subsurface formations may be required to achieve large-scale energy storage for very long duration storage periods of weeks, months, or even seasonal storage. Research is needed to advance and optimize this so-called "earth battery" concept, across different storage media (chemical, thermal, or mechanical), and for different geologies and storage depths (shallow aquifers to deep sedimentary reservoirs). While California has for a long time relied on natural gas storage in underground formations, more forward-looking technologies like hydrogen storage in depleted reservoirs or thermal energy storage in aquifers are less mature and need further testing and demonstration. Similar opportunities and research needs remain for mechanical energy storage underground, such as via injection and later recovery of compressed air or pressurized water or CO_2 into subsurface formations. Important questions about the feasibility, safety, efficiency and economics of such technologies have not been fully answered; integration with complex renewable energy systems needs to be improved. Opportunities for the repurposing of oil and gas industry assets (active and shut-in oil and gas wells, depleted oil and gas reservoirs, workforce) for subsurface underground storage need to be explored. Questions about environmental sustainability and equity need to be answered, along with Evaluating the feasibility, safety, efficiency and economics of such storage solutions in the California context. Moreover, demonstration projects for chemical (hydrogen), thermal (ATES), and mechanical (compressed air, compressed water) energy storage in the subsurface should be developed. Finally, exploration of inclusion of aquifer thermal energy storage (ATES) into integrated energy systems such as energy hubs and microgrids will help to cater the increasing cooling demands during extreme climate events while accommodating the fluctuations in renewable energy generation and grid conditions.

- **Machine learning, big data, and computer vision for technology development:** Failure modes of energy storage devices need to be clarified at a systematic level. An organized effort to study the failure mechanisms of various kinds of battery devices with different electrode materials, electrolyte compositions, and cycling conditions - using recent advances in big data handling, computer vision, and machine learning algorithms - has the potential to address the failure mechanism of batteries. This requires multimodal characterizations with a compilation of advanced techniques that are developed and available at the DOE national labs from microscopy (e.g., National Center for Electron Microscopy) to light sources (e.g., Advanced Light Source). This is a critical issue for both developments of low-cost high-energy battery systems, and the recycling of battery materials for reuse. For example, Berkeley Lab has many imaging facilities and has been creating advanced machine learning/deep learning algorithms and software to tackle the ever-increasing data collections produced by high-throughput instruments, for example, to detect defects from batteries during cycling tests and understand the mechanisms for dendrite formation and pitting.

- **Deployability and cybersecurity:** A large cost of installing, using, and maintaining storage technology is the expense of integration. In IT systems, 'plug-and-play' principles have led to devices being able to be plugged into each other and 'just work'. The same is possible for electricity systems, but only if power is digitally managed - technology available today but only at low power levels. We need universal technology for digitally managing power distribution at the local (in-building) level to enable this, so that storage can be easily deployed at whatever combinations of location and scale in a building are desired, including central, distributed, internal to end-use devices, vehicles, in-generation, and both AC- and DC-coupled that can greatly reduce the cost of integrating storage to increase the amount deployed to facilitate grid decarbonization. More, and more usable, storage will increase Resilience & Reliability, including for cybersecurity risks by making it much less expensive to distribute the storage and control. It will contribute to Affordability and Equity by allowing anyone to install storage themselves, without professional labor, and so greatly reduce costs. Cybersecurity of energy storage systems also need to be seriously considered, including both security of the devices themselves, security of remote access to the systems, including insider threats, and stability of the grid if these devices are manipulated.

On behalf of Berkeley Lab, we appreciate the opportunity to provide these comments on the EPIC 4 Investment Plan.

Sincerely,

Noël Bakhtian
Executive Director
Berkeley Lab Energy Storage Center
noel@lbl.gov

Alecia Ward
Leader, Program and Business Development
Energy Technologies Area
award@lbl.gov