EPIC Strategic Goals **New and Emerging Strategies** Workshop Report

EPIC POLICY + INNOVATION COORDINATION GROUP

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California's Electric Program Investment Charge (EPIC) program is funded by California utility customers under the auspices of the California Public Utilities Commission.

This report was completed by The Accelerate Group, a consultant to the California Public Utilities Commission and the Project Coordinator for the EPIC Policy + Innovation Coordination Group. The information herein was collected and summarized by the Project Coordinator, with input from members of the EPIC Policy + Innovation Coordination Group and does not reflect an official position of the California Public Utilities Commission.

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I. EXECUTIVE SUMMARY

In its most recent EPIC decision,[1] the California Public Utility Commission (CPUC) directed that program-wide goals are needed to evaluate the progress of innovation investments and the extent to which investment plan portfolios maximize ratepayer benefits and impacts in achieving California's clean energy and climate goals. As part of that decision, the CPUC directed the establishment of a public workshop process to inform how Strategic Goals and Objectives should be articulated and established by the Commission in its next guidance Decision for the EPIC 5 cycle (2026-2030). The overall goal of the Strategic Goals Workshop process is to collect stakeholder input on critical pathways, gaps, roles and outcomes in achieving the State's climate goals that would be best fulfilled by EPIC's research, development, and demonstration (RD&D) funding, considering its unique role and opportunities.

On September 20, 2023, the CPUC hosted the EPIC Strategic Goals New and Emerging Strategies Workshop, which focused on a selection of critical pathways and topic areas identified in the Kick-Off Workshop, including Offshore Wind, Geothermal, Green Hydrogen, Biomass, Carbon Sequestration and Role of Artificial Intelligence (AI).

Ninety-seven stakeholders participated in the workshop. Within the critical pathways for emerging strategies, participants highlighted the following key gaps and opportunities for EPIC research: developing strategies and equity guideposts for wind and solar supplements to reach the last 10% of the 100% carbon free grid; developing strategies and targets for CO_2 removal; developing California targets for offshore wind, geothermal and renewable hydrogen technologies; performing resource availability studies, particularly for geothermal resources; performing demonstrations and testing and streamlining permitting for geothermal, offshore wind, geothermal, renewable hydrogen, biomass and AI integration; funding cost reduction research in California specific areas and areas not funded elsewhere that have high cost reduction potential, like geothermal exploration and drilling efficiency; identifying best uses for green hydrogen and understanding hydrogen leakage and local pollution impacts and mitigation; and studying impacts of all of these technologies on Environmental and Social Justice (ESJ) communities and developing guideposts and filters to avoid projects that harm them.

[1] CPUC Decision (D.)23-04-042

II. BACKGROUND

What is EPIC?

The EPIC program is funded by California utility customers under the auspices of the California Public Utilities Commission.

The Electric Program Investment Charge (EPIC) is a California ratepayer funded program that drives efficient, coordinated investment in new and emerging clean energy solutions. Its mandatory guiding principle is to provide ratepayer benefits, with a mission of investment in innovation to ensure equitable access to safe, affordable, reliable, and environmentally sustainable energy for electricity ratepayers. EPIC invests in a wide range of critical innovation, including building decarbonization, cybersecurity, demand reduction, distributed energy resource integration, energy storage, entrepreneurial ecosystems, grid decarbonization, grid decentralization, grid modernization, grid optimization, grid resiliency and safety, high penetration renewable energy grid integration, industrial and agricultural innovation, smart grid technology, transportation electrification, and wildfire mitigation. From 2012 through 2030, EPIC will have invested nearly $3.4 billion in clean energy technology innovation.

What is the Policy + Innovation Coordination Group?

The California Public Utilities Commission (CPUC) oversees and monitors the implementation of EPIC research, development, and deployment program. For current EPIC funds from investment periods 1 (2012-2014), 2 (2015-2017), 3 (2018-2020), and 4 (2021-2025) there are four program administrators: the California Energy Commission (CEC), Pacific Gas and Electric (PG&E), Southern California Edison (SCE), and San Diego Gas & Electric (SDG&E). The CEC administers 80% of the funds and the utilities administer 20%.

In Decision 18-10-052, the CPUC established the Policy + Innovation Coordination Group (PICG)—comprised of a Project Coordinator, the four Administrators, and the CPUC—to better align EPIC investments and program execution with CPUC and California energy policy needs. In Decision 23-04-042, the CPUC directed PICG to convene the Strategic Goals and Objectives process to inform Commission guidance on the EPIC 5 funding cycle (2026-2030).

Workshop Process Goals

The Strategic Goals Workshop Process will focus on identifying four core elements:

Pathways:

Set of critical actions necessary to support meeting the State's 2045 zero carbon goals via the most effective strategies and technology innovation.

Gaps:

Key challenges for achieving zero carbon goals and how RD&D should be prioritized to address opportunities and barriers more quickly along critical pathways.

Roles:

The best-positioned stakeholders (ratepayers, state, federal, private sector) to lead innovation investment in addressing identified gaps, including through coordination and collaboration.

Outcomes:

Clear, measurable, and reasonable targets to be used by administrators in developing EPIC portfolios and used in program evaluations to measure impacts of EPIC in supporting achievement of California's 2045 zero carbon goals.

III. WORKSHOP SUMMARY

Agenda

The Workshop was hosted on September 20, 2023, from 1 pm – 4:45 pm and consisted of two roundtables. The stakeholder discussions following each roundtable welcomed questions and comments from the audience in the room and participants connected virtually. CPUC Commissioner Genevieve Shiroma provided opening and closing remarks. The PICG Project Coordinator provided an initial introduction to the Workshop Process and the purpose of the event.

Opening and Closing Remarks: Commissioner Genevieve Shiroma welcomed workshop participants and outlined workshop goals. The Commissioner noted that she is looking forward to hearing from the participants on the range of strategies for the net zero future and how EPIC can ensure benefits to disadvantaged, tribal and low-income communities. The Commissioner reminded participants that their comments along with the CPUC Staff proposal will contribute to a proposed CPUC decision on establishing EPIC research goals and strategies. Commissioner Shiroma noted the importance of looking at local air pollution and developing guideposts discussed by presenters to ensure that no harmful projects are funded. Commissioner Shiroma also asked presenters to supply more details on the referenced research projects that fund combustion technologies and invited CEJA to submit source information for closer consideration. The Commissioner also asked about fuel cell technology and how it should be considered, if at all. The Commissioner thanked speakers for sharing their expertise, as well as Commissioner John Reynolds, CPUC Administrative Law Judges, CPUC Legal Staff, and CPUC Energy Division Staff who have been working on these proceedings and workshop series to ensure that EPIC funding achieves California goals and benefits disadvantaged, low-income and tribal communities.

Roundtables: The two roundtables focused on the following:

I. Strategies for a Net Zero Future (1)

Presenters:

- Brian Sergi, National Renewable Energy Laboratory (NREL)
- Sarah Baker, Lawrence Livermore National Laboratory (LLNL)
- Jill Haizlip, Geologica Geothermal Group (GGG)
- Alexis Sutterman, California Environmental Justice Alliance (CEJA)
- Tim Yoder, Pacific Northwest National Laboratory (PNNL)

During the roundtable, NREL shared findings from recent studies[2] on achieving the last 10% of a 100% carbon free grid and listed data gaps and research needs to identify the most effective and cost-beneficial solutions for California. LLNL discussed its recent study "Getting to Neutral"[3] that looks at a portfolio of approaches to carbon removal to reach California's carbon free energy goals and highlighted that biomass gasification through thermo-chemical conversion into hydrogen, paired with carbon storage, was identified as a viable technology for California. GGG discussed California's research needs for geothermal technologies, noting California's potential and current use of geothermal energy. GGG explained that the two current uses for geothermal resources are electricity generation, measured as MegaWatt-electric (or MWe) or heating, measured as MegaWatt-thermal (or MWth). CEJA

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[2] NREL, On the Road to 100% Clean Electricity: Six Potential Strategies to Break Through Last Few Percent, September 09, 2022. https://www.cell.com/action/showPdf?pii=S2542-4351%2822%2900405-6

[3] LLNL, Getting to Neutral: Options for Negative Carbon Emissions in California, January 30, 2020. https://livermorelabfoundation.org/2019/12/19/getting-to-neutral/

outlined environmental justice concerns with new and emerging technologies, noting that CEJA views the energy transition as a way to also redistribute power and benefits among the communities historically affected by fossil fuel generation. CEJA highlighted equity considerations for EPIC to consider in the EPIC funded projects, in particular prioritizing the most vulnerable communities and ensuring that ESJ communities benefit from, and are not harmed by, the clean energy transition. PNNL discussed the role of artificial intelligence (AI) in the energy transition and noted various areas where AI is applied today, including modeling and forecasting, distributed energy resources (DERs) and load flexibility integration, and affordability solutions. During the stakeholder discussions after the presentations, participants discussed potential targets and timelines for innovation and EPIC's role in advancing discussed technologies and strategies. Participants also discussed equity safeguards, incentives, and concerns related to these technologies. One of the questions from the audience was on the availability of wave energy analysis and its potential for California. CPUC Staff Fredric Beck answered the question noting work conducted by the United States Department of Energy (US DOE), including resource maps and wildlife impacts, and pointed to the DOE website for further information.

II. Strategies for a Net Zero Future (2)

Presenters:

- Kori Groenveld, National Offshore Wind Research & Development Consortium (NOWRDC)
- Walter Musial, NREL
- Jeffrey Reed, University of California, Irvine (UCI)
- Woody Hastings, The Climate Center (TCC)
- Ari Eisenstadt, California Environmental Justice Alliance (CEJA)

During the roundtable, NOWRDC and NREL discussed key RD&D needs for offshore wind technology, particularly floating structures, including the modeling, engineering, environmental sustainability, and infrastructure research gaps. NOWRDC noted that among seven research areas it funds, the two major areas are floating offshore wind and transmission and grid stability. NOWRDC research goals are established in its Research and Development Roadmaps that NOWRDC develops every three years —the last one published in 2023.[4] NOWRDC noted that it is working with the California Energy Commission (CEC) on the California/NOWRDC offshore wind initiative in which the CEC approved $5 million for competitive solicitation in the spring and summer of 2024 to fund RD&D projects. NOWRDC noted that they are now in the process of identifying research priorities through a stakeholder process and invited anyone interested to provide feedback into that process. NREL discussed its modeling of offshore wind costs, performance, and weather forecasts, and noted several data gaps that need to be filled to adjust this modeling to California-specific needs, particularly in weather predictions. UCI shared findings from the 2020 Renewable Hydrogen Roadmap for California,[5] a report developed for the CEC. UCI discussed the potential portfolio of hydrogen technologies viable to produce renewable hydrogen for California. TCC highlighted a need for a formal definition of "green hydrogen" and discussed the role of state funded RD&D for this technology. TCC noted that the first solar hydrogen demonstration project took place in 1995 under the White House Technology Reinvestment grant, which included a 40kW solar array electrolyzing water on site to produce hydrogen for utility pickup trucks at the Xerox El Segundo campus. This project was part of a program to convert WWII technologies for civil use since the project used nuclear submarine electrolyzers. CEJA discussed equity considerations in the clean energy transition, noting that EPIC should consider a full suite of pollutants that affect ESJ communities in its decarbonization programs. CEJA raised concern over using hydrogen combustion and Carbon Capture and Storage (CCS) or Carbon Capture, Utilization, and Storage (CCUS) to extend the life of fossil fuel technologies in contradiction with California climate goals. Instead, CEJA recommends a focus on proven technologies that benefit ESJ communities, such as demand response, energy efficiency, and DER. CEJA stressed the need to develop filters for harmful projects, like hydrogen combustion, CCS, or dairy digesters. In the stakeholder discussion after the presentations, participants discussed potential targets for hydrogen and offshore wind and EPIC's role in cost reduction research. Many participants noted that EPIC research should not duplicate federal- and private- funded research efforts or focus on areas where cost savings can come from market scale up and process

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[4] NOWRDC, Research and Development Roadmap 4.0, April 2023, available at https://nationaloffshorewind.org/wp-content/uploads/NOWRDC-Research-Development-Roadmap-4.0.pdf

[5] UCI, Roadmap for the Deployment and Buildout of Renewable Hydrogen Production Plants in California, Final Project Report prepared for the California Energy Commission, Clean Transportation Program, June 2020, available at http://www.nfcrc.uci.edu/PDF_White_Papers/Roadmap_Renewable_Hydrogen_Production-UCI_APEP-CEC.pdf

automation. Instead, participants recommended focusing on gaps that remain unfunded that can drive down costs. Participants also suggested EPIC could help identify best uses for hydrogen in hard-to-electrify industries or in the "best fit for least cost" scenarios. Participants also discussed the potential role of fuel cell research, in response to a question posed by Commissioner Shiroma, noting the potential use of fuel cells to provide peak load support and displace diesel backup generators, if green electrolytic hydrogen is adopted. Participants further discussed specific needs and a possible EPIC role in hydrogen leak detection, clarifying that the focus should be on hydrogen-designated pipelines, rather than hydrogen-gas blending in the gas pipeline infrastructure, that many participants oppose.

Presentations

The link to each presentation is included in the Appendices to this report.

Attendees

Ninety-seven individuals participated in the workshop, virtually and in person, including CPUC Commissioner Genevieve Shiroma and CPUC Staff, representatives from the EPIC Program Administrators (California Energy Commission (CEC), and the three utilities), as well as research institutions, community leaders, technology solution providers, government entities, utilities, non-governmental organizations, and industry.

IV. STAKEHOLDER RECOMMENDATIONS

Workshop participants provided the following recommendations for EPIC funded research opportunities that can address key gaps identified during the workshop:

Key Items of General Consensus

Workshop discussions and presentations highlighted the following key areas of consensus among workshop participants:

Critical Pathways:

The discussions focused on the main pathways of Emerging Strategies, identified in the previous workshops: Offshore Wind, Green Hydrogen, Geothermal, Biomass, Carbon Capture and Storage and Artificial Intelligence (AI). The two new potential pathways discussed were Wave Energy and Fuel Cells. No recommendations were made by the participants on Wave Energy. On Fuel Cells, CEJA noted that if California adopts a green hydrogen solution, fuel cells may play a role to displace diesel backup generators and provide peaking load but stressed that only green hydrogen —not combustion or biogas as a feedstock — should be considered in any scenarios. Many equity considerations were raised generally and related to specific pathways that are addressed below.

Key Gaps:

Overall, the participants agreed that California needs to map out key technologies to prioritize reaching its climate goals by 2045, including options to decarbonize the last 10% of the grid, and remove CO_2 from the atmosphere. Offshore wind and geothermal resources overall appear to have general support from workshop participants and no opposition was raised during the workshop, particularly with respect to research data and modeling gaps and research needs. The participants overall also agree on the potential value of green hydrogen for hard-to-electrify industries. Participants' general area of disagreement was the use of CCS technologies and hydrogen. Most advocacy groups, including CEJA and TCC, oppose the use of CCS as well as any hydrogen, other than green hydrogen produced through electrolysis from renewable energy resources, and oppose any technology that involves combustion, biogas and biodigesters. They also urged narrowing the use of green hydrogen to limited industries that are hard to electrify. Research institutions and groups, including LLNL, UCI, and NREL, noted the value of CCS, direct air capture and various hydrogen technologies, with proper controls, to achieve the necessary scale of decarbonization to reach California's climate goals. LLNL noted that renewable hydrogen produced from biomass and biogas that does not involve combustion could be considered carbon and air pollution neutral or even negative, as it uses basically no electricity from the grid, prevents flaring, and removes carbon and other pollutants from the atmosphere by capturing biomass and biogas carbon and other air pollutants that would otherwise be released into the atmosphere. Participants raised no specific objections or concerns with respect to the utilization of the AI, except for the potential carbon footprint and cybersecurity concerns. The PNNL presenter noted that these concerns may be removed in the future with the decarbonization of the grid and more cybersecurity research.

Unique Role of EPIC:

Participants agreed overall that, as a ratepayer funded resource, EPIC is best suited to fund research on the following: 1) developing strategies to supplement wind and solar to get the last 10% of the CO_2 off the grid to reach 100% clean energy goal; 2) evaluating resource availability, particularly for geothermal and offshore wind, and mapping out biomass availability for renewable hydrogen that does not involve combustion; 3) streamlining permitting processes for geothermal, biomass and other technologies, particularly on the environmental impact assessment requirements and coordination; 4) funding technology gaps research that has high cost reduction potential that is not funded elsewhere; and 5) performing system analytic and review based studies.

Desired Outcomes and Quantitative Targets:

Participants identified opportunities for the following quantifiable targets:

- **Renewables.** A certain capacity (X MW) of wind and solar installed by 2045;
- **Geothermal.** A certain capacity (X Gwe and Y GWth) of geothermal electricity and heating installed by 2045;
- **Hydrogen.** 4 billion kg of renewable hydrogen produced by 2050;
- **Reducing the Cost of Green Hydrogen.** $3/kg cost of green hydrogen by early 2030s without subsidies;
- **CO_2.** 125 mil metric tons of removed CO_2 per year by 2045 and/or a certain quantity of removed CO_2 per year from Biomass Gasification and/or Biogas Carbon Capture and Storage by 2045.

Participants, however, disagreed on whether hydrogen and biomass related technologies should be considered carbon free and suitable for EPIC funding without particular safeguards in place to prevent negative impacts on ESJ communities.

Desired Outcomes and Targets

Specific suggestions of the potential targets for EPIC research suggested during this workshop included the following:

#1: Target: Wind and Solar.

- **X MW of wind and solar by 2045**: NREL's recently published study "Getting to 100%: Six Strategies for the Last 10%"[6] shows that accelerating wind and solar generation deployment can result in high levels of decarbonization at relatively low costs. Yet

[6] NREL, On the Road to 100% Clean Electricity: Six Potential Strategies to Break Through Last Few Percent, September 09, 2022, available at https://www.cell.com/action/showPdf?pii=S2542-4351%2822%2900405-6

NREL acknowledges that removing the last portion of carbon on the grid is more challenging because the seasonality of these resources does not always align with the grid load and relying on a 100% weather dependent system can pose many risks and challenges.

#2: Target: Geothermal.

- **X GWe geothermal electricity and X GWth of geothermal heating installed by 2045:** GGG notes that the US DOE 2019 GeoVision Study[7] indicates that, with current technology, the U.S. has the potential to increase use of geothermal power by 26 times to achieve 60 GW of geothermal power generation by 2050. In 2023 US DOE updated its projections to 90 GW by 2050.[8] GGG noted that, currently, U.S. geothermal installed capacity is at 3,800 MWe, 71% of which is operating in California, totaling 2,800 MWe. California also has more than 25% of the world's geothermal capacity, and about 50 years of extensive geothermal experience and expertise in exploration, field development, and operation of a variety of geothermal systems. GGG also noted that there is great potential for increasing the amount of geothermal electricity in California, since approximately 6% of California power already comes from geothermal energy (this is larger than in any other country). However, GGG believes that approximately 40% of California geothermal resources are yet to be identified. GGG also noted that it takes about 7-18 years to permit a new geothermal project; therefore, to get to necessary scale, deployment needs to start as soon as possible.

#3: Target: Renewable and Green Hydrogen.

- **4 billion kg of renewable hydrogen by 2050:** UCI noted that the Renewable Hydrogen Roadmap for California[9] estimates the renewable hydrogen demand by 2050 to reach about 4 billion kg statewide and can come from the two technologies

[7] US DOE Geothermal Technologies Office, GeoVision: Harnessing the Heat Beneath Our Feet (2019), available at https://www.energy.gov/sites/default/files/2019/06/f63/GeoVision-full-report-opt.pdf
[8] US DOE NREL, Enhanced Geothermal Shot Analysis, January 2023, available at https://www.energy.gov/eere/articles/doe-analysis-highlights-opportunities-expand-clean-affordable-geothermal-power
[9] UCI, Roadmap for the Deployment and Buildout of Renewable Hydrogen Production Plants in California, Final Project Report prepared for the California Energy Commission, Clean Transportation Program, June 2020, available at http://www.nfcrc.uci.edu/PDF_White_Papers/Roadmap_Renewable_Hydrogen_Production-UCI_APEP-CEC.pdf

identified as most viable for California: thermochemical conversion from biomass and electrolysis from renewable energy.

- **$3/kg cost of green hydrogen by early 2030's:** UCI noted that the US DOE's Hydrogen Shot[10] program aims to reduce costs of hydrogen production to $1/kg by 2030. UCI notes that this goal is very ambitious, and a $2/kg cost is more realistic. UCI notes that, judging from the current deployment economics in different sectors, by the 2030s, economic adoption can be achieved without subsidies at $3/kg cost, and $2/kg for industrial hydrogen. UCI noted that the base case forecast for green hydrogen from electrolysis is below $15 per Giga Joule (GJ) by the early 2030s and below $15 per GJ by the mid-2030s for bio hydrogen.

#4: Target: Biomass.

- **125 MT of removed CO_2 per year by 2045:** LLNL states that its studies indicate that 125 million metric tons (Mt or MT) of CO_2 removal per year is needed to achieve California's 2045 zero emissions goals. According to an LLNL study, this goal can be reached by a combination of technologies that average at $60 per ton.
- **X MT removed CO_2 per year from Biomass Gasification and/or Biogas Carbon Capture and Storage by 2045:** LLNL recommended that EPIC should set goals for deployment rate of these technologies to help achieve California's decarbonization goals. LLNL states its research shows that Gasification of Waste to fuel, like hydrogen, paired with CO_2 storage and Biogas CO_2 Capture at Dairy, Landfill and Wastewater Treatment facilities paired with storage are shown to be the impactful solutions that can provide significant CO_2 removal at the lowest costs. LLNL estimates that these technologies can deliver about 84 Mt of carbon removal per year at $29-$64 per ton. However, LLNL notes that to achieve the 125 Mt per year, these technologies will have to be supplemented with about 16 Mt of CO_2 removal from Direct Air Capture, at $193-198 per ton, and about 25 Mt of CO_2 removal from natural and land CO_2 absorption, at about $11 per ton.

[10] US DOE NREL, Enhanced Geothermal Shot Analysis, January 2023, available at https://www.energy.gov/eere/articles/doe-analysis-highlights-opportunities-expand-clean-affordable-geothermal-power

Unique Role of EPIC

This workshop included specific additional discussion on the unique role of EPIC in addressing gaps in pathways. Many participants agreed that, overall, these are the key areas where EPIC has a unique role to play:

#1: Role: Strategies and Equity Guideposts for getting to 100% carbon free grid.

NREL suggested that EPIC can help develop strategies to supplement wind and solar generation to get to 100% carbon free grid. The NREL study "Getting to 100%: Six Strategies for the Last 10%"[11] noted that most of grid decarbonization can be achieved through wind and solar generation but the last portion needs to be supplemented by other resources to ensure reliability and less dependence on seasonality of the wind and solar resources. NREL studied the following six scenarios: 1) adding more wind and solar and energy storage; 2) adding other renewable resources, like biomass, geothermal, and hydrogen resources; 3) adding nuclear and fossil fuel resources with carbon capture; 4) adding seasonal storage, like hydrogen; 5) adding CO_2 removal with direct air capture and bioenergy + carbon capture and storage (BECCS); and 6) adding demand side resources. NREL suggested that EPIC research of these scenarios and other scenarios of supplementing wind and solar generation can help fill the data gaps on costs savings and costs certainty potential of each scenario, demand response constraints and reliability, and other factors, to help inform grid and resource planning. CEJA noted that EPIC needs more guideposts to ensure that the solutions deployed to get to 100% clean energy, particularly in decarbonizing the last 10%, do not negatively impact ESJ communities. CEJA notes that it would be helpful to know what the suite of options are for California to be able to create a matrix to analyze these options and create filters, beyond cost effectiveness, that consider social value impacts to communities. For example, when looking at the wind/solar + storage option discussed by NREL, CEJA noted that it would advocate for prioritizing DERs first and looking for ways to optimize and site DERs to provide the greatest value, before deploying these larger scale solutions. CEJA asserts this would minimize land use and deliver more local community benefits. LLNL noted that an example of considering equity is the reporting practice that US DOE is beginning to

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[11] NREL, On the Road to 100% Clean Electricity: Six Potential Strategies to Break Through Last Few Percent, September 09, 2022, available at https://www.cell.com/action/showPdf?pii=S2542-4351%2822%2900405-6

implement in carbon removal projects. This practice requires community feedback on the information, measurements, and reporting verification that the community wants to see. GGG also noted that having general guideposts for all projects will help to measure and evaluate projects and can also help expedite permitting (particularly for geothermal projects).

#2: Role: Resource availability studies.

GGG noted that it is important for California and EPIC, as ratepayer funded program, to evaluate and map out available resources, particularly the geothermal and biomass resources, because California can benefit from utilizing the potential of these resources and technology. Surveying available resources and developing priority or ranking for these resources can help to reduce costs of exploration and sourcing and help to reach the needed scale.

#3: Role: Demonstrations and testing.

Most participants, particularly the research institutions (LLNL, PNNL, UCI, NREL, and GGG) agree that EPIC can play a key role in demonstrations and testing to help bring research from the labs to the market as quickly as possible. Demonstrations could help build trust and show value proposition, identify gaps, and provide a roadmap for others in deploying these technologies. Demonstrations could also improve technology understanding among stakeholders and generate support for these technologies which will streamline their permitting process.

#4: Role: Streamlining permitting processes.

GGG noted that EPIC could play a key role in streamlining the permitting process for many resources, including green hydrogen, biomass, and geothermal energy. GGG suggested that EPIC could help with coordination and collaboration between different agencies in the Environmental Impact Review (EIR) and Studies (EIS) processes. GGG noted that National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) requirements often overlap, and EPIC could help coordinate and identify who the lead agencies are and provide clarity on those requirements for geothermal projects. NEPA and CEQA reviews are noted as typical areas that significantly complicate and delay permitting process. GGG noted that geothermal projects take, on average, approximately 7 years to get through the permitting process if there are no complications, and about 18 years if a more complex NEPA/CEQA process is required. LLNL also noted that it can take 35 years to get from the lab demonstrations to production for biomass and hydrogen projects. Participants agreed that EPIC's support with collaboration and demonstrations could improve public awareness and greatly reduce permitting delays by improving understanding of the green hydrogen, geothermal, and biomass energy technologies among key stakeholders.

#5: Role: Funding unfunded or California-specific research gaps.

Many participants agreed that EPIC funding should not be used for research that is duplicative of federally and privately funded research. For example, participants noted that research on hydrogen cost reduction may not be an efficient use of ratepayer funds, because a majority of cost reductions will come from federal and private research and the scaling up and automation of the hydrogen market. Instead, NOWRDC and NREL suggested that EPIC could identify remaining gaps that can drive costs down but are not funded elsewhere, or research California-centric issues and define California targets for different resources, such as offshore wind.

#6: Role: System analytic and review studies.

UCI recommended that EPIC fund system analytic- and review-based studies such as NOx emission impacts of hydrogen blending in turbines and other debated areas of hydrogen production. These areas could benefit from neutral and properly charted research.

Key Gaps

Workshop participants provided the following recommendations for EPIC funded research opportunities that can address key gaps identified during the workshop:

Offshore Wind

NOWRDC noted that RD&D has the potential to advance technoeconomic solutions to engineering, environmental and policy challenges. NOWRDC runs competitive solicitations to fund projects that can respond to those challenges. NOWRDC research has a design feedback process that incorporates industry input and guidance along the entire project development process, from fundamental science to deployment, to ensure that solutions are useful to the industry and deployable in the future. RD&D in offshore wind is focused on solutions that are safer, higher performing, lower cost, and have the potential to accelerate project development timelines. RD&D near term impacts, including narrowing down viable technology offerings, often result in standardization of manufacturing and development practices that yield cost savings inherent in economies of scale.

#1: Gap: Floating offshore wind research needs.

NOWRDC noted that RD&D needs for offshore wind, particularly for floating offshore wind technology, are focused in three main categories: 1) floating platform engineering; 2) environmental sustainability and ocean co-use; and 3) infrastructure and supply chain. NOWRDC noted that floating offshore wind borrows a lot of technology solutions from oil and gas exploration. NOWRDC asserts that this technology needs to be adjusted for offshore wind, which has more dynamic loads, is more spread-out and has smaller units, requiring more efficient and cost-effective design.

- **Potential Role of EPIC:** NOWRDC listed a number of RD&D needs for floating offshore wind technology, highlighting the following:
    - Design and engineering:
        - Testing four main floating platform technologies available today to identify the most cost-efficient approach that is best fit for California.
        - Designing California-specific solutions that mitigate extreme earthquake loads.
    - Environmental stability and ocean co-use:
        - Developing solutions that lower impact on offshore environment and other ocean users.
    - Infrastructure and supply chain:
        - Since California infrastructure requires a lot of traditional infrastructure, RD&D can help identify alternative infrastructure upgrade designs that are higher performing, cost effective, and built for California-specific floating offshore wind needs.
    - Transmission:
        - Optimizing performance to reduce transmission needs, by designing higher performing and lower cost profiles- for example higher capacity dynamic power cables or shared landfall design - to have more efficient onshore land redevelopment and avoid having radio transmission connection in every project.

#2: Gap: Offshore wind modeling needs.

NREL noted that its offshore wind modeling research is currently focusing on cost modeling tools, wind and waves modeling, single turbine and full -pant performance and loads, mooring systems, and grid integration and reliability, and noted gaps in these areas where additional research is needed.

- **Potential Role of EPIC:** NREL highlighted the following data and research gaps that can feed into improved modeling for offshore wind:
  - Cost modeling: On the cost modeling side, NREL is developing models to evaluate actual cost of energy for the whole system and future cost predictions. NREL is doing this by looking into individual turbines, plant level and project lifecycle, analyzing various cost data sets from the industry, and bottom-up estimates of material, labor, and other costs. NREL suggested that further research is needed on higher resolution of temporal scale of cost reduction, to answer questions such as: What costs are going to be like in 2030, including for different components? What are the tradeoffs between cost reduction opportunities in turbine standardization, upscaling and mass production versus the costs of new infrastructure needed to support these new turbines? NREL noted that further research is needed to extrapolate these data inputs for the full-scale floating wind plants, that currently have not matured beyond pilot stage.
  - Weather Research and Forecasting (WRF): NREL uses WRF model for wind and extreme weather modeling with California CA20 dataset, that has best validations available in 2020, including California ocean surface buoys, four coastal radars and three floating lidars in the Mid-Atlantic. NREL notes, however, that there are not enough datapoints for validation. For example, the standard setup used on the East Coast and Hawaii doesn't work for California. To trust these models, more research is needed to understand the physics causing the California wind bias in WRF. Further data and research are also needed to better understand the physics and the coupled wind/wave models as well as extreme weather events.
  - Multi-Fidelity Performance and Loads Models: NREL tests technology through two levels (individual turbine and full-plant level) and multi-fidelity modeling (with low to high fidelity scenarios). NREL uses the open-source tool OpenFAST, which has been tested over time, and NREL trusts and finds accurate, as a primary engineering tool to develop 80% of full-scale floating wind prototypes. NREL notes that further research is needed into the accurate behavior of floating systems and deeper water and steep slope mooring.
  - NREL noted that validation of the modeling results with field data is needed in all areas.

- NREL noted that grid modeling and capacity expansion tools also need more research, particularly with the congestion issues in California. Currently, the best resources are on the North Coast and are stranded right now. More research could go into delivering these resources to load centers in the Bay Area and potentially integrating with the interregional grid with Oregon and resources that are North of Del Norte.

Geothermal Energy

GGG noted that geothermal energy can contribute to low carbon energy generation, heating and cooling, and other direct uses of heat. It is low carbon but not carbon free. GGG notes that California has more than 25% of the world's geothermal capacity, with the two world largest known geothermal developments: steam-dominated in The Geysers, at about 800 MW, and liquid-dominated in Salton See area at about 500 MW, both trying to expand their capacity in the near future. Further, GGG stated that California has approximately 50 years of extensive geothermal experience and expertise in exploration, field development, and operation of a variety of geothermal systems. California hosts 11 operating geothermal fields ranging from less than 1 MW in Wendel/Amedee area to 820 MW in The Geysers. California also has a large research capacity in both technological and market research, due to the National Labs potential, like LLNL. GGG noted that the main challenges that prevent expedited development of this sector are: 1) location constraints, as geothermal resources need to be converted into electricity or heat at the site where it is present; 2) technological challenges —exploration is high risk and enhanced geothermal system (EGS) power conversion technologies remain unproven; 3) capital cost constraints, with high initial upfront costs due to drilling but good long-term returns; 4) permitting delays, due to varying state and local regulations and unpredictable permitting timelines.

#1: Gap: Develop detailed survey of California's geothermal resources.

GGG believes that approximately 40% of California's geothermal resources are not identified yet. GGG noted that the last review and documentation was performed in the 2000s. GGG notes that, due to advances in technology, a wider range of resources could be potentially used now.

- **Potential Role of EPIC:** GGG noted that a new and more detailed review of California's geothermal resources is needed to increase development and reduce costs of exploration and resource characterization. GGG noted that this area is important for California and EPIC research because California can benefit from utilizing the potential of this technology, and it is important to explore available resources and develop resources prioritization or ranking.

#2: Gap: Improve exploration and drilling efficiency.

GGG noted that there are many technological gaps that require more research to lower costs of geothermal energy resources. GGG stated that exploration techniques and methodologies are the biggest gaps.

- **Potential Role of EPIC:** GGG noted the need for more research to improve exploration, assessment, production, and management of geothermal resources. GGG noted that research is needed to improve techniques and methodologies of exploration, to reduce drilling costs, and to improve the currently low success of drilling. GGG noted that this technology is not ready to be deployed at scale yet and, to get to scale of producing enough MWs, research must focus on improving drilling, exploration, and validating and improving power conversion on the enhanced geothermal system (EGS) technologies. Considering that permitting takes on average 7 to 18 years, GGG notes this as an urgent need to meet 2045 goals.

#3: Gap: Identify incentives to make geothermal projects economically viable.

GGG noted that another area that needs research is in mapping out the credits and incentives that geothermal projects could use to become more economically attractive.

- **Potential Role of EPIC:** GGG suggested looking at power purchase agreements (PPAs) and credits or payments that geothermal electric generation projects can receive for the benefit they can provide to the grid. Geothermal electric generation can stabilize the grid and reduce congestion through baseload and flexible power.

Green Hydrogen

UCI introduced its report published in 2020 for CEC on the "Renewable Hydrogen Roadmap for California" ("Roadmap"), which discusses a potential portfolio of renewable hydrogen technologies and analyzes demand across various sectors, different production options, and supply chain constrains. The Roadmap analyses renewable hydrogen produced with the following key technologies:

1) electrolysis and artificial photosynthesis using renewable resources;

2) thermo-chemical conversion of biomass that either produces biomass or renewable natural gas (RNG), with the RNG then further converted into hydrogen through reformation; and

3) anaerobic digestion of biomass that produces RNG that is then reformed into hydrogen.

Carbon capture, utilization, and storage (CCUS) technologies are not included in the Roadmap scope.

UCI stated that its Roadmap analyzes both methane and hydrogen technologies and finds renewable hydrogen from electrolysis and thermo-chemical conversion to be the two primary pathways for California for renewable hydrogen, with equal share for each in the California portfolio. UCI finds that both technologies have an abundant supply potential and relatively mature technology. Anaerobic digestion only has approximately one-tenth of the resource potential of the other two technologies. The Roadmap estimates about 4 billion kg statewide renewable hydrogen demand from these two technologies by 2050. The Roadmap analyzes renewable hydrogen impacts from its point of production to its points of use, including production, processing, storage, transportation, and end use. The Roadmap further finds that many of the logistical steps have issues that need to be addressed with further research. UCI noted that while some local production options are available that eliminate many of the steps, like storage and transportation, these are limited cases as hydrogen production requires large land plots. UCI concluded that the most economically viable option for renewable hydrogen at scale to reach California's climate goals is producing hydrogen from electrolysis from wind and solar at high renewable resource availability areas, such as the desert, and transporting it to the end user. UCI stated that this approach, however, requires further research into many of the steps in hydrogen logistics to address potential issues and impacts of these steps.

#1: Key Role: Demonstration and deployment and policy and regulations.

UCI noted that EPIC can be most valuable in the field demonstration, validation, and measurement of things like leakage, California-specific techno-economic and lifecycle analysis, and system planning for optimal deployment. UCI also noted that policy and regulations are currently more critical than technology research in advancing green hydrogen technology.

#2: Key Role and Equity Consideration: Model impact of hydrogen on ESJ communities.

CEJA noted that EPIC research should not focus on developing new technologies for hydrogen combustion, but on modeling hydrogen's health impacts on ESJ communities. This includes hydrogen combustion, storage, transportation, and the full life cycle of its infrastructure.

#3: Gap: Adopt unified definition of "green hydrogen."

TCC discussed that there are multiple definitions of green hydrogen that come from different stakeholders, which integrate various requirements, like "no fossil" and "electrolytic" or "no polluting feedstocks."

- **Potential role of EPIC:** TCC suggested that the first step in green hydrogen advancement should be developing a formal and unified definition of "Green Hydrogen."

#4: Gap: Make green hydrogen production cheaper.

UCI listed key technology gaps that need further research on the hydrogen production side, including electrolyzer cost reduction opportunities. This is particularly relevant regarding the precious metals content in the catalysts that drive costs up and pose supply issues in the long-term. TCC noted that capital costs of proton exchange membrane electrolyzer system went down over 90% since 2001 according to the US DOE. Many participants agreed, however, that further cost savings may potentially come from industry automation and scaling up and the federal and private research in this field, so it may not be a good use of ratepayer funds for EPIC to fund any duplicative research.

- **Potential Role of EPIC:** TCC highlighted that a key role for ratepayer funded RD&D is to address the question of how to develop and deploy a green hydrogen economy without repeating past mistakes and avoiding negative impacts on ESJ communities and the environment.
- **Potential Role of EPIC:** TCC suggested that, since green hydrogen production is currently nearly non-existent, ratepayer funded RD&D should prioritize production, not deployment. TCC stated that RD&D can help address the problems with electrolytic hydrogen production, such as leakage, water use efficiency, energy resource shifting, and high costs. TCC asserts that research should focus on the 3 pillars of hydrogen production: 1) Electrolyzers powered by new sources of zero-emissions electricity; 2) Directly supplying produced energy into the same distribution circuit where the electrolyzers are connected; and 3) Do so at the same time when the generators are running, with hourly matching of production and supply. TCC recommended that if EPIC funds research on the deployment side, it should focus on local hydrogen production to avoid transportation costs and risks, as it is easier and cheaper to move electrons than hydrogen. EPIC could study financial and technological risks of the green hydrogen deployment scenarios where hydrogen production and end uses are co-located. TCC and CEJA argued that technologies with hydrogen combustion for electricity generation should be avoided.

#5: Gap: Identify the best use for green hydrogen.

Many participants noted that hydrogen use should be limited to hard-to-electrify areas and industries to ensure that it is not displacing more environmentally beneficial technology alternatives.

- **Potential Role of EPIC:** TCC recommended that EPIC evaluate the best potential green hydrogen end uses by narrowing down the hard-to-electrify sectors that cannot be addressed by other technologies. This research should assess social impacts, potential GHG emissions, cost, and energy efficiency of using hydrogen as compared to alternatives, such as electrification, as well as associated health, safety, environmental, and climate risks. UCI recommended utilizing the "least cost best fit" approach, including environmental impacts in the cost analysis, so that hydrogen can be considered for areas that can potentially be electrified but where the cost of electrification is too high to be viable.

#6: Gap: Better hydrogen storage and transportation opportunities.

UCI noted that geological storage and hydrogen pipelines are the key areas for research, as these solutions are most cost economical (approximately 5 times cheaper than other options, such as vehicle transportation).

- **Potential Role of EPIC:** UCI noted that one of the key and timely research areas is understanding the feasibility of underground hydrogen storage in depleted oil and gas reservoirs. UCI notes that hydrogen is most commonly stored in salt caverns, particularly on the Gulf Coast where there is significant deployment of hydrogen pipelines. UCI noted that some experts estimate that it may take approximately 15 years to gather knowledge on the oil and gas reservoir storage viability, but California climate goals call for much more expedited results and recommends that this research is elevated to the top of the timeline on the priority list.
- **Potential Role of EPIC:** UCI noted liquefaction and cryogenic technologies, particularly the efficiency and boil-off issues, as key areas for research — particularly if hydrogen is used to fuel vehicles and industry, where the potential penalty on smaller users and negative environmental impacts if anything goes wrong will be too high. UCI notes that these technologies should also be prioritized, as they could play an important role in the supply chain within the next 5 to 10 years.

#7: Gap: Understand hydrogen leakage and air pollution risks.

UCI, TCC, and other participants noted the high importance of avoiding hydrogen leakage and understanding the potential environmental impacts of hydrogen lifecycle, such as GHG and local air pollutants emission.

- **Potential Role of EPIC:** UCI stressed the importance of understanding hydrogen leakage detection and mitigation, from production to end use, to avoid global warming impacts of hydrogen emitted or leaked through the process. TCC, UCI, and other participants further clarified that the focus should be on the hydrogen designated pipelines, rather than gas pipelines that blend gas with hydrogen, since this technology has high opposition among many stakeholders. UCI asserted that leakage is one of the key areas that needs further research, but EPIC will need to identify where it could fit best to not duplicate any federal research efforts. UCI noted that the Pipeline Research Council International (PRCI) performed a hydrogen "state of the art" and "gap analysis" study and EPIC could perform a similar type of analysis from California perspective. Further, UCI stated that EPIC could also develop a survey on the available data and conduct field validations, instead of basic science research. TCC noted that leakage becomes a more crucial issue with a scaled deployment, particularly in residential areas, as more potential risks arise. TCC noted that industries that use hydrogen have deployed comprehensive detection and monitoring systems to ensure they avoid any potential disasters.
- **Potential Role of EPIC:** UCI also noted the need for further research to understand NOx impacts and reduction approaches in hydrogen combustion applications, such as industrial heat and power generation. UCI noted that current research indicates that NOx from these uses can be reduced below the current gas emission levels, but further research is required to explore this.

#8: Gap: Market facilitation.

UCI asserted the need to study market falsifications to enable successful business models of renewable hydrogen production.

- **Potential Role of EPIC:** UCI highlighted following areas that need further research:
    - Consistent policy and adequate subsidies in the launching and scaling up phases.
    - Environmental goals-based subsidies, such carbon intensity or NOx reduction.
    - Time-matching, deliverability, and additionality provisions.
    - Regulatory framework and market rules for hydrogen pipelines and hydrogen blending in the natural gas system.
    - Rates for grid delivered power to electrolyzer that reflect the cost-to-serve, including grid benefits.
    - Establish market rules allowing electrolyzer operators to procure electricity from wholesale generators.

#9: Gap: Reduce ratepayer burdens from infrastructure investments.

Many participants also highlighted the need to identify approaches to pay for green hydrogen infrastructure equitably.

- **Potential Role of EPIC:** Many participants noted that EPIC could evaluate what role green hydrogen should play in advancing an equity-centered, resilient, decentralized, democratized, and decarbonized energy grid, and what role ESJ communities should play in paying for green hydrogen infrastructure. UCI recommended that subsidies from ratepayers and taxpayers that support the launch and scaling of infrastructure be provided based on the long-term costs and benefits of the technology. UCI noted that this should also include the cost of externalities and be commensurate with subsidies provided to "similarly situated" technologies and pathways.

#10: Gap: Optimize variable resources through green hydrogen.

- **Potential Role of EPIC:** TCC recommended that EPIC research could help evaluate how green hydrogen can optimize variable resources and harness curtailed solar and wind. EPIC could help evaluate the viability of business models in harnessing curtailed power.

Biomass

LLNL's study "Getting to Neutral" shows that California needs 125 Mt of CO_2 removal per year to reach its climate goals. This LLNL study identified that biomass solutions could be the most impactful, removing the most carbon at the lowest cost. LLNL found that the two leading technologies in its study are:

1) Thermo-chemical gasification of waste, including municipal, agricultural, and forest to convert into fuels, like hydrogen, paired with biogas CO_2 storage; and

2) Capture and Storage of Biogas CO_2 from dairies, landfills and wastewater treatment facilities.

Another recent study conducted by LLNL, called "Carbon Negative by 2030,"[12] shows that California is suitable for biomass and CO_2 storage projects due to the availability of both biomass and storage resources. LLNL finds that there are approximately 58 million tons of

[12] LLNL, Carbon Negative by 2030: CO_2 Removal Options for an Early Corporate Buyer, February, 2022, available at https://www-gs.llnl.gov/content/assets/docs/energy/LLNL-MSFT-CarbonRemoval_Final_28Feb22.pdf

waste biomass available across California, including municipal, agricultural, forest, and other waste. However, supply chain and logistics, including sourcing, siting, and offtake, pose the greatest barriers for these technologies.

#1: Gap: Set biomass gasification targets for California.

LLNL asserted that thermo-chemical gasification of waste biomass, particularly municipal, agricultural, and forest waste, to produce hydrogen is one of the options that has the highest carbon removal capacity at lowest cost per ton of CO_2. LLNL considers hydrogen generation from waste biomass paired with CO_2 storage to be a leading technology for California in removing CO_2. LLNL stated that this technology can generate about 4 million tons of hydrogen a year and help California reach its hydrogen goals. However, this technology poses a logistical challenge, particularly with sourcing a stable and long-term biomass supply. LLNL finds that the high upfront costs of facilities to get to economies of scales poses high investment risks as well: these facilities process approximately 2,000-5,000 tons of biomass per day and requires approximately $500 million of capital investment, so it is important that there is a reliable long-term supply of biomass upfront that can last for 20 years to catalyze the capital investment.

- **Potential Role of EPIC:** LLNL noted that research in biomass hydrogen production is needed to identify potential cost reduction opportunities, incentives, and risk reductions in the supply chain to make this technology economically viable.
- **Potential Role of EPIC:** LLNL noted that modular deployment and large-scale demonstration are the areas that can benefit from additional research as well. While LLNL finds gasification to be a proven technology, for other feedstocks, since feedstock variability and unique biomass attributes pose some technical risks to the facilities, it finds that mid-scale demonstrations could help to identify these risks and opportunities to reduce risks of project failure due to complications from biomass attributes and variability. LLNL further finds that research on potential opportunities to deploy modular units that can scale up easier, cheaper, and requires a lower capital investment.
- **Potential Role of EPIC:** LLNL recommended that EPIC can help identify the potential deployment rates needed to reach California's climate goals as well as opportunities to reduce costs of production and incentives for the industry to invest in this technology. LLNL considers this technology to be not just carbon neutral but carbon negative as it does not draw significant grid electricity and removes CO_2 from the atmosphere. LLNL noted that EPIC can play a key role in providing demonstrations on the emissions profile and carbon removal potential

of this technology. EPIC can also help to address community concerns by demonstrating the effectiveness of pollution controls that work best.

#2: Gap: Set biogas carbon capture and storage targets for California.

LLNL identified capture and storage of biogas CO_2, particularly at dairies, landfills and wastewater treatment facilities, as a viable near-term biomass carbon removal technology to supplement biomass gasification and storage. LLNL finds that this technology does not have sourcing challenges, like biomass gasification, since biomass is already present and there is a constant supply of it at the facilities where this technology is deployed. LLNL stated that carbon capture and storage of biogas CO2 reduces the carbon intensity of the produced renewable natural gas and that this technology helps avoid flaring when the CO_2 from biogas is captured and stored underground. LLNL finds that the main barrier to implementation is the small scale: the sources of biogas are small scale, typically farm scale or treatment facility scale, but the CO_2 capture technologies are usually available on the large scale to be economical (such as a power plant level), so the biogas needs to be collected from several small sources, which poses a technical and logistical challenge.

- **Potential Role of EPIC:** LLNL asserted that research is needed to identify cost reduction opportunities and incentives for the industry. LLNL recommended that EPIC could help identify potential deployment rates for capture and storage of biogas CO_2 for California to support its climate goals and help solve the logistical and technical issues in small scale carbon capture from biogas resources.

Carbon Capture and Sequestration (CCS)

#1: Gap: Understand CCS role in low-cost solutions for 100% clean grid.

NREL suggested that EPIC can further research strategies to achieve California's goal of a 100% carbon free grid, continuing from an NREL recent study.[13]

- **Potential Role of EPIC:** NREL suggested that EPIC can perform further studies into various scenarios of how CCS, direct air capture and BECCS can be used to achieve 100% clean electricity and to identify the most effective and low-cost solutions for California.

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[13] NREL, On the Road to 100% Clean Electricity: Six Potential Strategies to Break Through Last Few Percent, September 09, 2022, available at https://www.cell.com/action/showPdf?pii=S2542-4351%2822%2900405-6

#2: Gap: Direct air capture research opportunities.

LLNL finds that direct air carbon capture and storage can deliver about 16 Mt of CO_2 a year at approximately $193-$198 per ton to supplement natural and biomass-based carbon removal solutions. LLNL asserted that California has areas that provide opportunities for direct air capture and can supply jobs for the reduced fossil fuel industry. LLNL also noted that CCS demand currently exceeds the supply and the market is paying high prices, with costs varying from $1200/ton for ocean electrochemical to $112/ton for biomass, with the $550/ton average price. LLNL stated that the Boston Consulting Group estimates a global demand of about 70-230 Mt CO_2/yr in 2030-2040 with direct air capture prices estimated to be at about $230/ton in 2030 and $200/ton in 2040. LLNL noted that the direct air capture industry grew substantially in the last 2 years reaching $2 billion and is projected to reach $45 billion globally by 2045, with North America's share of the global market estimated at about 36%. LLNL stated its research shows that California can take a lead in the nation's CO_2 removal effort as it has great potential, particularly due to the agricultural, forest, and municipal waste supply and geologic storage availability.

- **Potential Role of EPIC:** LLNL noted the following research opportunities for direct air capture research include: 1) improving sorbents durability, since the costs decline with the increased sorbents lifetime; and 2) adjusting design to local and seasonal conditions, to accommodate large temperature swings in the Central Valley, since the systems operate differently at different temperatures and humidity levels. LLNL noted that EPIC can play a key role in providing demonstrations on the emissions and carbon removal potential of this technology and what controls work best to address community concerns.

#3: Equity Considerations: Identify CCS cost to society.

- **Potential Role of EPIC:** CEJA asserted that EPIC research should not focus on trying to improve CCS and CCUS capture rates, but rather on finding the appropriate metrics necessary to illustrate its true cost to society, and finding ways to ensure that CCS isn't necessary.

Artificial Intelligence (AI)

PNNL noted that AI and machine learning have been utilized in the energy industry for some time, including in DER integration, decarbonization road-mapping and impact analysis, energy efficiency, energy equity and environmental justice, forecasting and system planning, and grid reliability and resilience.

#1: Gap: Demonstrations and data analytics.

PNNL highlighted that the biggest gaps in using AI for the clean energy transition are data availability and quality to enable greater analysis and more accurate models and predictions. Trustworthiness and validation, bias, and unforeseen events, as well as data privacy and security, are the other key concerns and gaps in this sector. PNNL noted that stakeholders often call for regulations and standards, particularly related to critical infrastructure systems, as well as data privacy and security. PNNL noted that research and demonstrations are critical in the AI space, especially because technology changes rapidly. PNNL stated there is significant AI research currently being undertaken, particularly in physics models with machine learning methods to increase interpretability and transparency of different models. PNNL suggested that more research is needed to help improve modeling in grid planning.

- **Potential Role of EPIC:** PNNL asserted that more demonstrations are needed to take AI research from the labs, including national labs of ratepayer funded programs like EPIC, to the industry as quickly as possible. PNNL noted that demonstrations are also needed to build trust and demonstrate value propositions, identify gaps, and provide a roadmap for others to deploy AI technologies. PNNL noted that one of the roles EPIC can play in this area is providing demonstrations on how to apply available AI tools to the areas important to California and on how to use AI to manage and analyze large data sets. PNNL confirmed, in reply to the CPUC Staff' question, that cybersecurity and carbon footprint of AI technology are potential concerns but noted that a lot of research is under way on cybersecurity measures.

#2: Gap: Applying AI to track impacts on ESJ communities.

- **Potential Role of EPIC:** PNNL asserted that AI can be applied effectively in affordability analyses to support equity impact assessment and inform regulatory decisions. PNNL noted an example of a project at PNNL that applies AI to enable a framework that evaluates equity. The project identified inconsistent tracking for ESJ communities, with only snapshots of information of census years. PNNL stated its project is building a framework to connect the timelines between these snapshots and fill the information gaps with stakeholder feedback and research. This will enable PNNL to track the evolution of these ESJ communities and impacts on them over the long term.

Equity Considerations

#1: Gap: Improve participation of ESJ communities in project selection.

CEJA noted concern over the track record of EPIC funds going towards harmful combustion-based projects in ESJ communities with very little benefit to those communities.

- **Potential Role of EPIC:** CEJA recommended creating a more transparent and community-driven process for project selection. Particularly, involving ESJ stakeholders early in the project selection process.

#2: Gap: Improve ESJ communities' access to green economy.

CEJA asserted that more investment is needed to improve access to green economy solutions in ESJ communities, as these communities face greater and different barriers and burdens.

- **Potential Role of EPIC:** CEJA recommended that EPIC develop strategies on how to bring the benefits of and improve access to the green economy solutions, such as community solar and storage, resilience centers, demand response, energy efficiency, and DERs. CEJA notes that these solutions should be designed around community-specific barriers. CEJA also recommended that EPIC consider innovations that will help ESJ households participate in demand-side programs and to account for the typical constraints in those communities, such as poor internet access, limited ability to shift load, and limited availability of smart technologies. EPIC should also consider affordability, such as how ESJ communities are protected from increased bills. Overall, EPIC should consider what benefits of the energy transition ESJ communities should receive.
- **Potential Role of EPIC:** CEJA recommended that EPIC develop a holistic approach to delivering benefits to ESJ communities, including healthy homes, community resilience hubs, community based renewable generation and energy storage, demand flexibility, energy efficiency. CEJA recommended that EPIC could help develop more community resilience centers, microgrids, and solar + storage projects for ESJ communities to increase community resiliency. CEJA noted that EPIC should think about where to site resiliency projects so that they reach the most vulnerable communities that are the most impacted by extreme weather events.

#3: Gap: Prioritizing the most vulnerable communities.

- **Potential Role of EPIC:** CEJA recommended implementing a targeted investment approach in ESJ communities by prioritizing investments for communities with the least resources and who are most vulnerable to impacts of climate change. CEJA recommended retiring fossil fuel infrastructure and providing backup generation in areas with high levels of air pollution to improve local air quality.

#4: Gap: Prioritize clean energy investment to retire gas.

CEJA noted that hydrogen combustion and CCS have potential to harm ESJ communities given the existing location of gas plants and that EPIC funding to support such technologies is inappropriate and could have negative impacts on these communities.

- **Potential Role of EPIC:** CEJA noted that over $3 billion investment can be more meaningfully be used to advance locationally targeted, clean, distributed solutions to meet reliability, while benefiting ESJ communities.

#5: Gap: Develop filters to avoid harmful projects.

CEJA raised a concern that EPIC continues to fund combustion research projects in ESJ communities, noting that of the $43 million in EPIC funding allocated to combustion projects, $41 million funded projects located in ESJ communities, primarily focused on dairy digester gas. Commissioner Shiroma asked CEJA to supply more details on these referred projects and invited them to submit source information for further consideration.

- **Potential Role of EPIC:** CEJA recommended EPIC take stock of how much funding went towards benefiting ESJ communities and create a filter for "bad projects" that perpetuate more harm to the ESJ communities. CEJA suggested that harmful projects, such as hydrogen combustion, CCS, and dairy digesters, can be avoided by using appropriate filters, such as the White House Justice 40 Guide. CEJA recommended that sufficient filters, paired with strong social cost-benefit accounting, can help identify beneficial projects and prevent harmful projects. CEJA also stressed that EPIC funding should not be used for combustion projects, particularly in the ESJ communities, or any projects that increase or maintain criteria pollutants emissions and GHG emissions in ESJ communities. CEJA argued that EPIC must measure the full spectrum of impacts of new technologies, such as hydrogen and CCS, and quantify the harms; this can inform future project selection.

V. APPENDICES

Video Recordings:

Workshop video recording

Agenda: PDF

Presentations:

Opening remarks: Commissioner Genevieve Shiroma, California Public Utilities Commission (no slides)

Andrew Barbeau, EPIC Policy + Innovation Coordination Group Project Coordinator (no slides)

Roundtable: Strategies for a Net Zero Future (1):

Brian Sergi, National Renewable Energy Laboratory - Presentation Link

Sarah Baker, Lawrence Livermore National Laboratory - Presentation Link

Jill Haizlip, Geologica Geothermal Group - Presentation Link

Alexis Sutterman, California Environmental Justice Alliance - Presentation Link

Tim Yoder, Pacific Northwest National Laboratory - Presentation Link

Roundtable: Strategies for a Net Zero Future (2):

Kori Groenveld, National Offshore Wind Research & Development Consortium - Presentation Link

Walter Musial, National Renewable Energy Laboratory - Presentation Link

Jeffrey Reed, UC Irvine - Presentation Link

Woody Hastings, The Climate Center - Presentation Link

Ari Eisenstadt, California Environmental Justice Alliance - Presentation Link