UC National Laboratory Fees Research Program – 2024 Workshops

Community-Engaged Research for Clean Energy Solutions (CERCES): Executive Summary

The UC National Laboratory Fees Research Program (LFRP) sponsored two workshop convenings in October and November 2024 to identify research priorities for UC and National Labs on the topic of Community-Engaged Research for Clean Energy Solutions (CERCES). The resulting report presents a roadmap to enhance UC and National Labs' leadership in the clean energy transition by leveraging their complementary strengths while ensuring long-term sustainability. It aims to inform and support UC-national lab collaborations with communities, identifying promising avenues of research.

The report identified ten research areas with near-term deployment potential in California. Notably, strong cases were made for UC, Industry, National Labs, and community partnerships in agrivoltaics and renewable energy planning and adoption, including solar PV, transportation, and low carbon communities. The report highlighted various avenues for LFRP funding, including:

- **Grand Challenge Projects**: Launch multi-year funded flagship projects addressing global challenges and leveraging complementary expertise across UC and National Labs.
- **Interdisciplinary Research Networks**: Incentivize the creation of research clusters around topical areas and challenges primed for federal, state, and foundation funding.
- **Proposal Development Sessions**: Incorporate sessions to develop joint proposals for federal or state funding.
- **Community Building and Recognition**: Establish awards for outstanding UC-National Lab research partnerships and host annual showcases, such as UC Irvine's "Born in California Demo Day."
- **Offer a planning or seed grant mechanism** for those scientific teams that have not yet developed genuine community engagement in their research program

To sustain partnerships beyond CERCES workshops, the report suggests:

- Establishing a small CERCES Coordination Committee to discuss funding opportunities and manage strategic communications with workshop participants.
- Generating UC Systemwide/National Lab resources for community-engaged research accessible in a central portal.
- Leveraging the Climate Action Seed and Matching grants applicant pool to encourage forums for researcher collaboration.
- Exploring opportunities for university researchers to participate more meaningfully in the National Lab LDRD funding program.
- Coordinating UCOP-funded on-site visits to national laboratories to explore their capabilities, shared facilities, and test beds, further strengthening University-Lab partnerships.

LFRP Workshop Report

Workshop Title: Community-engaged Research for Clean Energy Solutions (CERCES)
Host/Coordinating Institution: University of California, Irvine
Workshop PI Name: Pramod Khargonekar
Workshop Report Authors: Dressen, Tiff (UCB), Hapke, Holly (UCI), Kurtz, Sarah (UCM), Lee, Helen (UCI), Mayfield, Kim (LLNL), Peffer, Therese (UCB), Rodriguez, Dan (UCB), Taylor, Keith (UCD), Van Wijk, Jolante (LANL), Walker, Barbara (UCSB), Zenyuk, Iryna (UCI)

Executive Summary

Workshop purpose and goals

The purpose of the Community-Engaged Research for Clean Energy Solutions (CERCES) workshop series is to provide a forum to discuss research advancing clean energy solutions in dialogue with community collaborators, and to propose a roadmap that considers UC and National Lab complementary strengths and expertise as well as lessons learned from existing clean energy collaborations for the University of California (UC) and the UC National Laboratories (NL) to advance the field.

The workshop series included two workshops convening researchers, students, and staff from the UC and NL, as well as members from the community. Through plenary sessions, CER project panel discussions among UC, NL, and community members, and breakout group discussions, the workshops enabled dynamic discussions, shared learning, and collaborative thinking in tackling critical challenges in CERCES.

These strategic priorities would strengthen the UC and National Labs' capacity to lead the clean energy transition with long-term sustainability for the community and to promote our ethical responsibility to contribute to a sustainable, resilient and just energy future.

Background and Current Status

As described in the Executive Summary, the goal of the two-workshop series was to identify research priorities in the area of community-engaged clean energy solutions. This topic is strategically significant for UC and the national laboratories, as community engagement and education are essential for the effective deployment of technologies developed across these institutions. While many research centers, initiatives, and collaborations focus on clean energy research—a critical area for achieving California's decarbonization goals for 2030 and beyond—relatively few initiatives incorporate a strong community component.

To address this gap, the workshop series aimed to identify barriers to engaging non-profit organizations, NGOs, neighborhoods, the private sector, and other stakeholders. To begin, we examined current and ongoing community-engaged clean energy solutions projects involving UC campuses and national laboratories, particularly those with nascent or established collaborations with community partners. A few examples include:

- UC Berkeley's EcoBlock project[1], an urban block-scale energy retrofit in collaboration with residents in the City of Oakland.
- ARCHES, Alliance for Renewable Clean Hydrogen Energy Systems[2], a public-private partnership funded by DOE and the State of California, that seeks to accelerate renewable hydrogen projects and the needed infrastructure where 40% of benefits from project activities will go directly to underserved communities. Four UC campuses plus LLNL, LBNL, and LLNL are currently participating in ARCHES.
- The UC Berkeley and LBNL led CalDAC[3], a DOE funded effort to do a feasibility assessment of an equity-focused regional Direct Air Capture (carbon dioxide removal) hub in Madera, Fresno, and Kern counties.
- LLNL's community-based LEAP (Local Energy Action Plan)[4] project in the Sacramento-San Joaquin Delta area that explores, with community partners, the risks and impacts involved in sequestration of carbon in their region, in addition to LEAP collaborations in West Fresno and Bakersfield.
- UCOP Climate Action Award led by three UC campuses, NREL, LBNL, and a Community Advisory Board to provide climate resilient electric distribution networks for low-income communities[5]

- UC Merced Professor Ricardo de Castro's Central Valley based project to improve preparedness of communities for evacuations using EVs.

As illustrated by the diversity of the projects listed above, these ranged from single-laboratory efforts to multi-billion-dollar Hydrogen Hub projects. Through the workshop series, we sought to include these projects in the agenda to better understand the strengths and weaknesses of their approaches and strategies for fostering successful collaborations between the UCs, national laboratories (NLs), and local communities. Specifically, we aimed to hear directly from community members involved in the existing projects and gather their feedback on improving engagement practices.

Unlike many other technical topics, this area presents unique challenges due to the critical role of community engagement. Consequently, we focused primarily on research activities and projects with potential for near-term deployment in California, as fundamental research is typically conducted by researchers within the UCs and NLs and may not directly apply to community needs. To guide our evaluation, we considered the Department of Energy's Office of Technology Transitions Adoption Readiness Levels (ARL) [6] framework, which assesses factors such as product-market fit, demand pull, supply chain robustness, regulatory risks, community perceptions, and workforce availability. However, we propose expanding this framework to incorporate additional elements of community readiness. These include the affordability of solutions and their potential impact on energy burdens, the community's understanding and acceptance of associated risks and benefits, inclusivity in determining who benefits from the proposed energy solutions, and the availability of funding and incentives to encourage adoption.

Furthermore, we considered solutions that could be implemented in the short term (2-3 years) and medium term (3-5 years). In the following section, we outline the research priorities in this area and provide specific recommendations for advancing this field, including strategies for effective community engagement. Given the interdisciplinary nature of the selected topic, this report was crafted with input from a diverse team of researchers representing various schools and disciplines.

Research Priorities to Advance the Field

As a result of the workshop series, attendees identified the following research priorities which are listed in alphabetical order. In each of the areas research directions were identified, as well as approaches to leverage UC and NL expertise and capabilities to advance this specific topic were highlighted.

Agrivoltaics

Agrivoltaics (combining agriculture with solar electricity generation) is attracting substantial interest primarily because it: 1) enables more solar electricity generation without reducing land used for agriculture[7], and 2) multiple studies have shown that crops can be grown with less water when agrivoltaics is used[8,9], which will be of growing importance as the Sustainable Groundwater Management Act is implemented[10]. The three strategies most commonly used for agrivoltaics are A) grazing as a strategy for weed management in the array field, with sheep being most common currently, B) pollinator crops that act as a ground cover without shading the solar panels, while providing habitat for bees, improving the productivity of adjacent fields, and C) row crops that are grown in between the rows of solar panels. Across the U.S., about half of the agrivoltaic installations use grazing and about half use pollinator crops. California is in a somewhat unique situation: In California's Central valley, the value of the agricultural produce may be greater than the value of the generated electricity, potentially providing a bigger opportunity, especially for crops that experience damage from too much heat and/or sun.

The primary research gap that needs to be addressed is to demonstrate to growers that agrivoltaics will increase their revenue enough to offset the added challenges[11]. The approach of "seeing is believing" may be most effective for convincing growers to adopt agrivoltaics. Research gaps include identifying:

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- strategies and value of agrivoltaics for improving worker conditions (shade, easy access to electricity)
- overcoming barriers to acceptance of agrivoltaics through education and resolution of concerns
- best crop choices (e.g. shade tolerant crops and crops that may suffer damage from heat/sun)
- best agrivoltaic designs that simultaneously optimize revenue and ease of implementation, including providing workers with shade without bumping their heads
- best approach to enabling agrivoltaics combined with cattle ranching
- financial mechanisms and communication of these to growers to facilitate their decisions
- needed policy changes ranging from how current incentive programs apply or don't apply to agrivoltaics to what new policies may be needed ranging from zoning to whether the Williamson Act can still be used
- how the benefits of agrivoltaics may be more equitably distributed
- understanding why agrivoltaics has not taken off in the US to identify any additional research gaps that must be addressed before adoption of agrivoltaics accelerates.

Efforts related to agrivoltaics may be extended to include aquavoltaics (solar panels over the water)[12,13].
To ensure that the benefits of agrivoltaics will be equitably distributed, community participation needs to be supported financially, including funds for language translation and direct payments for community members who are restricted from receiving honoraria.

Agrivoltaic studies that demonstrate successful implementation of plant growth in the shade of solar panels should be expected to take years. It could be useful to consider projects that are planned to obtain results after 4-5 years and/or projects that include a plan for continued community engagement after the main project is completed.

The research and training collaboration between UC and national laboratories leverage the following capabilities of the UC campuses and UC national laboratories:

- *LLNL has been developing community contacts to define the opportunity for agrivoltaics to make a difference, especially in the communities that need it most*.
- *LLNL is partnering with UC Davis to study the effects of agrivoltaics on greenhouse gas fluxes and soil chemistry in the field.*
- *UC Davis has been hosting an annual workshop on agrivoltaics as a way to connect with the larger community and has been publishing about agrivoltaics with a focus on policy*
- *UC Merced has been developing a mobile agrivoltaic system and is in the process of installing a 50-kW agrivoltaic system*
- *UC Berkeley has a seed grant to integrate research on just and equitable agricultural transitions with research on just and equitable clean energy transitions.*

CO_2 Storage and community readiness

Underground storage of CO_2 in mature oil & gas fields to enhance the recovery of fossil fuels whereby a portion of the CO_2 is sequestered has been ongoing for decades[14,15]. This storage is however linked to the production of fossil fuels and existing petroleum fields, and the volume of sequestered CO_2 is limited. Geologic storage in porous media outside of oil & gas fields has several benefits, including larger geographic areas and more reservoirs where sequestration may be possible to allow for avoiding geomechanical concerns (such as induced seismicity), reducing the transport distance of CO_2 from the capture source to the injection side, and decoupling sequestration from production of fossil fuels. At present, several dozens of such permanent-storage CO_2 injection wells are in use in the U.S., and more than 100 permit requests are being considered (epa.gov). To meet net-zero energy demands in the next decades, permanent CO_2 storage efforts need to be up-scaled to basin-wide scales (netl.doe.gov). CO_2 for underground or geologic storage can be captured directly at the source (point source capture, for example from fertilizer plants) or by Direct Air Capture (DAC) whereby CO_2 is removed from the atmosphere.

The CO_2 injection technology is mature, but community concerns persist and readiness for adoption varies. The permit application process for CO_2 injection wells is handled by the EPA (epa.gov)[16], and it currently takes a few years to approve a permit. Induced seismicity and leakage risk are components of the permit review process. Historical and recent examples of CO_2 leaks from pipelines or underground storage reservoirs (for example, a leak in the Archer-Daniels-Midland Decatur injection site in Illinois reported in September 2024) make news headlines and form the basis for ongoing concerns.

Addressing community concerns continues to be critical work and may lead to new technological developments to avoid and mitigate leaks and induced seismicity, as well as better informing communities on the risks involved, possible mitigations, and long-term (decades) perspectives of the injection site. Several research priorities could be promoted:

- Addressing the leakage risk by innovative storage options that reduce leaks
- Improving monitoring of the injected CO_2 plume to capture its location
- Developing fast and effective leak mitigation responses

In addition, to improve adoption–readiness, a catalog of ongoing and past CO_2 storage initiatives and associated community engagement and response could form a database for studying what forms of community engagement are successful. Such a catalog could inform future outreach efforts. The catalog could include both sequestration projects as part of enhanced oil recovery sites and injection sites elsewhere. It is important to clearly explain to communities what is expected in the future. Terminology such as "permanent storage" (what does that mean- 30 years? 100 years?), how the volume of sequestered CO_2 is calculated and monitored, or who will be responsible for addressing leaks now and in the future need to be clarified. Such information could perhaps be included in educational or informational material.

The list below is a selection of the research and training collaboration between UC and national laboratories on carbon management:

- *The three UC labs continue to collaborate closely on several projects related to carbon sequestration, including DOE's National Risk Assessment Partnership (NRAP) and DOE's Science-informed Machine Learning to Accelerate Real-Time Decisions in Sub-surface Applications (SMART) project. These projects focus on safe underground storage of CO2. The labs contribute complementary capabilities to these projects.*
- *UC Davis continues to be active in organizing workshops on reducing and storing greenhouse gases, including initiatives such as CLEAR and State of the Science Summits. These workshops focus on topics that are integral to the carbon management challenge, and cover areas where UC universities are leaders.*
- *The UC Merced campus was the first campus to reach carbon neutrality and can be a role model for the three UC labs that have goals to reach carbon neutrality in the next decades.*
- *UCLA and UC Berkeley researchers are working on carbon management through direct air capture and ocean-based carbon removal. Notably, UC Berkeley chemists have developed a new porous material known as a covalent organic framework (COF) that efficiently absorbs carbon dioxide from ambient air, including a COF capable of capturing carbon dioxide at the elevated temperatures typical of industrial exhaust streams.*
- *LBNL and LANL are working in these areas as well, and the institutes have complementary expertise in these fields.*
- *Scientists at UCI are developing technology that causes injected CO2 to become negatively buoyant, preventing leaks. This technology will be invaluable for collaborative proposals with the three UC labs responding to carbon sequestration funding opportunities in CY25.*

- *LANL has developed extensive expertise in community impacts of energy transition and cola power plant closure in the Four-Corners region that is transferable to other regions.*

CO_2 Conversion to Useful Products

While underground storage is an obvious opportunity for captured CO_2, it would be even more useful if captured CO_2 could be converted to plastics, fuels, or other products that are critical to the function of today's world. Foundational R&D is needed to enable CO_2 conversion to useful products at adequately low enough financial and energy cost. Reaching these goals will benefit from coordinated partnerships between national labs, academics and companies. Key research topics include:

- Identification of near-term markets for molecules that can be made from CO_2
- Identification of low-cost catalysts and hardware to enable conversion of CO_2 into useful materials/products
- Increase in efficiency of processes capable of converting CO_2 to useful materials and products

The research and training collaboration between UC and national laboratories leverage the following capabilities of the national laboratories:

- *All three national laboratories are involved in CO_2 conversion projects.*
- *One of the few start-ups in electrochemical conversion of CO_2 to CO and other value-added products is based at Cyclotron Road program at LBNL.*
- *Sponsored by DOE, LANL is leading the Intermountain West Energy and Transitions initiative in deployment of various CO_2 conversion technologies.*
- *LLNL has both computational and experimental laboratories that work on projects in CO2 reduction reaction technologies and they have existing partnership with UC Merced in this area.*

Critical materials use and recycling

Clean energy technologies require use of critical elements such as rare earth elements, and critical materials, which are areas of research at the DOE national labs and UCs. Rare earth elements, such as noble metals are valuable as they are inert under various harsh conditions and are used as catalysts and electrocatalysts for hydrogen-based technologies and CO_2 reduction technologies. These include platinum, palladium and iridium. Reducing the use of these materials in electrochemical technologies through materials design, device optimization and operation conditions is an active area of research. Furthermore, recycling of these materials is still at a low TRL. Critical materials might not be necessarily precious, but they are key for various technology deployment. For example, cobalt (Co) is a critical component for battery cathode fabrication, as it is used as one of the major active materials in the cathode.

Research needs in this area include:

- Development of advanced materials and optimized device designs that minimize or replace the use of rare earth elements and critical materials in key technologies such as hydrogen-based systems, CO_2 reduction catalysts, and battery electrodes.
- Significant research is required to advance the TRL of recycling processes for critical materials, including rare earth elements and battery components. This includes developing efficient, cost-effective, and environmentally sustainable methods to recover and reuse materials like platinum, cobalt, and other key elements from end-of-life devices and industrial waste, ensuring a closed-loop supply chain.

Various research activities at UCs are ongoing to create Co-free cathodes and to enable effective recycling of cathode materials.

- *The Critical Materials Institute at LLNL develops substitutes to reduce demand of overused materials and explores new methods for reuse and recycling of critical materials that have an environmental and economic benefit.*
- *LBNL focuses on various novel material formulations to enable battery recycling, such as their award-winning Quick-Release Binder, which allows separating valuable materials in lithium-ion batteries.*

Geothermal

Advancements in oil and gas technology are enabling development of enhanced geothermal systems, which can be implemented over a much broader geographical range and may be more flexible in its deployment compared with conventional geothermal energy. Enhanced geothermal systems have two important benefits as they 1) can complement intermittent solar and wind generation, reducing need for energy storage and 2) provide application of skills of oil and gas workers, alleviating the social disruption that may occur when oil and gas wells are shut down.

Key research topics include:

- Development and demonstration of new drilling technologies for viable implementation of enhanced geothermal energy systems, reducing induced seismicity, and enhancing geothermal reservoirs
- Understanding opportunities to retrain today's oil and gas workers for new opportunities in enhanced geothermal or other geological storage approaches.

The research and training collaboration between UC and national laboratories leverage the following capabilities of the national laboratories:

- *LANL, LLNL, and LBNL are leaders in developing and demonstrating innovative drilling and reservoir engineering technologies. Their expertise supports reducing induced seismicity and enhancing geothermal reservoirs for the viable and sustainable deployment of enhanced geothermal systems.*
- *The labs leverage deep knowledge in geophysics, materials science, and computational modeling to optimize geothermal systems. Their research enhances the integration of geothermal energy with other renewable sources like solar and wind, contributing to grid stability and flexibility.*
- *The labs actively research strategies for retraining oil and gas workers, using their geological expertise to transition into geothermal and energy storage applications. This reduces social disruption and aligns workforce development with energy transition goals.*

Hydrogen

Currently, 95% of California's hydrogen is produced through a steam-methane-reforming (SMR) process and is used in refineries. Either SMR is used, or hydrogen is purchased from merchant suppliers. In the past several years hydrogen purchased through merchant suppliers is almost double that of on-site generated in the Western US. This presents an opportunity to have cleaner methods of hydrogen production even for CA refineries in California, as merchant supplied hydrogen can be cleaner. The new California Hydrogen Hub, ARCHES, is expected to produce hundreds of metric tons per day across various sites, primarily in the Central Valley, using mainly two pathways: **electrolytic production from water** using renewable electricity and **biohydrogen production** using biogenic feedstock such as municipal waste, woody waste, and wastewater treatment gas [17]. The CO2 emitted from the second pathways can be captured to ensure carbon negative emissions. These two pathways will be primarily focused on this report, as they are critical for California's CA future clean hydrogen production. Currently, low-temperature electrolysis technologies are on the market, whereas the remaining are entering the market or still at a low technology readiness level (TRL). Low temperature electrolysis technologies (60-80C) can be divided into proton-exchange-membrane water electrolyzers (PEMWEs), hydroxide-exchange-membrane water electrolyzers (HEMWEs), and liquid-alkaline water electrolyzers (LAWEs). LAWE is the most commercially available technology and uses concentrated hydroxide electrolyte for ion conduction. PEMWEs use proton-exchange membrane to separate anode from cathode, operate at high current densities, have a lower footprint compared to LAWEs, and can operate dynamically and at higher differential pressures. Membrane stability and durability are major concerns for HEMWEs. Solid-oxide electrolysis cells (SOECs) operate at higher temperatures (800-1000C), allowing the highest overall efficiency. Biogenic feedstocks, such as municipal solid waste, woody biomass, and wastewater off-gas, are renewable, making biohydrogen production a sustainable alternative. For example, anaerobic digestion or gasification can be used to break down organic matter in municipal solid waste producing biogas or syngas, from where hydrogen can be reformed or separated. SG2 Energy's plant in Lancaster, CA, produces green hydrogen with plasma gasification, where mixed paper waste is used as a feedstock for hydrogen production. The Lancaster plant will be producing up to 3.8 million kilograms per year, which is three times higher than any other green hydrogen plant in the world[18].

Known Gaps

Transition from SMR to low-emission hydrogen generation in the short term will be fueled by the ARCHES hydrogen hub in collaboration with industry and UC campuses. Only biomass gasification is currently cost-competitive to SMR, while electrolytic hydrogen generation is still costly.

- Technologically, LAWE electrolyzers need to overcome low operational current density ranging from 0.2 to 0.8 A/cm2, achieving optimal system efficiency of 50-78 kWh/kg_h2. For PEMWEs, the main challenge is to reduce IrOx loadings without hindering their durability, which enables significant cost reduction of the stacks.
- Key challenges for biogenic feedstock use for biohydrogen production include feedstock variability, low conversion efficiency, high costs compared to SMR, technical complexity due to the need of precise temperature, pressure and oxygen level controls, and challenge of by-product management, as CO2 needs to be captured and stored[6].
- Educating community on hydrogen safety and applicability including definition of standard hydrogen handling procedures. Hydrogen leak detection and safe use in communities.
- Hydrogen use in difficult to decarbonize sectors such as aviation, cement and steel manufacturing and its potential to do so.
- Low-cost hydrogen storage and distribution strategies, including metal hydrides, liquid organic hydrogen carriers and/or ammonia.
- Geologic hydrogen extraction is at an early technology readiness level but has a strong potential to be a good alternative for hydrogen production.

The research and training collaboration between UC and national laboratories leverage the following capabilities of the national laboratories:

- *LANL has historic competency in fuel cells technology (and electrolysis) in their MPA11 group. The group is currently collaborating with UC researchers;*
- *LLNL uses high-fidelity and high performance supercomputer simulations to accelerate materials development for water electrolysis. LLNL also has historic strength in hydrogen storage.*
- *LBNL's Energy Technology Division has a strong group in fuel cells and electrolysis technology. The Energy Geosciences Division has projects on subsurface hydrogen extraction and storage.*

Low Carbon Communities

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Background and current status: Buildings generate nearly 40% of **greenhouse gas emissions**, and two-thirds of existing buildings will still exist in 2050; only 0.5-1% buildings are renovated every year. Older homes often have inefficient electrical capacity for full electrification. The electrical utility grid is undersized to handle electrification of buildings and transportation. Driven by aging infrastructure and wildfires, **power outages** in California are increasing in number and duration, and increasingly occurring in urban areas, affecting more people and costing billions of dollars[19]. Extreme heat events kill more Americans every year than any other weather-related disaster [20], and as climate change progresses, heat waves are increasing in intensity and frequency[21]. Personal carbon footprint reduction through electrification or fuel switching from fossil fuels (natural gas, gasoline) is expensive; residential adopters of solar photovoltaic (PV) electricity generation have a significant higher median household income than the national average household[22]. **Energy-intensive cooling** through air conditioning has become a necessity in many climate zones. Low income populations are increasingly more vulnerable as these communities often lie in areas disproportionately warmer than wealthier communities[23], their houses tend to be less efficient, and they pay more of their income for energy[24]. Currently, many community solar energy projects focus on new construction in suburban environments, with solar owned by utilities.

The CEC-funded Oakland EcoBlock[1] project explored prototyping a pathway to affordable urban decarbonization by means of block-scale retrofitting: using economies-of-scale to conduct energy and water efficiency retrofits to reduce carbon emissions and to provide community-owned rooftop solar energy generation in a low-middle income urban residential neighborhood of 1-4 unit homes. The homes received needed insulation and air-sealing and new electrical service panels; natural gas-fueled appliances (space conditioning, water heaters, cooking, clothes dryers) were replaced with electric appliances. The project invited communities to self-nominate and guided the chosen block to form a Homeowners' Association to co-own and manage the rooftop solar. Researchers developed a newsletter with local articles and graphical how-this-works sheets, and compensated participants with free home energy upgrades. Community meetings started with music when possible and food; meetings had small groups to receive feedback. The most popular gatherings were the planting party and the laundry-to-landscape irrigation: people gathered together to do something tangible, with a sense of altruism and making a difference. People contributed with their expertise, whether software, economics, or art. The most effective part of the research was the **neighbor effect**: providing a means for neighbors to talk to each other about these technologies; this was especially impactful in reaching low income and minoritized households.

Research priorities:

1. Education: A real research gap is in creating effective prosumers. Most people (residents and small business owners) **do not know** how heat pumps work, how to operate them effectively, or how to maintain them; they often misunderstand the impacts of solar on the grid and time of use pricing. Educated customers will be more prepared to replace appliances at end of life or failure and may be more inclined to understand demand flexibility goals. *Suggestion:* Communities need information that is easy to understand and need it repeated (at least 5x).
2. Creating and nurturing the Research-Community relationship: The relationship between the researchers and community takes time to **develop trust** and understand mutual benefits. The communities' immediate concerns (security, comfort) will be different from the research team's goals. How do researchers keep on goal, but alter course based on the communities' priorities? *Suggestion:* Consider having a dedicated community liaison and having leadership from the community; compensate people for their time and/or provide child-care. Provide opportunities for community choice and input; this may allow the researcher to pivot as necessary. Follow best practices for communication: provide translation/interpretation, speak out of humility and respect, open communication.

3. Strengthen community: in disasters, the first line of resilience is in nearby neighbors. Research can help strengthen ties within a community, providing opportunities for people to come together in conversation or a physical project. In turn, neighbors can be trusted sources of information about new technologies.
4. Value of resilience: current utility rates do not value resilience of keeping the lights on through power outages, through load management or energy storage. Research could include study of potential demand load management on electric grid capacity growth needs.
5. Workforce training: heat pump installation requires specialized knowledge: setpoints and duct distribution are different from legacy systems. It is not uncommon for contractors to not tighten refrigerant lines properly or to let refrigerants from old, removed HVAC systems leak into the air, use old undersized ducts that undermine performance, use third party thermostats that do not take advantage of variable speed control, etc.
6. System optimization: Integration of technology in most efficient ways including load management (within home, among homes behind a distribution transformer) and optimized integration of storage and use of DC hardware.
7. Capacity building: One of the fastest strategies of reaching many people is to train those who provide relevant services. If the furnace repairperson is informed and heartily recommends replacement of a furnace with a heat pump, the repair can be a strong partner in introducing new technology.

The research and training collaboration between UC and national laboratories leverage the following capabilities of the national laboratories:

- *LANL is a key participant in the Department of Energy's GMI, focusing on enhancing grid resilience and reliability. Their work includes the development of advanced algorithms and modeling tools to predict and mitigate disruptions caused by extreme weather or grid overload, directly addressing challenges related to building and transportation electrification.*
- *LANL has researched and developed microgrid technologies that integrate renewable energy sources like solar PV with battery storage. This is especially relevant for addressing power outages and improving energy reliability in low-carbon communities.*
- *LLNL's energy flow studies, such as the Carbon-Free Energy by 2050 project, identify pathways to decarbonize the built environment. The lab's work on demand response and grid interaction strategies aids in integrating electrified buildings and transportation with existing utility infrastructure.*
- *LBNL houses the Building Technology and Urban Systems Division, which develops innovative solutions for building energy efficiency, including advanced heat pump systems and tools like the Home Energy Saver calculator, helping households optimize energy use and plan electrification efforts.*

Renewable Energy Planning and Adoption

Research priorities for renewable energy planning and community adoption in California must address the intersection of climate resilience, grid reliability, and socio-political dynamics. California's goal of achieving 100% clean electricity and carbon neutrality by 2045 requires accelerating renewable energy deployment while navigating increasing risks of extreme weather, wildfires, and electricity supply-demand imbalances. Socio-political factors play a critical role in renewable energy siting, as community preferences, local ordinances, and land use considerations can significantly influence where projects are developed. These factors often lead to divergent outcomes from techno-economic models, requiring careful integration of stakeholder engagement and political dynamics to ensure successful and equitable renewable energy deployment.

Key considerations include:

- Linkage of Californian communities' efforts should be closely coordinated with those of regions across the western U.S., as the state evaluates trade-offs among carbon-neutral electricity imports, wildfire-related transmission risks, and inter-state policy alignment.

- Policymakers, utilities, and community stakeholders should prioritize infrastructure investment in underserved areas and the research community needs to better understand NIMBY resistance and effective solutions to mitigate.
- California should integrate techno-economic modeling with socio-political considerations, when crafting adaptive strategies that balance economic, environmental, and social priorities in its energy transition.

The research and training collaboration between UC and national laboratories leverage the following capabilities of the national laboratories:

- *LBNL collaborates with the California Energy Commission to develop models that optimize renewable energy deployment while balancing environmental, economic, and social factors. Their research integrates socio-political dynamics with techno-economic modeling for community-specific renewable energy planning.*
- *LBNL developed the DER-CAM (Distributed Energy Resources Customer Adoption Model) to assist stakeholders in designing cost-effective and resilient renewable energy systems tailored to community needs.*
- *LANL contributes to renewable energy siting and grid resilience studies, focusing on integrating renewable energy sources with regional climate adaptation strategies. This includes evaluating risks such as wildfires and extreme weather for infrastructure planning.*
- *As part of the Grid Modernization Laboratory Consortium (GMLC), LANL investigates advanced grid analytics and transmission optimization to ensure renewable energy deployment aligns with regional and interstate resilience and policy goals.*
- *LLNL conducts studies on the integration of renewable energy across the western U.S., focusing on trade-offs between carbon-neutral electricity imports, wildfire risks, and transmission infrastructure. LLNL develops frameworks to address equity in renewable energy adoption.*

Solar PV: coupling it with storage, microgrids

The integration of solar photovoltaic (PV) devices into the design architecture of power systems and microgrids plays an important role in decarbonizing the electrical grid and power sector, supporting sustainability, reliability, and resilience. Solar PV devices convert sunlight into electricity, and their integration into microgrids offers localized energy solutions. By combining distributed energy resources such as solar PV, various forms of energy storage, and controllable loads with advanced control systems, microgrids enhance dynamic power generation, distribution, utilization and management capabilities. These systems can operate either in conjunction with traditional utility grids (grid-connected mode) or independently (island mode) to support energy resilience, security, and independence. This capability is particularly critical in California, where the risk of grid disruptions from extreme weather events, emergencies, wildfires, or increasing peak demand requires robust decentralized energy solutions.

Innovations in microgrid technology are further reshaping energy landscapes and creating an opportunity to work directly with communities to deploy, demonstrate, and validate advancements in energy arbitrage, peer-to-peer trading, and sophisticated demand-response mechanisms, along with innovative technology solutions to redefine how electricity is generated, consumed, and shared within and across communities. Despite progress in solar PV and efficiency of power systems, grid integration, and real-time energy management, significant challenges persist. Key areas for research include 1) enhancing energy storage solutions to ensure long duration support, 2) optimizing microgrid designs for resilience against climate-induced events, and 3) improving the efficiency of energy and power systems under diverse environmental conditions, as well as simplifying microgrid design and the permitting and interconnection process.

Additionally, addressing community engagement gaps is critical, particularly for underserved areas that can benefit from decentralized solutions. To advance solar PV and microgrid technologies when working specifically with communities, several research priorities could be promoted:

- Simplifying the connection process for distributed energy resources to reduce barriers, lower costs, and speed up deployment.
- Expanding large-scale demonstration projects to build confidence and de-risk technologies by proving their performance and reliability.
- Collaborating with utilities on programs (e.g., demand response and peer-to-peer energy) to encourage market adoption and enhance grid stability while lowering cost.
- Ensuring robust power conversion electronics and protective equipment to support reliable microgrid scalability and resilience, including use of DC hardware when it increases efficiency and/or lowers cost.
- Engaging communities and providing workforce training to build awareness, inclusiveness, technical skills, and equitable access to clean energy opportunities.

The research and training collaboration between UC and national laboratories leverage the following capabilities of the national laboratories:

- *LANL has developed advanced control algorithms for optimizing the integration of solar PV, energy storage, and distributed energy resources within microgrids. Their work focuses on improving reliability, resilience, and real-time energy management under diverse environmental and grid conditions. LANL is also involved in projects that assess and mitigate the risks posed by extreme weather and wildfires on decentralized energy solutions, contributing to the design of robust, climate-resilient microgrids.*
- *LBNL leads demonstration projects integrating solar PV and energy storage systems with advanced microgrid architectures, including community-focused deployments to validate performance, reliability, and economic benefits. LBNL has developed tools like DER-CAM (Distributed Energy Resources Customer Adoption Model) to streamline the design and permitting process for distributed energy resources, reducing barriers to adoption and simplifying integration.*
- *LLNL explores innovative market mechanisms, such as energy arbitrage and peer-to-peer energy trading, within microgrid systems. LLNL is advancing the development of robust power conversion electronics and protective systems to improve the efficiency, scalability, and resilience of microgrids, including those employing DC hardware for higher efficiency.*

Transportation

Transportation remains a critical sector for the implementation of clean energy solutions [25]. The freight sector represents an acute challenge given the infrastructure, vehicle, and logistical challenges involved. Although across all motorized transportation modes technological improvements remain a priority, some research questions have shifted from technological feasibility to implementation readiness including:

- Understanding clean energy demand for transportation in the face of changing price incentives and an uneven spatial supply of distribution and refueling stations
- Assessing the readiness of the power distribution network to support the demand for EVs, especially for heavy duty short-haul vehicles (e.g., transit vehicles)
- Improving the quality and operability of existing chargers and spatial coverage of charging stations for EVs and hydrogen refueling stations for heavy duty vehicles, for both everyday use and in case of evacuations
- Increasing effort to install charging infrastructure (both level 1 and level 2) at workplaces and other locations where cars are parked during the day, especially useful if coupled with solar-covered parking
- Identifying adoption barriers to EV charging in multifamily residential locations and urban locations and proposing possible solutions

- Working with drivers and transportation network companies (e.g., Uber and Lyft) to meet CA decarbonization mandates
- Improving the management of battery lifecycle, from mineral extraction to disposal
- Understanding the water (sea and river) and truck freight use cases and feasibility for clean energy solutions including use of ammonia or other energy carriers

The multiplicity of transportation modes and use cases around transportation underscores the importance of working with user groups to redefine problems and co-develop and test solutions. Engaged research is critical to define what constitutes an equitable energy transition, which varies for each context and situation[26]. Workshop presentations suggest the importance of multiscale engagement with partners, from residents and employees to neighborhoods, cities, counties, and not-for-profit organizations.

The research and training collaboration between UC and national laboratories leverage the following capabilities of the national laboratories:

- *LBNL develops tools and models to assess and optimize the spatial distribution of EV charging and hydrogen refueling infrastructure, considering urban and multifamily residential challenges. Their work supports equitable access to clean transportation energy solutions.*
- *LBNL explores the integration of solar PV with workplace and public charging infrastructure, such as solar-covered parking, to enhance charging reliability and reduce grid stress.*
- *LANL researches the impact of EV adoption, particularly heavy-duty and short-haul vehicles, on power distribution networks. Their work focuses on grid resiliency, energy management strategies, and readiness to meet increased demand.*

Cross-cutting topic on enabling tools

By bridging data-driven insights with actionable strategies for clean energy implementation, while ensuring inclusivity and equity in planning processes, the engagement framework can be further improved keeping in mind the following points:

- **Environmental Justice and Comprehensive Planning Databases**: Catherine Brinkley's research[27] at UC Davis emphasizes the use of comprehensive plans, such as the California General Plan Database Mapping Tool, as a critical tool for accessing, querying, comparing and spatially visualizing general plans across California's cities and counties. This can be a powerful tool to identify clean energy gaps in communities. Such databases derived from these general plans can serve as a repository to guide the integration of environmental justice principles in clean energy initiatives, focusing on equitable deployment and policy gaps.
- **EJ-Specific Data Tools like CalEnviroScreen**: The use of tools such as CalEnviroScreen demonstrates how integrating environmental and health metrics can help map disadvantaged communities. This approach is instrumental in clean energy planning by identifying priority areas for solar PV deployment, EV charging infrastructure, and microgrids.
- **Quantitative Text Analysis for Plan Evaluation**: By employing machine learning techniques such as topic modeling, researchers can analyze extensive datasets of city plans to identify policies supporting clean energy and environmental justice. This capability can streamline the assessment of readiness for renewable energy adoption and the alignment of policies with community needs.

Recommendations for Supporting Community-Engaged Research and Regional Development for Clean Energy Solutions

Adoption of new energy technologies often face a range of technical and social challenges. Research on clean energy, and the production, storage, and consumption of clean energy have localized community impacts.

Communities thus play a key role in energy transitions, through uptake of new technologies and ways of engagement with energy[28]. Energy transitions and research can have positive impacts on local communities such as the creation of a skilled labor force, economic benefits from specializing in clean energy technologies, and the consumption of clean energy that might reduce localized emissions which can lead to improved air quality, etc. Yet, energy transitions often lead to unequal and unjust outcomes for underrepresented, low-income, and marginalized communities. Marginalized groups bear the brunt of multiple injustices, such as systematic exclusion from decision-making; loss of land to the production, transmission and storage of clean technologies; disproportionate exposure to environmental hazards; economic hardship; limited access to environmental resources; and heightened vulnerability to climate change driven by CO2 emissions [29]. Similarly, underrepresented, low-income, and minoritized communities have a long history of negative experiences with research and researchers who often approach such communities from a data extraction perspective rather than one that engages communities in a process of co-production. Hence, approaches to working with communities that are mindful of the ethical considerations of community engagement are necessary. Research justice is critical to successful community engagement in research and should be a part of the research process (see Appendix E: References for Supporting Community-Engaged Research). California research experience has underscored key lessons in the inclusion of communities in research partnerships around clean energy. Based on this input, we recommend the following actions to be considered for the design of community-engaged research requests for proposals:

- <u>Ensure early engagement of community groups in drafting requests for proposals</u>:
  a) establish criteria for including community groups in proposed clean energy projects,
  b) identify relevant evaluation metrics, and
  c) contribute to the assessment and evaluation of proposed research.
- Encourage researchers and community collaborators to <u>co-create research objectives and methods that are context-appropriate and community-centered.</u> For example, the Community Local Energy Action Program integrated community needs and inclusion at several stages of the research process, to ensure community needs were appropriately served by the project. In the CalDAC project, community groups are co-producing data and accountability metrics to determine project success and guide future activities.
- Require applicants <u>to include an explicit community engagement plan,</u> similar to Department of Energy “Community Benefits Plans,”[30] that includes:
  – Identification of all communities who will be affected and engaged through the research
  – A summary of the expected potential impacts on the communities and how these will be mitigated
  – A plan for how community members have been and will continue to be integrated into project conceptualization, the development of research questions, and throughout the implementation of the project, including ways in which feedback and communications will be solicited and adapted in the management strategies of the research project
  –Plans for continued engagement and its sustainability after the funded project ends
  –Potential for workforce development and educational opportunities in the community
- Encourage researchers to consider expanding ways of involving community collaborators in multiple capacities in clean energy projects. Advisory roles for community members are current practice, as with the California Climate Action Seed and Matching Awards. If appropriate, researchers should consider further whether community involvement can be more effective if community members are more actively involved in the research, <u>beyond advisory roles</u>. This also strengthens knowledge transfer among community members and researchers.

- Include funding dedicated specifically to community engagement efforts and make it a requirement that UC/National Lab led projects remunerate community collaborators for devoting personal and organizational time to a research project.
- Review criteria should include a separate section beyond technical merit devoted to the community engagement component of the project, including:
  a. Is there evidence of genuine and sustainable engagement with appropriate communities?
  b. Are there clear roles and responsibilities defined among investigators and community members to ensure effective and equitable collaboration, processes, and outcomes?
  c. Does the community engagement plan identify and address potential pitfalls and harm and the potential benefits to communities?
  d. Does the budget reflect genuine community engagement, such as equitable payments for community member time, resources, and contributions to the project?
- Offer a planning or seed grant mechanism for those scientific teams that have not yet developed genuine community engagement in their research program. The planning grant would enable teams to create authentic relationships with appropriate communities and integrate them into the foundational conceptualization and design of the project research questions, methods, approaches, and expected outcomes in ways that address community needs and avoid harm.

Partnerships and Training Opportunities

The CERCES workshops provided a much needed forum for Universities and National Labs to share and discuss relevant community-engaged clean energy projects and focus areas of expertise while also hearing first hand from a few key community collaborators about their experiences in pursuing University and National Lab partnered research projects. Moreover, we invited participation and perspectives from funders of CERCES work, the California Energy Commission and the Sloan Foundation.

These types of thematic forums are necessary to help catalyze future collaborations across the UC system and National Labs and prepare for future funding opportunities. At the time of writing, for example, we can point to the CERCES workshop series having led to an exploration to collaborate between the UC Berkeley agrivoltaics CER team (PI Timothy Bowles) and a team led by UC Merced (PI Sarah Kurtz). As well, we have been able to make introductions between the Berkeley led CalDAC project (PI Louise Bedworth) and LLNL led (PI Kim Mayfield and Minerva Uribe Robles) CER project with a community partner, Restore the Delta, that explores the Sacramento–San Joaquin River Delta as a potential site for carbon storage. We don't believe these connections would have been made without participation in the CERCES workshops.

By carefully curating workshop agendas to include a diverse range of relevant topics and technologies, and conducting targeted outreach to faculty, staff researchers, lab scientists, community collaborators, postdoctoral researchers, graduate student trainees, we successfully fostered broad interest and participation in these workshops. Additionally, we recognize the motivating power of potential funding in bringing these researchers together. While convening hybrid workshops can be technically challenging at times, it allowed for broader participation if it had been an in-person only event.

In addition to convening thematic and conferences, here are other ways we believe UCOP could help stimulate collaboration across UC campuses and National Labs

- Creation of Grand Challenge Projects: Launch multi-year funded flagship projects that address global challenges, and leverage complementary expertise across UC and National Lab teams.
- Talent Development and Exchange: create fellowships for graduate students, postdocs, faculty, to spend time at national labs, and vice versa.

- Creation of interdisciplinary research networks: Incentivize researchers to create research clusters around topical areas and challenges that are primed for federal, state and/or foundation funding.
- Proposal Development Sessions: Incorporate sessions to develop joint proposals for federal or state funding.
- Community Building and Recognition: Consider establishing awards for outstanding UC-National Lab research partnerships. Host annual showcases to highlight fruitful collaborations, share findings and encourage new partnerships. The UC Irvine hosted Born in California Demo Day is an example of a showcase that brings together some of the most promising startups from across the UC-system.

To ensure diverse participation in future UC system-wide and National Lab research programs and initiatives we recommend:

- Any future solicitations should explicitly encourage roles for graduate, graduate students, postdoctoral researchers, early career researchers, especially those from underrepresented groups.
- Establish leadership roles for early career faculty's participation.
- Require plans from application teams that address how early career faculty will benefit from their involvement in programs and initiatives.
- For community-engaged research focused projects, encourage and incentivize community collaborators to have a Senior Personnel take on roles in projects.

Leverage existing resources for undergraduate and graduate student internships opportunities such as University of California Livermore Collaboration Center (UCLCC).

Sustaining and Extending Partnerships beyond the Workshop

Sustaining partnerships beyond CERCES LFRP workshops

- Establish a small CERCES Coordination Committee, consisting of Planning Committee members, to meet regularly and discuss, for example, federal, state, and foundation funding opportunities relevant to CERCES LFRP workshop participants. Strategic communications with the broader group of workshop participants can be managed through a listserv.
- Identify multi-campus seed funding programs relevant to CERCES participants. Examples include CITRIS (UC Berkeley, UC Davis, UC Santa Cruz and UC Merced); UC Institute of Transportation Studies (UC Berkeley, UC Davis, UC Irvine and UCLA)
- Generate UC Systemwide/National Lab resources for community engaged research that are easily accessible in a central portal.
- Leverage the Climate Action Seed and Matching grants program; not only the awardees but those who submitted LOIs (non selected) and full proposals (unfunded). The teams who submitted Climate Action LOIs and full proposals represent a large portion of UC researchers devoted to climate action and climate resilience work. Consider forums (e.g. workshops and conferences) that would encourage these communities of researchers to come together.
- Consider opportunities for university researchers to participate more meaningfully in the National Lab LDRD funding program.
- Coordinate UCOP-funded on-site visits to national laboratories to explore their capabilities, shared facilities, and test beds. Highlighting the laboratories' capabilities during workshops proved highly beneficial, and in-person visits could further strengthen University-Lab partnerships.

Workshop Title: CERCES (Community-engaged Research for Clean Energy Solutions)
Host/Coordinating Institution: University of California Irvine
Workshop PI Name: Khargonekar, Pramod
Workshop Report Authors: Dressen, Tiff (UCB), Hapke, Holly (UCI), Kurtz, Sarah (UCM), Lee, Helen (UCI), Mayfield, Kim (LLNL), Peffer, Therese (UCB), Rodriguez, Dan (UCB), Taylor, Keith (UCD), Van Wijk, Jolante (LANL), Walker, Barbara (UCSB), Zenyuk, Iryna (UCI)

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Appendix A: Workshop Agendas

UC Berkeley October 24th workshop, please visit: https://vcresearch.berkeley.edu/about-us/research-advisory-groups-and-initiatives/cerces-2024
UC Irvine November 20/21 workshop, please visit: https://sites.research.uci.edu/uci-cerces/

Appendix B: Organizing Team, Invited Speakers, and Workshop Attendees

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Appendix C: Links to CER project presentation slides

Workshop #1 link: https://docs.google.com/presentation/d/1d4tG-20SFKXLz1T77smtHDOwjpc_2las/edit?usp=drive_link&ouid=117871264958829122596&rtpof=true&sd=true

Workshop #2 link: https://docs.google.com/presentation/d/1mucHAqsQd6Dr0Uuj2T4zsnENz0We9315/edit?usp=drive_link&ouid=117871264958829122596&rtpof=true&sd=true

Appendix D: Lessons learned from Bednarek paper

Lessons learned from *Angela Bednarek and Vivian Tseng* **"A Global Movement for Engaged Research"**

Definition and Vision of Engaged Research

Engaged research involves the active collaboration of researchers with policymakers, practitioners, and communities to produce and use knowledge that addresses real-world challenges. The approach aims to:

- Democratize the research process by incorporating diverse perspectives.
- Produce "socially robust knowledge" that is co-created, validated outside traditional academic settings, and directly applicable to societal needs.

Challenges of Traditional Research

The authors critique the conventional research enterprise for:

- Prioritizing academic outputs (e.g., publications, citations) over societal relevance.
- Misaligning academic incentives with the goals of engaged research.
- Lacking sustainable funding models and trained intermediaries for connecting research with policy and practice.

Systemic Barriers to Engaged Research

Barriers include:

- Academic reward systems that undervalue engaged research.
- Limited career pathways and funding for roles like boundary spanners, who mediate between researchers and stakeholders.
- A lack of structured frameworks for sustaining long-term research-practice partnerships.

Role of Philanthropic Organizations

Philanthropic funders play a pivotal role by:

- Encouraging research initiatives focused on societal challenges in areas like environment, education, public health, and international development.
- Breaking down systemic barriers by supporting partnerships and incentivizing engagement with policymakers and communities.

Transforming Evidence Funders Network (TEFN)

The TEFN, established in 2020, is a global coalition of over 30 funders working to promote engaged research. Its objectives include:

- Supporting effective grantmaking practices to encourage meaningful stakeholder participation.
- Building a coordinated evidence base for understanding how to improve the use of research in policy and practice.
- Developing infrastructure to sustain research-practice partnerships.
- Reshaping academic incentives to reward engaged research outputs.

Promising Practices and Initiatives

TEFN has identified practices critical for successful engaged research, such as:

- Allocating time and funding for stakeholder involvement in defining research questions.
- Building relationships and trust through regular engagement.
- Involving practitioners in review panels to ensure research relevance.
- Supporting the development of boundary-spanning roles and organizations.

Call to Action

The document concludes by urging funders, researchers, and institutions to adopt engaged research as a core strategy to address pressing global challenges, including climate change, pandemics, and inequities. This requires:

- Structural changes in academia to support and reward engaged research.
- Collaboration among governments, civil society, and academia to co-produce actionable knowledge.

Conclusion

Engaged research offers a pathway to make science more inclusive, impactful, and responsive to societal needs. Through collaborative efforts, the research community can better address "wicked problems" of the 21st century.

Appendix E: Research justice definition

Research justice is a framework that communities and researchers use to confront structural inequities in research, transform exclusionary research paradigms and practices, and broaden participation in research to make research processes and products more inclusive, equitable, and just[31]. With respect to energy and energy transition research, energy justice has emerged as a new social science-informed approach that seeks to apply justice principles to energy policy, energy production and systems, energy consumption, energy activism, energy security and climate change[32]. Energy justice scholars emphasize the need to integrate energy justice into public engagement practices[33], which include the importance of prioritizing community needs, respecting diverse expertise, building trust, designing for transparency and accountability, flexibility, and aiming for long-term collaboration[34]. For more information on Research Justice, please visit the Research Justice Shop at UC Irvine

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