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January 19, 2021

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

RE: **Lawrence Berkeley National Laboratory Recommendations for the Development of the EPIC Interim Investment Plan 2021-2022**

Dear Chair Hochschild and Vice Chair Scott,

Lawrence Berkeley National Laboratory (Berkeley Lab) appreciates the opportunity to submit recommendations on the development of the 2021-2022 EPIC Interim Investment Plan. Managed by the University of California for the U.S. Department of Energy (DOE) Office of Science, Berkeley Lab conducts basic and applied public mission-oriented basic and applied research across a broad range of energy and environmental fields. Together California's four national laboratories (Berkeley Lab, Lawrence Livermore National Laboratory (LLNL), Sandia National Laboratories/California (SNL/CA) and SLAC National Accelerator Laboratory) employ more than 13,000 California residents and represent more than $7 billion in annual expenditures in support of cutting-edge research and development.

Berkeley Lab supports the ambitious energy and climate policy goals of the State of California to achieve maximum energy savings and market transformation of California's energy infrastructure - from buildings and transportation to the power grid. To achieve the state's ambitious, but necessary, goal of carbon neutrality, California will need aggressive development, deployment, and adoption of new clean energy technologies. Berkeley Lab agrees with the Commission that the goals enunciated in the Interim Plan research -- decarbonization, resilience and reliability, and entrepreneurship -- are critical to advancing the State's energy and environmental priorities.

Acknowledging that the Interim Plan represents a "bridge" project with a more rapid timeline and narrower focus, and that the Commission will undertake a broader scope in the remainder of EPIC 4, Berkeley Lab offers these recommendations for a limited expansion of research scope to provide foundational support for the timely, successful realization of 2045 goals.

Decarbonization:

- Berkeley Lab suggests incorporation of a greater focus on innovative approaches and methods to scale up building retrofits for deeper energy efficiency and decarbonization to much higher volumes by evaluating potential for innovative policies such as more on-bill financing, block level retrofits, or integrated approaches for building shell retrofits, electrification, rooftop PV, and vehicle electrifications; and piloting or demonstrating in

the field.

- In addition to modulating (time shifting) power demand, we recommend supporting projects to reduce power demand and enhance climate resilience through efficiency measures for critical facilities (especially those that are residential such as nursing homes) through approaches such as designing or retrofitting to employ passive or low-energy cooling measures that minimize power demand during extreme heat events. When power needed for HVAC is lost, it is important to ensure that tight building envelopes do not exacerbate indoor temperatures during such events.

- Develop an industry decarbonization roadmap that could be organized by end use application (e.g. steam systems, drying systems) and/or process temperatures (low/med/high temperature process heating). This could include for example, more focused R&D on the potential and demonstrations for electric boilers and/or hybrid electric and gas boiler systems for decarbonized steam systems and responsive to utility rates; and more development and demonstration of decarbonized high temperature process heating technologies e.g., for the cement and glass-making sectors.

- Develop a Negative Emissions Technology & Science (NETS) Roadmap to enable the state to meet its carbon neutrality target by 2045 (e.g. 50-150MMt CO2e by 2045). Even with aggressive electrification and other carbon reduction measures, studies on California pathways to achieve carbon neutrality generally agree on the need for implementation of significant carbon removal to compensate for sectors that cannot achieve full carbon neutrality. There remain substantial uncertainties or technology needs associated with a number of these pathways.

    - Mineralization/enhanced weathering. More can be done to evaluate enhanced weathering in California. A modeled evaluation of climate, deployment type and available materials could help the state evaluate potential and create a road map. The Strategic Growth Council is currently supporting a project evaluating soil amendments, but there are more soil types that could be evaluated, as well as other strategies, like weathering of mine wastes in place, reclamation of marginal lands, and coastal/delta strategies, that should be conducted in advance of field tests.

    - Metal-Organic Framework. Industrial separations account for 10-15% of the total global energy consumption, and developing more efficient separations processes is therefore a key strategy toward reducing worldwide energy consumption. Owing to their immense tunability and high volumetric capacities, amine-functionalized metal-organic frameworks (MOFs) could enable efficient capture of CO2 from ambient air. We propose the design, synthesis, and testing of novel MOFs exhibiting multidimensional cooperative mechanisms for CO2 adsorption, selectively in the presence of water. Multidimensionality could enable a reduction in the energy needed to regenerate the adsorbents along with improvements in adsorption kinetics, both of which are critical considerations in the design of direct air capture processes. The Commission may wish to consider support for electrochemical approaches for direct CO2 capture, sorbent regeneration, and

conversion to commodity chemicals.

- Bioenergy with Carbon Capture and Sequestration. Most of the 1.5 and 2 C scenarios featured in recent reports by the Intergovernmental Panel on Climate Change project extensive dependence upon bioenergy with CCS (BECCS), in which biomass or biomass-derived fuels are converted into heat/electricity, and the CO2 evolved from this conversion is captured and stored underground. BECCS therefore enables simultaneous power generation and carbon dioxide removal from the atmosphere. The vast majority of studies focusing on BECCS have explored the use of aqueous amine scrubbers, which are conventionally used for point-source carbon capture. However, the large amounts of water present in the aqueous amine solutions limit the efficiency of these separations. Here we propose the development and testing of MOFs for BECCS, with the goal of reducing the parasitic load associated with the CO2 capture operation.

  Electrochemical conversion of CO2 to fuels and products, particularly when integrated with biological processes (e.g. biomass gasification, fermentation) can give biogenic carbon (i.e. forest and agricultural wastes) a "second life" and ultimately enable long-term sequestration into useful products such as building materials and durable goods. Electrochemical conversion of CO2 can also provide a means of capturing, valorizing, and sequestering non-biogenic CO2 streams that are difficult to eliminate, such as those from cement manufacturing plants.

- Intensify focus on the “demand side” to sharply reduce material consumption, reduce demand for virgin materials, and reduce energy consumption. We believe that the three areas that need more R&D focus and policy development include: (1) materials efficiency (e.g., using less concrete, cement, steel in buildings); (2) designs, technologies and systems to enable a circular economy (e.g., materials recovery upon building deconstruction and planning for more recovery during building design and construction phase; development and broad deployment of products developed from waste streams, such as bio-based substitutes produced through sustainable low-carbon processes); and (3) deep conservation such as evaluation of international policies and or innovative programs for deep energy and/or material conservation – e.g., pilots or demonstrations for feebates for vehicles or other high GHG goods, congestion charges, incentives for deep reductions in utility/water/plastic use. Some of these policies have been explored or implemented in other countries (such as feebates in France), but few have been implemented here. The potential for energy and GHG savings of these programs and policies needs to be better understood and quantified.

- In addition to leveraging and complementing the RDD&D funding available through the incoming federal administration as proposed in Initiative 9, the Commission should consider collaborations with federal agencies like the U.S. Department of Energy in the many areas beyond the entrepreneurship areas where collaborations provide strong opportunities to advance California priorities, leverage limited California resources, and bring to scale solutions developed in the State. The Commission should reserve

sufficient flexibility to maximize opportunities for partnerships in these areas in the coming year.

Resilience:
Berkeley Lab recognizes the urgency of measures for increased resilience in the face of climate change - particularly providing tools for those vulnerable and under-resourced communities that bear the burden of disproportionate impacts. Our efforts are centered on the interface between the built environment and transportation and grid systems, in the presence of natural stressors such as weather-related events and phenomena, including: wildfire, wind and flood, severe heat and cold, sea level rise that are exacerbated by climate change and an increase in health-related threats like airborne pathogens.

In addition to the metrics and measurements to enable the valuation of resilience, we recommend that CEC consider funding for -

- Modeling, simulation and prediction to support risk assessment, and decision-making tools;
- Design and development of bundle packages of technologies for scaled adoption to improve community infrastructure;
- Technologies and processes to provide design stronger community response strategies to address vulnerable communities in their adaptation to extreme weather events.

Regarding the need to ensure an equitable transition, the Commission's proposal references a four prong strategy to embed equity into the EPIC program going forward including increasing awareness of EPIC and the opportunities it provides, encouraging technology/project developers to seek out projects in under-resourced communities (where more than 60% of the CEC's demonstration projects are now located, as well as including community based organizations as paid partners); scoping many solicitations around specific issues facing under-resourced communities; and embedding equity in clean energy entrepreneurship. Berkeley Lab supports this strategy and encourages the Commission to include sufficient support in its solicitations to enable full participation by researchers and organizations representing under-resourced communities.

In addition to the broad comments listed above, we have also included comments specific to the initiatives listed in the EPIC Interim Investment Plan below. Should you need any clarification on the comments we would be delighted to provide it.

INITIATIVE SPECIFIC COMMENTS

INITIATIVE 1: Advanced Prefabricated Zero-Carbon Homes

Berkeley Lab agrees that prefabricated zero-carbon homes with fire- and energy-resilient design features offer the potential to save energy, increase resistance to wildfires, lower costs and help communities build back better and more quickly. The Commission may wish to consider whether to expand eligibility to multi-family units. The Commission has been thoughtful in incorporating fire-resistant designs. To advance broader state objectives, the Commission may

wish to consider coordination with the Joint Institute for Wood Products Innovation, which has recommended the use of mass timber to encourage the use of wood fiber gleaned from forest thinnings in new construction.

In addition to zero-carbon new constructions, the Commission should continue its pioneering work in building efficiency/decarbonization to support innovative approaches and methods to scale up retrofits of existing building stock for deeper energy efficiency and decarbonization to much higher volumes are recommended. More than 12 million existing housing units in California are more than 10 years old. Critical challenges include upgrading the predominantly older housing stock to higher levels of energy efficiency, electrified heating (fuel switching), required panel upgrades, deferred maintenance, and roof repair (many single-family homes are not "solar PV" ready). We recommend that the CEC consider evaluating the potential for furthering progress on innovative policies such as more on-bill financing, block level retrofits, or integrated approaches for building shell retrofits, electrification, rooftop PV, and vehicle electrifications.

INITIATIVE 2: Energy Efficiency and Demand Response in Industrial and Commercial Cold Storage

Berkeley Lab supports the focus on commercial refrigeration equipment (CRE) energy efficiency improvements and shifting to low global warming potential (GWP) refrigerants. CRE represents about 40% of total refrigerant leakage and CRE units typically operate 7x24. LBNL authored a report in 2019[1] on this topic, finding a very large potential GHG savings (over 200 Gt CO2e by 2050 globally) from shifting the global stock of air conditioning and commercial refrigeration equipment to high energy efficiency and low GWP refrigerants.

INITIATIVE 3: Energy Efficiency and Load Shifting in Indoor Farms

- No Comments

INITIATIVE 4: Optimizing Long-Duration Energy Storage to Improve Grid Resiliency and Reliability in Under-resourced Communities

Significant quantities of energy can be stored on a long-term (i.e. seasonal) basis in the form of heat or cold in the subsurface below all types of communities. These energy reserves can provide direct grid services by reducing heating and cooling loads. Development of technologies for energy storage in the form of temperature gradients, i.e. heat or cold is recommended under this initiative.

The Commission may wish to consider support of R&D projects in California for repurposing depleted oil and gas reservoirs for energy storage, either using compressed air, H2 or other energy-rich chemicals/fuels. On the technical side, subsurface energy storage in depleted natural gas reservoirs has been carried out successfully in over a dozen places in California for many decades as demonstrated by the seasonal storage of natural gas. Use of the same or

[1]https://www.osti.gov/biblio/1559243-benefits-energy-efficient-low-global-warming-potential-refrigerant-cooling-equipment

similar reservoirs for compressed air energy storage has been demonstrated (e.g., PG&E, 2018; https://www.osti.gov/servlets/purl/1434251). Much of this opportunity is located in parts of the southern San Joaquin Valley where there is high unemployment. Repurposing idle oil and gas infrastructure for energy storage can provide continuity of employment and sustainability for the local oil and gas workforce as the state moves toward electrification of transportation. We recommend that long duration storage consider including a green fuel that can be stored or used and not be limited to just batteries.

Mobility of energy storage assets in the case of resiliency can be useful. This can also include inexpensive and green storage where the primary storage is done off site and delivered to a generator when needed in response to an event such as PSPS or wildfires. While this could be thought of as similar to the way diesel generation sets currently operate, we recommend considering inexpensive green alternatives beyond biofuels which could include delivering green hydrogen or other chemicals for fuel cells and electrode materials for rechargeable and primary batteries.

Supplies of lithium and other critical elements can play a limiting role in multiple types of resiliency strategies due to their essential role in battery technology. In addition to the CEC's leadership in advancing recovery of lithium from Salton Sea brines, efforts that look at lithium battery recycling, other non-conventional natural lithium resources and other critical element availability, and new cost-effective extraction technologies that are relevant under this research topic.

INITIATIVE 5: The Role of Green Hydrogen in a Decarbonized California—A Roadmap and Strategic Plan

Berkeley Lab recommends that the roadmap consider ways in which hydrogen fuel cells can be leveraged to other manufacturing technologies such as CO2 reduction to enable decarbonization. We recommend that the roadmap/study under this initiative consider answer the following questions for Green H2:

- Particularly as the Commission considers hard-to-decarbonize sectors, green hydrogen use in manufacturing should be included.
- What is the role for bridge pathways to green hydrogen such as blue hydrogen?
- What are future likely/prospective demand ranges for hydrogen by application (e.g., what can H2 provide that is unique and economic relative to other technologies?)
- Transportation, energy grid support, industrial applications are three potential areas for green H2 – how would these be efficiently linked or coordinated as either decarbonization pathways or in supporting policies? Would there be the need for some sort of "industrial policy" that goes beyond what is currently practiced due to the potential interlinkage and synergies between the sectors?
- Hydrogen storage: California does not have a recognized unconventional oil or gas resource that can benefit from long-reach horizontal wells and hydraulic fracturing. Because of this, unlike other areas of the U.S. that have seen large increases in oil and gas production with the use of hydraulic fracturing, California's oil and gas production are

in decline. The result is depleted oil and gas reservoirs and idled oil and gas wells. At the same time, a critical part of the hydrogen economy is large-scale and long-term hydrogen storage. Research into re-purposing depleted oil and gas reservoirs for hydrogen storage is needed to develop this technology and allow green hydrogen to become a significant part of California' decarbonization goal.

There is a large volume of activities on hydrogen and hydrogen systems internationally and at the DOE's Hydrogen and Fuel Cell Technologies Office. We recommend that the roadmap make an effort to comprehend and synthesize the various activities, learnings, and policies from outside of California.

INITIATIVE 6: Valuation of Investments in Electricity Sector Resilience

For the approach to "Include analyses of recent historical weather-related events and other situations (e.g., PSPS) that resulted in power outages," we recommend that the valuation of scenarios also focus on future weather-related events and worst-case possibilities, since climate conditions are shifting and are quite different from the past. It would be informative to try to model (or compile) the risk of low probability events such as coronal mass discharges as well as the risk of a confluence of events such as extremely hot weather across the West, concurrent wildfires, earthquakes, and any other known risks, to bound the scale of the problem.

INITIATIVE 7: Vehicle-to-Building Technologies for Resilient Back-up Power

We recommend that the research and development of Vehicle-to-Building technologies consider the following:

- The communication interoperability between the electric vehicle charging infrastructure and the building needs to provide maximum demand flexibility with long duration while meeting resilient back-up power needs (e.g., open-source communication standard OCCP for electric vehicle charging, building automation and control protocol such as BACnet, Modbus)
- Vehicle-to-Building technologies should include the event-ahead (power outage notification), day-ahead or real-time prediction of essential building load during the critical operation mode, as well as predictive energy allocations considering uncertainties of individual electric vehicles that are available for resilient back-up power.
- The use of electric vehicles for resilient back-up power in buildings should be integrated with other kinds of building demand flexibility in HVAC, lighting and plug loads.

INITIATIVE 8: Offshore Wind Technologies

Given the large cost of deploying a structure in the ocean which far exceeds the typical funding level from CEC, the program should emphasize subcomponents or partial integrations that can be tested in simulated marine environments.

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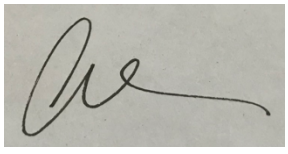
INITIATIVE 9: Entrepreneurial Ecosystem
9e. Cost Share for U.S. DOE Funding Opportunities

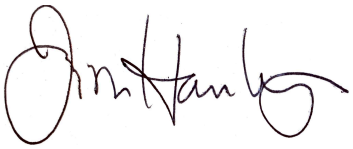
Technologies developed in the national lab and university ecosystem in California provide a valuable source of cutting-edge ideas and patents in the areas of clean energy such as energy efficiency, renewable energy generation, and energy storage, that in turn provide a robust pipeline of early and low technology readiness level (TRL) technologies with commercialization potential to be developed further by entrepreneurs for meeting California's energy goals. For example, Berkeley Lab has been a beneficiary of the cost share offered by CEC for the U.S. DOE Funding Opportunities, most recently, the $3 million cost share from CEC for the DOE funded $100 million NAWI Energy-Water Desalination Hub awarded to the Berkeley Lab-led National Alliance for Water Innovation.

It is likely that we will see significant opportunities to align U.S. Department of Energy and California policy objectives. This will present California with opportunities to attract significant federal and outside investment that supports state objectives, potentially scale solutions developed here and make the best possible use of limited state resources. As previously noted, we recommend that the Commission continue to provide robust support for cost share for the U.S. Department of Energy projects supporting early stage technologies that can be developed and scaled by California-based entrepreneurs.

On behalf of Berkeley Lab, we appreciate the opportunity to provide these comments on the Interim Investment Plan and look forward to supporting the Commission in its mission to build a clean, resilient, and affordable energy future for all Californians.

Sincerely,





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