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Berkeley Lab Industrial Decarbonization Workshop Comments

Attached.

Thank you!

Berkeley Lab

Additional submitted attachment is included below.

BERKELEY LAB
Bringing Science Solutions to the World

July 23, 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 - **Industrial Decarbonization** workshop

Thank you for the opportunity to provide comments on the EPIC 4 Investment Plan and for the CEC's leadership to develop the new breakthrough technologies that will help the State realize its ambitious climate and clean energy goals. Berkeley Lab strongly supports the CEC's efforts to identify and invest in potential breakthrough technologies to improve efficiency and reduce greenhouse gas emissions from industrial processes. As one example, Berkeley Lab participates in the U.S. Department of Energy's High Performance Computing for Advanced Manufacturing program which provides DOE high performance computational resources to help companies optimize their production processes to save energy, reduce emissions and boost global competitiveness.

The Commission's July 16 workshop examined challenges in high-temperature industrial heating for sectors such as steel and glass; as well as opportunities to improve energy efficiency in the industrial, agricultural and water sectors and advance decarbonization in sectors such as cement. These workshops were helpful in highlighting many of the most important industrial decarbonization opportunities.

On July 2, Berkeley Lab submitted "Recommendations for the Development of the EPIC 4 Investment Plan - Research Concept Proposals" which address some topics explored at the July 16 workshop, including opportunities to improve energy efficiency in water treatment and desalination. On July 15, Berkeley Lab submitted comments on clean hydrogen production also relevant to industrial decarbonization. We invite reference to these comments as they touch on some of the issues discussed at the industrial decarbonization workshop.

Decarbonizing the industrial sector poses significant challenges. In addition to sectors such as cement, food processing, metals, chemicals, and glass, we believe that research and development, demonstration and deployment will be necessary in other sectors including, the development of low carbon (including bio-based) industrial processes to replace current fossil energy-intensive processes, and use of carbon capture and sequestration and carbon removal technologies to help hard-to-decarbonize industrial sectors reduce net emissions while sustaining employment levels in a manner that utilize many of the skillsets of our current workforce.

This letter provides additional examples of research and development needs that will enable the realization of affordable and scalable technologies deployable in California.

- **Develop advanced biomanufacturing processes and technologies that enable industrial decarbonization at scale:** Biomanufacturing has the potential to be a short-term and medium-term option for industrial decarbonization and the establishment of a net zero circular carbon economy in California and beyond. This can be accomplished by harnessing renewable and sustainable inputs, such as fermentable sugars and other intermediates derived from non-food biomass, that can be drop-in alternative technologies that can generate fit-for-purpose replacements for a wide range of products in the marketplace today made through standard manufacturing technologies. There is also the potential of converting CO_2 directly into these products as well that have the potential to offer compelling solutions to the complex challenges presented by developing stand-alone carbon capture and sequestration (CCS) technologies.

There are already several companies in California that are pioneering this marketplace transformation to net-zero carbon biomanufacturing. One example is Lygos, a California company that has developed and deployed a technology for the scalable production of malonic acid and other renewable platform chemicals through optimizing the microbial conversion of sugars. Another example is found in Genomatica, a California company that has developed a microbial route for the production of 1,4-butanediol that is used in the manufacturing of polymers and textiles.

Even with these significant advances, currently every new biomanufacturing product must go through a development cycle that starts from scratch. A vigorous biomanufacturing industry requires an integrated approach where product development is conducted in a Design-Build-Test-Learn system based on automation and high-performance computing that generates robust organisms, genetic circuits, and conversion pathways that are tunable to develop products of interest within any industry on demand and at relevant scales where potential downstream process development impacts are addressed from the start and scaling of the process is predictable. This approach will make California's biomanufacturing industry more robust in terms of responding to market fluctuations by creating a process with multiple inputs and outputs.

The DOE national laboratories and universities in California have all the required capabilities and expertise to form expansive public-private partnerships with industry that can catalyze the rapid deployment and commercialization of next-generation biomanufacturing technologies that enable industrial decarbonization at a massive scale. Significant economic and environmental justice issues would be addressed by harnessing and realizing the true potential of California's renewable lignocellulosic resources, including the woody biomass generated through wildfire risk mitigation activities and agricultural residues produced throughout the state.

Description of technological advancement and breakthrough

- Develop new biomanufacturing technologies that can convert all of the major components in non-food biomass, CO_2, and municipal solid waste
- Ability to handle mixed inputs/feedstocks from a variety of sources, including low value California forest biomass.
- New best practices and industry standards in biomanufacturing that enable commercialization in all industry sectors
- >90% conversion efficiency
- >80% thermal efficiency

Anticipated outcomes
- Net-zero carbon emission biomanufacturing technologies
- Significantly reduced GHG emissions relative to state-of-the-art technologies
- Near zero emission technologies
- Affordable, distributed and scalable production of fit-for-purpose products
- Improved health and economic opportunities in rural and historically underserved communities

- **Develop advanced manufacturing processes and technologies that enable low-carbon solutions for high- volume, high-value chemicals and materials to reach the market place more rapidly:** There is a critical area in decarbonization of chemical manufacturing and associated industries, which are a large source of CO_2 emissions both using various carbon-containing feedstocks as well as the temperatures required for traditional thermal processes. Electrification of the chemical reactions and key feedstock formation should be considered using renewable reactants such as hydrogen, CO_2, biomass, and perhaps CH_4 instead of oil and coal.

  Similarly, there is a need to reduce the time from concept to commercialization and enable innovative product design that facilitates recyclability and the development of highly reconvertable or biodegradable materials instead of single-use consumption. Additionally, it is critical to update traditional manufacturing methodologies and processes to accelerate scale-up, dramatically reducing the timeframe from discovery to implementation, currently often marked in decades.

  Solutions include developing approaches for innovation and holistic understanding within the manufacturing methods and materials used for high-volume or high-value chemicals with a concentration on decarbonization of the entire pathway by focusing on the science of synthesis and scale-up, coupled with intelligent and adaptive analysis tools and techniques. Some of the early concepts that could leverage the approach stated above to address California's industrial decarbonization challenges include:

  - *Electrochemical Refinery* - Design of scalable chemical-manufacturing trains informed via the life-cycle and techno-economic analysis and scalability studies. Execute a demonstration of bench-scale, novel, low-carbon processes for chemical and material production offering the potential for integration with renewable energy sources followed by larger scale technology processes

  - *Circular Economy* - Improve the rapid characterization of new polymers, focusing on their compatibility with waste management infrastructure and their fate in the environment. Develop techno-economic and life-cycle analysis framework and modeling capabilities for evaluating novel synthesis methods and recovery of key materials for manufacturing. Integrate efforts with U.S. Department of Energy advanced manufacturing and plastic waste reduction efforts.

  - *Decarbonization of Industrial Heat* - Find carbon-free means of providing industrial process heat, to >2,000°C) depending on the application.

The long-term goals of such an approach would be to develop a portfolio of technologies dedicated toward electrochemical refining, hydrogen combustion, new material and thermal fluid development, and circular manufacturing strategies with the ultimate goal to shorten the design-build-test-learn cycle for key materials in manufacturing and commercialize technology prototypes. On the analysis side, the goals would include developing an integrated effort that combines automated platforms for novel chemical/material synthesis, testing, and systems analysis.

- **Carbon capture and sequestration (CCS) for hard-to-abate industries:** Energy-intensive industries (EIIs) that produce basic materials, such as petrochemicals, steel, aluminum, cement, and fertilizers, are responsible for a significant fraction of global CO_2 emissions; the same applies to California. CCS is a critical technology to achieve emissions reductions for these industries, as other decarbonization options like electrification or moving away from carbon-containing feedstocks may be technically infeasible or too expensive.

  California has a huge capacity for storing captured CO_2 in its deep sedimentary basins, across much of the State and often in close proximity to industrial emitters. As also discussed below, low-hanging fruits for geologic CO_2 sequestration are the many producing or depleted oil and gas fields in the State, transitioning their use to the purpose of decarbonization. While multiple large projects across the world are already capturing and sequestering carbon, there are remaining challenges: (a) carbon capture technology needs to be advanced and optimized for hard-to-abate industries, and (b) monitoring and and risk assessment methods need to be improved and deployed to ensure that very large volumes of CO_2 can be safely stored in California's complex and tectonically active subsurface.

- **Utilization of oil and gas subsurface infrastructure (wells and reservoirs) for geothermal energy production and storage:** One potential step forward with decarbonization would be to transform active and shut-in oil and gas wells into geothermal wells that would utilize hot water found in deep (and hot) sedimentary basins in California. This would accomplish several important goals. First, it would alleviate a critical issue facing the State of California in that thousands of unused oil and gas wells need to be plugged and abandoned - if they could be converted to a new use, this would no longer be needed, saving many millions of dollars.

  Second, it would allow for a transition of these fields from producing hydrocarbons to producing hot water, both for thermal energy and as a water source. In existing mature oil fields, the produced fluids often have a high water cut, which is not utilized currently and could be desalinated and converted to usable water for agriculture and other purposes. For deep reservoirs, this produced water is often quite hot, and currently the thermal energy of the water is not utilized. Identifying uses (such as district heating and cooling which would displace fossil fuel used to power such systems, or potentially, if hot enough, using a heat exchanger and the organic Rankine cycle to generate electricity) would be a critical next step - the uses would depend on the temperature of the produced fluids as well as local needs for these fluids. For mature fields that have utilized steam flooding for enhanced oil recovery, this would provide an opportunity to recover this thermal energy in a clean manner. Another potential use of these former hydrocarbon reservoirs would be for thermal energy storage - hot water produced in times when there is a surplus of electrical power on the grid could be stored in these reservoirs and later retrieved and used when power is needed. Third, this initiative would allow the current workforce in the oil and gas industry to pivot to clean energy jobs, as many of the skill sets are very similar.

Berkeley Lab appreciates the opportunity to provide these comments in support of development of the EPIC 4 Investment Plan.

Sincerely,

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