



**CALIFORNIA
ENERGY COMMISSION**



California Energy Commission

COMMISSION REPORT

Electric Program Investment Charge 2022 Annual Report

Gavin Newsom, Governor
April 2023 | CEC-500-2023-012-CMF

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PREFACE

The California Energy Commission's (CEC) Energy Research and Development Division supports energy research and development programs to spur innovation in energy efficiency, renewable energy, energy-related environmental protection, energy transmission and distribution, and transportation.

In 2012, the California Public Utilities Commission (CPUC) established the Electric Program Investment Charge (EPIC) to fund public investments in research to create and advance new energy solutions, foster regional innovation, and bring ideas from the lab to the marketplace. The CPUC selected the CEC and the state's three largest investor-owned electric utilities — Pacific Gas and Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company — to administer the EPIC funds and advance novel technologies, tools, and strategies that provide benefits to electric ratepayers.

The CEC awards EPIC research funds to projects that promote greater reliability, lower costs, increase safety for the California electric ratepayer, reduce greenhouse gas emissions and other pollutants, and spur economic development, among other program objectives.

For more information about the Energy Research and Development Division, please visit the CEC's website at <https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program>.

ABSTRACT

The California Energy Commission (CEC) is the state's primary energy policy and planning agency. As part of its overall mission, the CEC administers several clean energy research and development programs that drive innovation and advance science and technology in energy efficiency, renewable energy, energy-related environmental protection, energy transmission and distribution, and transportation. The CEC is one of the administrators of the state's Electric Program Investment Charge (EPIC). In administering EPIC, the CEC funds research, development, and demonstrations of clean energy technologies and approaches that will benefit electricity ratepayers of California's three largest investor-owned electric utilities and lead to technological advancement and breakthroughs to overcome the barriers that prevent the achievement of the state's statutory energy goals. For information on specific projects, visit the [Energize Innovation Showcase](https://www.energizeinnovation.fund/projects) at <https://www.energizeinnovation.fund/projects>.

This report outlines the progress and status of CEC activities funded by EPIC from January 1, 2022, through December 31, 2022. The report was prepared in accordance with applicable California Public Utilities Commission decisions and California Public Resources Code Section 25711.5.

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CHAPTER 1:

2022 in Review: A Year of Bold Climate Action

Fellow Californians,

2022 was a truly historic year for the clean energy future we are all trying to build together. During a day last spring, for the first time in state history, 100 percent of California's electricity demand was met by clean, carbon-free sources. At the federal level, President Joe Biden signed into law the Inflation Reduction Act, the most significant climate legislation in our nation's history, which provides a decade of tax credits for wind, solar, geothermal, electric vehicles, energy storage, electric heat pump technology, and more. With these incentives and the federal infrastructure law, we are now seeing the massive infusion of public dollars needed to bring these technologies mainstream.

Here in California, Governor Gavin Newsom signed a suite of bold climate laws in September, including Assembly Bill 1279, which requires carbon neutrality in California by 2045. The state's unprecedented climate budget over the past two years — nearly \$50 billion — will support clean energy research and deployment in areas such as direct air carbon capture, clean hydrogen, more efficient food production, industrial decarbonization, and load flexibility.

However, last year also highlighted the climate and energy challenges we face in California and globally. Extreme weather exacerbated by climate change continued to challenge our state's electricity infrastructure. Last September's heat storm resulted in the highest peak electricity demand, straining the capacity of the grid. On December 20, an earthquake along the North Coast was a stark reminder of how vital our energy infrastructure is in providing shelter and safety. Abroad, the ongoing war in Ukraine impacted global supply chains and underscored the strategic imperative of reducing our reliance on imported fossil fuels and increasing production of domestic clean energy.

Throughout all this, the Electric Program Investment Charge (EPIC) has provided a ray of light and hope by continuing to enable California to be a garden bed for new clean energy technology solutions that will help us reach our goals faster and at a lower cost. I would like to thank our colleagues at the California Public Utilities Commission for voting to extend the EPIC program for another decade. Since its inception in 2012, EPIC has invested \$1.125 billion toward the state's clean energy economy, providing validation for early-stage technologies that are often deemed too risky for private investment. Companies in the program's portfolio have gone on to raise more than \$10.5 billion in private investments and have commercialized more than 70 technologies.

And the rest of the world is taking notice. Technologies and companies profiled in this year's EPIC annual report are drawing broad attention, even earning places among *Time Magazine's* "Top 200 Inventions of 2022." EPIC initiatives are providing replicable models for federal and international agencies, and EPIC investments are making real-world impacts, driving clean energy progress, and even saving lives.

EPIC remains more critical than ever in bringing cutting-edge clean energy solutions to the market and setting an example of successful public-private partnership. While much work and

increasingly difficult challenges remain, programs like EPIC that harness the innovative spirit of Californians are continuing to chart the path forward for all.

Spotlight: Blue Lake Rancheria

On December 20, 2022, a 6.4 magnitude earthquake shook the North Coast in Humboldt County, severely damaging homes, businesses, and local infrastructure. Residents reported nearly 70,000 outages in the immediate aftermath across the region – an area that includes tribal lands and has seen underinvestment. Fortunately, a microgrid funded by EPIC in 2017 at the Blue Lake Rancheria Casino was able to island itself from the grid nearly instantaneously, maintain power, and serve an estimated 20,000 people. Residents were able to refuel gasoline vehicles and charge electric vehicles with the power available, and the microgrid is credited with saving four lives with emergency medical equipment. This is the third major event since its construction where the microgrid has provided critical services following an extreme event or natural disaster.

Sincerely,



David Hochschild
Chair

California Energy Commission

CHAPTER 2:

Accelerating the Clean Energy Transition With EPIC

Continued energy innovation will play a key role in ensuring California benefits from clean, affordable, safe, and reliable energy — propelling the state as the world’s fourth largest economy while advancing leading-edge climate change solutions.

Since its outset in 2012, EPIC has funded 474 project awards, encumbering about \$1.125 billion. Of that, EPIC has invested more than:

- \$236 million toward the clean energy Entrepreneurial Ecosystem, leveraging, aligning, and expanding California’s existing assets to build a more interconnected and inclusive statewide ecosystem and helping bring innovations to market.
- \$195 million for resiliency and safety, helping equip communities, businesses, and implementers of public services with the tools and technologies to provide critical resources during emergencies.
- \$249 million for building decarbonization, helping improve the energy performance, health, affordability, and comfort of homes and businesses across the state.
- \$223 million for grid decarbonization and decentralization, integrating and optimizing renewable energy for a cleaner electrical infrastructure.
- \$119 million for industrial and agricultural innovation, supporting California’s agricultural and industrial producers in achieving improved energy performance and greater energy cost savings.
- \$86 million for zero-emission transportation, enhancing the benefits of electric vehicle ownership for drivers and the grid while lowering costs.

EPIC investments have delivered tremendous and diverse benefits for Californians, including:

\$10.5 BILLION → Private investment raised by businesses after receiving EPIC support.

70+ → EPIC-funded technologies and related services successfully commercialized and now available to California customers.

1,300+ → Subsequent deployments that resulted from 48 EPIC-funded demonstration projects.

21% → Employment growth experienced by small- and medium-sized businesses following an EPIC award.

EPIC in Focus:

Unlocking World-Class Testing Facilities for California Innovators

The CalTestBed Initiative is a voucher program offering California’s clean energy entrepreneurs access to world-class testing facilities. CalTestBed is a unique opportunity to mitigate the complicated and often financially burdensome agreements needed for such testing, making it an exceedingly valuable opportunity for California's innovators and expediting their path to commercialization.

Since 2018, the network, which spans the nine University of California campuses and Lawrence Berkeley National Lab, has grown from the initial 28 testing facilities to 73 across the state.

As of 2022, CalTestBed had awarded 40 vouchers, and counting. Those recipients have since **created more than 243 jobs** and secured more than **\$295 million in follow-on funding**.

“That really established our bona fides. [CalTestBed] provides a conduit to capital and the global marketplace. A few months after we entered the program, a venture capital firm invested \$10 million in our company.”

Paul Donahue, NeWorld CEO and CalTestBed voucher recipient

Furthermore, EPIC advanced an inclusive clean energy economy with:

70% OF TECH DEMONSTRATION AND DEPLOYMENT FUNDS → Invested in underresourced communities — double the statutory requirement.¹

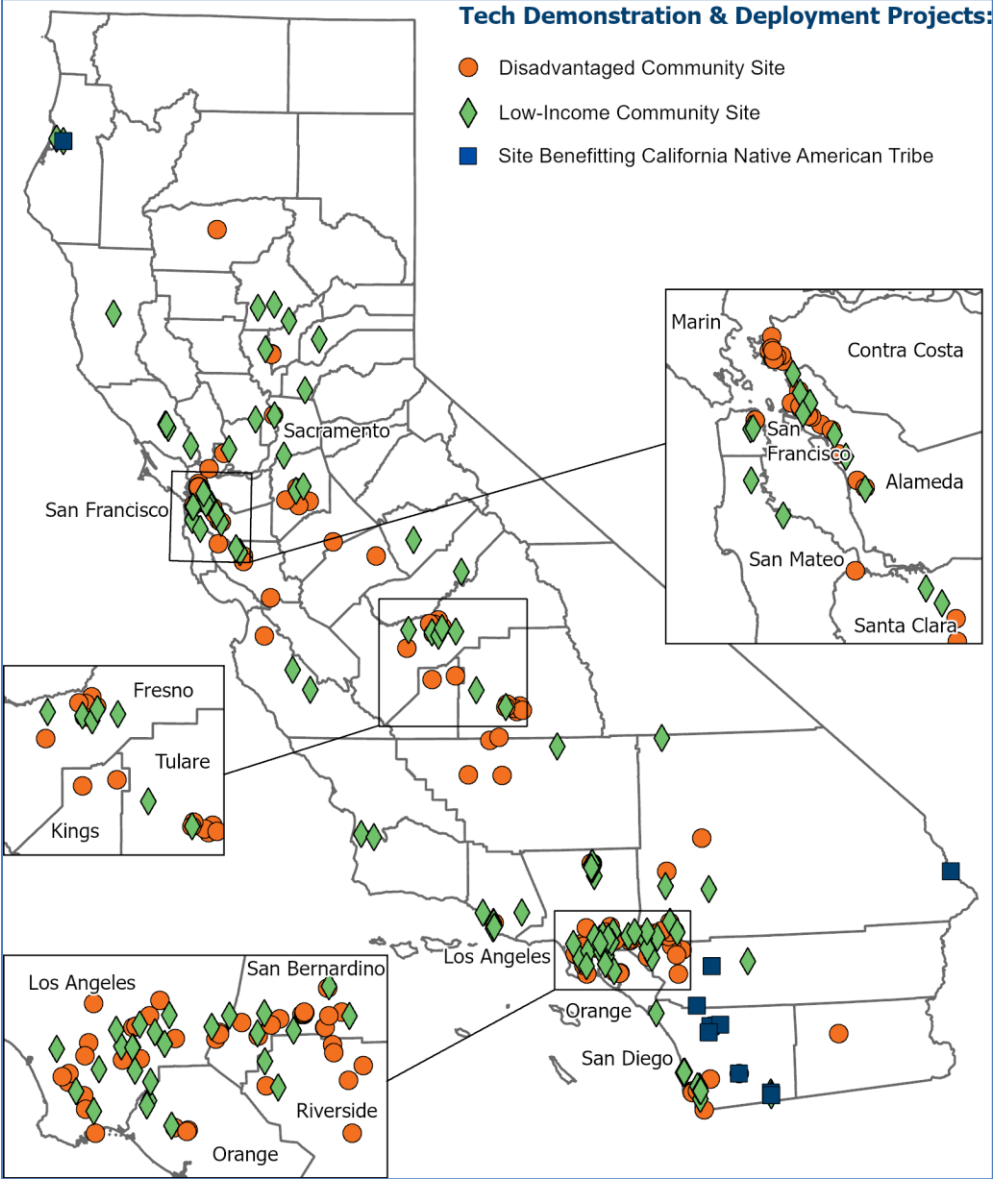
\$22 MILLION OF TECH DEMONSTRATION AND DEPLOYMENT FUNDS → Invested in projects benefitting California Native American tribes.

Projects such as those spearheaded by ZNE Alliance in Richmond to develop a scalable virtual power plant model and the Electric Power Research Institute to demonstrate a cost-competitive residential zero net energy community design in Fresno have helped center underresourced communities in energy innovation.

The CEC is committed to ensuring all Californians benefit from clean energy research. Consistent with legislation including Assembly Bill (AB) 523 (Reyes, Chapter 551, Statutes of 2017) and California Public Utilities Commission (CPUC) guidance, the CEC has prioritized energy equity in its research programs to ensure that underresourced communities benefit from emerging clean energy technologies and solutions. Projects located in, and benefiting, low-income communities, disadvantaged communities, and California Native American tribes can be seen in Figure 1.

¹ Including projects in disadvantaged communities and low-income communities, as defined by Assembly Bill 523.

Figure 1: EPIC Demonstration Projects in Underresourced Communities



Credit: California Energy Commission

CHAPTER 3:

2022 EPIC Features

Increasing Resilience and Reliability Amid a Changing Climate

Climate change continues to drive extreme weather events in the West, with an increased frequency and severity of heat waves and wildfires. The variability in weather patterns and increase in weather-related disasters have, in turn, challenged grid reliability. In August 2020, a west-wide heat wave resulted in rotating power outages with 1,000 megawatts (MW) of electricity that had to be taken out of service. In 2021, an Oregon wildfire impacted transmission lines that California relies on for electricity, resulting in a loss of 3,000 MW of overall import capacity to the state. Extreme weather again challenged the grid in 2022 when record-high temperatures resulted in a new record peak load at 52,061 MW — nearly 2,000 MW higher than the previous record. The CEC, through EPIC and other initiatives, is taking a multipronged approach to increase reliability and resiliency of the electric system. Within EPIC this approach includes:

- Developing **emerging, nonlithium long-duration energy storage** technologies that can deliver anywhere from 8 hours to several days of duration at a cost significantly less than lithium-ion batteries. Notable investments include Eos, Form Energy, and Antora Energy.
- Demonstrating technologies that can **unlock new load flexibility from buildings and electric vehicles** to respond to grid conditions, including enabling the use of electric vehicles as clean back-up power during outages. Notable investments include OhmConnect, Nuvve, and the CalFlexHub initiative at Lawrence Berkeley National Lab.
- Funding **first-of-their-kind microgrids** that power critical services during outages. Notable projects include BoxPower, Fremont Fire Station Microgrid, and Marine Corps Air Station Miramar.
- Advancing **climate science and tools** to better predict and respond to extreme weather events impacting the electricity sector. Notable projects in this space include Climformatics, CalAdapt, and Pyregence.

The Miramar Microgrid: Supporting Our Military and Our Grid

"MCAS Miramar is proud of the base's work to become a military leader in energy resilience readiness. Our success with the state's Emergency Load Reduction Program was made possible by connections fostered through the CEC, Naval Facilities Engineering Command Southwest, and the CPUC. We hope this can serve as a model for bases here and abroad."

— Colonel Thomas Bedell, Commanding Officer, MCAS Miramar

Microgrids have become a frontline resiliency resource in California as climate change increasingly challenges the electricity system. A microgrid demonstration project at Marine Corps Air Station (MCAS) Miramar, funded in part through the EPIC program, is producing real-world reliability benefits to the state's electric grid while advancing technologies that support national security.

Miramar's microgrid was conceived in 2011 in partnership with the U.S. Department of Energy's (DOE) National Renewable Energy Lab to meet power requirements for the base's critical missions as part of a U.S. Department of Defense (DOD) Energy Resilience Readiness Exercise and first became operational in 2020. With follow-on funding from EPIC, the microgrid will incorporate lithium-ion battery energy storage and advanced demand-response controls. These components will enable more reliable integration of intermittent electricity generated nearby from renewable municipal landfill gas captured from methane emissions that otherwise would have been flared. When the CEC-funded battery system is fully integrated, the MCAS microgrid will be able to island for an increased amount of time, with an improved ramp-up rate and greater reliability to serve the base and the state's grid.

This capability proved a valuable resource to the grid during the heat waves in September 2022 and especially on September 6, when California recorded its highest ever peak demand on the electric grid of 52 gigawatts (GW). The ability of the microgrid to island in seconds allowed Miramar to shed 6 MW of load from the state's electric system during peak hours. Over 10 days, disconnecting at critical times, the Miramar microgrid was able to provide load flexibility and support grid stability.

The Miramar microgrid has become a reliable partner to the state in shedding load from the grid during high peak demand events, demonstrating that microgrid projects such as these can benefit both grid reliability and resiliency for the base itself. The success of the microgrid has led to further interest throughout the DOD in replicating the model at different military bases, both in the United States and internationally.

By the Numbers

16: The number of times Miramar's microgrid supported the grid during demand response events since coming on-line in 2020.

10+: The number of full, base-wide island events coming from black start or full-base outage tests since its debut.

6MW: Amount of grid capacity relief Miramar can deliver in a single demand response event.

Figure 2: Generation at MCAS Miramar



Caption: A United States Marine walks by solar panels at MCAS Miramar

Credit: U.S. Marine Corps

Pyregence: Preventing Wildfires Through Big Data

*"We came together around a common vision and cause and are now providing groundbreaking models and tools that are changing the way we plan for and mitigate natural disasters."
— David Saah, PhD –Managing Principal at Spatial Informatics Group on EPIC-funded Pyregence*

With an uptick in the frequency and intensity of wildfires in California in the past decade, EPIC's investment in Pyregence is helping the state combat climate disasters while modernizing, democratizing, and accelerating wildfire science and climate change research.

Pyregence emerged directly from an EPIC call to action following the devastating Tubbs Fire in 2017 and Camp Fire in 2018. The CEC recognized a gap in available wildfire science data that impacted the ability of utilities and state emergency services to respond effectively to wildfires both in real time and in long-term planning. EPIC's \$5 million grant helped create a consortium of leading scientists across the nation from government, academia, and the private sector.

Pyregence's multidisciplinary approach has created a new paradigm for how best to plan for wildfires. The consortium has developed new software tools — including the wildfire forecasting tool **PyreCast** and climate change projection modeler **PyreClimate** — that use the most current analytical models and climate change data to deliver more granular results that improve the timeliness and accuracy of estimates.

Following the group's launch in 2020, Pyregence has since generated data for a wide range of California stakeholders, including utility companies, the California Independent System Operator (California ISO), California Department of Forestry and Fire Protection (CAL FIRE), local land-use planners, and insurance companies. Its models are also contributing to new science findings in California's *Fifth Climate Change Assessment*.

Pyregence is entirely open source, enabling any member of the public to use its tools, download the source code, and submit feedback or data to improve the analyses. This approach has supported tool usage globally and exemplifies how California's public dollars can catalyze teams and benefits extending far beyond its borders.

By the Numbers

4 million: The number of acres burned in California in 2020.

7 days: Number of days that can be forecasted out for active fires compared to industry standard of 4 days.

4x/day: The frequency of updates to the PyreCast 5-day fire weather forecast, providing hourly meteorological inputs and fuel moisture content values necessary to drive real-time fire risk forecasts.

20,000+: The number of PyreCast users during fire season since its launch.

50: Active team members across the United States.

\$0: Cost to users, including fire risk managers, utility companies, and concerned residents, to access information on wildfire risks.

Figure 3: 2021 California Monument Fire



Credit: USDA

Building a Circular Economy for Next-Generation Battery Technologies

Battery storage is vital to realizing the state’s clean energy policy goals, with as much as 50 GW of additions anticipated by 2045 to meet the goals of SB 100. Lithium-ion batteries make up the vast majority of energy storage systems in California and are expected to remain the dominant energy storage technology going forward. However, current lithium-ion batteries have safety and supply chain concerns that could slow the deployment of electric vehicles and stationary energy storage. Furthermore, despite significant cost decreases over the past decade, the price of lithium-ion batteries remains out of reach for many customers without incentives. To ensure electric ratepayers and customers have access to safe and affordable battery storage, the CEC has **invested more than \$57 million** in EPIC funding across the entire battery value chain, including:

- Technologies that can enable cost-competitive and locally beneficial **lithium recovery from geothermal brine** located in the Salton Sea. Notable investments include projects with SRI International, BHER Minerals, and Controlled Thermal Resources.
- **Advanced battery components and manufacturing** that can solve a range of technical challenges and lead to safer and cheaper battery storage. Notable investments include Sepion Technologies, Cuberg, Sparkz, and South 8 Technologies.

- Technologies that can **repurpose used electric vehicle batteries** into stationary energy storage systems at a cost much lower than that of systems using new lithium-ion batteries. Notable investments include RePurpose, ReJoule, and Smartville.
- Projects to advance the technology readiness, commercial scale-up pathways, and environmental benefits of **high-value, direct recycling processes for lithium-ion batteries**. Notable investments include UC San Diego and OnTo Technology.

South 8 Technologies:

Increasing the Safety and Affordability of Lithium-Ion Batteries

"We knew it wouldn't be easy to get off the ground, and our technology needed immense derisking when we started. EPIC funding was crucial in getting our development through that early stage."

— *Cyrus Rustomji, South 8 Founder*

Lithium-ion batteries are ubiquitous, powering devices ranging from personal cell phones to grid-scale energy storage. However, when damaged or subjected to extreme temperatures, these battery types can experience thermal runaway events that lead to fires. South 8 Technologies, a San Diego-based diverse small business, has developed a novel, nontoxic liquefied gas electrolyte called LiGas® to replace the conventional liquid electrolytes that are the catalyst for thermal runaway.

Because LiGas® becomes gaseous at room temperature, it safely and quickly vents from a damaged battery cell before a thermal runaway event can occur. In addition, batteries using this novel electrolyte can operate across a wider range of temperatures without safety concerns or a decrease in battery performance. LiGas® can also be adapted into existing lithium-ion battery manufacturing processes and facilities — significantly reducing the time and cost for this technology to be incorporated into new lithium-ion battery products.

South 8 credits the Energy Commission's Entrepreneurial Ecosystem² for helping it overcome the common barriers and challenges start-up companies face in bringing new clean energy innovations to market. Beginning with an initial California Sustainable Energy Entrepreneur Development Initiative (CalSEED) grant back in 2015, South 8 has received CEC funding and support at key stages of its technology's development and company's growth and is now getting ready for commercial deployment. With a recent \$3.125 million grant awarded by the U.S. DOE's Advanced Research Projects Agency-Energy (ARPA-E) to participate in its American Low-Carbon Living (EVs4ALL) program, South 8 plans to develop and evaluate high-power, rapid-charge Li-ion battery cells using its LiGas® electrolyte over the next three years in collaboration with a global automotive manufacturer. By year end, it expects to increase the size of its team from 23 to 33.

² The CEC's Entrepreneurial Ecosystem is a set of EPIC-funded initiatives that provide funding and support services to clean energy entrepreneurs in California.

By the Numbers

30%: Anticipated reduction in battery costs using the LiGas® electrolyte.

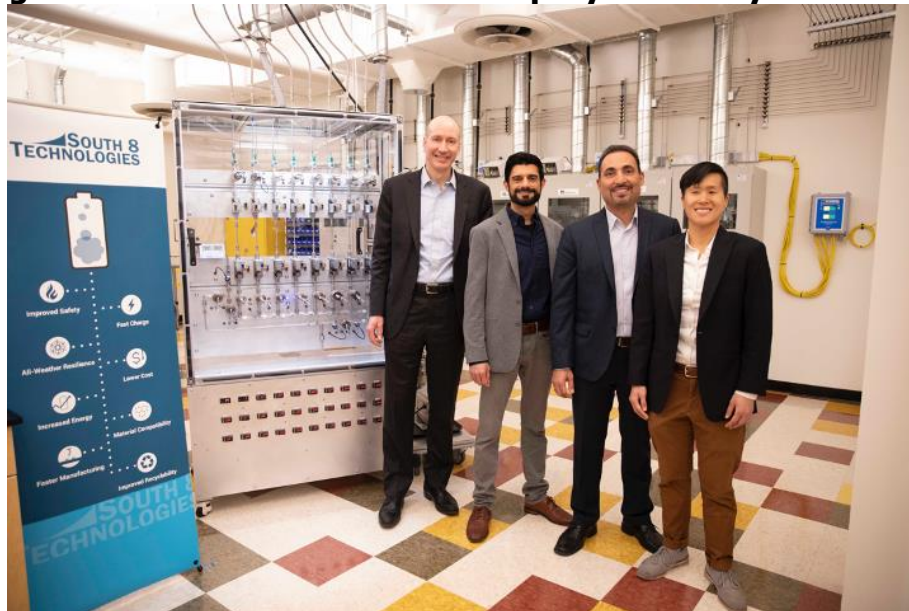
15 Minutes: Average fast-charge time goal for a South 8 battery in a light-duty vehicle.

-20 to 60 degrees Celsius: The safe temperature range for lithium-ion batteries using traditional electrolytes.

-60 to 60 degrees Celsius: The safe temperature range for lithium-ion batteries with LiGas®.

35%: Increase in lithium-ion battery energy density with LiGas®.

Figure 4: South 8 and U.S. DOE Deputy Secretary David Turk



Caption: Deputy Secretary of the U.S. Department of Energy David Turk, Cofounder and Chief Executive Officer Cyrus Rustomji, Chief Commercial Officer Hamid Sayadi and Cofounder and Chief Technology Officer Jungwoo Lee after recently being selected for a \$3.1 million award from the Advanced Research Projects Agency – Energy

Credit: South 8 Technologies

Smartville, Inc.:

Giving EV Batteries a Second Life Powering California

"This project is filling a very important kind of hole in the mosaic for California to achieve its clean energy goals. Reusing EV batteries for energy storage is exactly what the state needs."

— David Hochschild, Chair, California Energy Commission

With more EVs on the road, there is a concern over how to manage the rapidly growing stock of used EV batteries. Thankfully, California researchers are developing solutions. Smartville Inc., spun out of a UC San Diego lab, has a plan to repurpose these batteries and help with energy needs beyond transportation.

Smartville works with repurposed Tesla and Nissan Leaf batteries to provide an energy storage system that delivers building resiliency and load-shifting services for commercial buildings with

critical 24/7 power needs. Its prototype battery energy storage system, called MOAB™ (Modular Assembly Battery), addresses many of the challenges of repurposing EV batteries for grid storage, including battery imbalances of used lithium-ion batteries and low-cost integration of batteries with several form factors and electrical and thermal characteristics.

Smartville's research at UC San Diego was initially funded in 2018 by ARPA-E. Since spinning out its company, Smartville has seen support from CalSEED and CalTestBed and received two EPIC awards that have helped it develop and scale the technology, explore prospective customer bases, and develop plans for expansion.

In March 2023, Smartville was also awarded \$5.9 million from the U.S. DOE to scale the development of its MOAB™ energy storage systems — a grant that EPIC will also support by providing cost share funding. Smartville will use the new funds to get MOAB™ UL-certified as a second-life EV battery pack energy storage system and to fund a 4-megawatt-hour (MWh) demonstration project in Central California that is collocated with an existing power plant operated by a California independent power producer in an underresourced community. The battery pack energy storage system should help in improving local air quality in an area that has seen historically high levels of air pollution.

By the Numbers

15,000 MW: Amount of storage capacity that needs to come on-line in California by 2032.

100 MWh: Manufacturing production capacity planned by 2025, a 10x scale-up.

48+: Hours of back-up power in pilot test at the University of California, San Diego.

4 MWh: Total planned capacity at Wellhead Electric, a San Joaquin Peaker Plant.

Figure 5: Smartville MOAB™ Energy Storage System



Caption: Smartville MOAB™ Energy Storage System, powered by repurposed EV battery packs and charged by a UC San Diego solar energy array

Credit: *The San Diego Union-Tribune*

Enabling the Electrification of Everything

Electrification is a key strategy for meeting the state’s carbon neutrality goals and improving local air quality. Electrifying energy uses currently served by fossil fuels also has the potential to bring additional flexible load onto the grid — enabling increased integration of renewable electricity. But while the state is poised to see significant growth in electrification, barriers remain. Existing electric options are unable to provide the high thermal requirements needed for many industrial processes, while renters and residents of existing and multifamily homes may not be able to adopt electric appliances or vehicles because of the need for panel upgrades or other barriers. As the state electrifies more of its overall energy sector, new technology solutions will be needed to reduce overall and peak electricity demand. Electricity consumption for cooling is expected to increase over the coming decades as warming temperatures drive increased demand for air conditioning and refrigeration. To enable wide-scale electrification, EPIC invested more than \$17 million in 2022 in projects to drive building decarbonization and has supported a broad set of technology solutions, including:

- Technologies **such as novel electric heat pump designs** that can overcome customer barriers to electrification, particularly in multifamily and low-income buildings. Notable investments include Gradient, Neocharge, and the Sonoma Advanced Energy Center.
- **Solid-state cooling technologies** that avoid energy-intensive vapor compression systems or global-warming refrigerants. Notable investments include SkyCool Technologies and General Engineering and Research.
- Technologies to electrify **industrial processes** including electrochemical catalysts and advanced membranes to replace thermal processes using fossil fuels. Notable investments include Twelve, Porifera, and Skyven Technologies, Inc.
- **Transparent, lightweight, and flexible solar PV technologies** that can be embedded into windows, EV roofs, and building façades to reduce electricity demand from increased electrification. Notable investments include Next Generation Technologies, Ubiquitous Energy, and Swift Solar.

Gradient:

Making Building Electrification Accessible for All

"We are reimagining the HVAC industry by building products that keep homes comfortable and healthy for the people who inhabit them without compromising the environment."

— Vince Romanin, Gradient cofounder and CEO.

Multifamily units, low-income households, and renters have historically had few technology options for their heating and cooling needs, having to largely rely on inefficient cooling systems and gas wall furnaces. Gradient’s window heat pump technology provides a much-needed space heating and cooling solution for these important customer groups. Gradient uses R-32, a refrigerant with a significantly lower global warming potential than others in the industry, and a design that sits below the window, allowing unimpeded light and airflow. The technology is shelf-ready and can be installed and removed without the assistance of a contractor or specialized tools, allowing renters to take the product with them when they move.

As it did for South 8 Technologies and Smartville, the CEC's Entrepreneurial Ecosystem has played a critical role in Gradient's technology development, product commercialization, and company growth. Gradient's CEO, Vince Romanin, entered the Cyclotron Road program³ in 2017 with an idea to reimagine an industry that had previously seen little innovation. Following the Cyclotron Road program, Gradient went on to receive two Energy Commission EPIC awards to improve the heating performance of its heat pump system for colder climates and establish its initial manufacturing line in California.

Since coming to market with its product, Gradient's trajectory has been meteoric. In August 2022, Gradient was named one of two winners of New York State's Clean Heat for All Challenge and awarded a contract to manufacture and supply 10,000 units for public housing in New York City. Gradient has also received national media recognition, including from *Time Magazine*, which named the technology one of the Top 200 Inventions of 2022.⁴

By the Numbers

4 billion: Anticipated number of AC units worldwide by 2050.

95%: Reduction in greenhouse gas emissions in single-family and multifamily units when Gradient is used to both cool and heat.

\$5,000: Savings on installation costs for a Gradient heat pump (\$0) compared to conventional technology.

30–60 minutes: Average amount of time it takes a customer to install a Gradient heat pump in their residence.

33% and 70%: Increase in efficiency provided by Gradient's modular heat pump for cooling and heating, respectively.

3 Cyclotron Road is a two-year fellowship program supporting technology and entrepreneurship development located at Lawrence Berkeley National Lab and co-funded by EPIC.

4 Mock, Jillian. November 10, 2022. "[Breaking the AC-Climate Change Doom Loop: Gradient Heat Pump AC Window Unit.](https://time.com/collection/best-inventions-2022/6224874/gradient/)" *Time*, <https://time.com/collection/best-inventions-2022/6224874/gradient/>.

Figure 6: Gradient



Caption: Gradient fits below the window sill, allowing a better view than traditional in-window AC units.

Credit: Gradient

Twelve: Electrifying Chemical Manufacturing

"Twelve's solution uses renewable electricity to convert CO₂ emissions into high-value products. Our system can operate at a steady state, or it can ramp from 0 to 100% capacity in seconds to operate only during periods when load is needed. We are creating the foundation for a new value chain based on recycled CO₂, rather than on fossil fuels."

— Etosha Cave, co-founder and Chief Scientific Officer, Twelve

The chemical manufacturing sector is critical to the economy, supplying many of products consumers use in their everyday lives, including plastics, cleaning supplies, and fuels.

This sector is also one of the most challenging to decarbonize, as it relies on fossil fuels for feedstock and the process heat to manufacture these products. Twelve (formerly Opus 12) is a chemical company that uses carbon dioxide (CO₂), water, and renewable electricity to produce the building blocks for a wide array of chemical products, from apparel to jet fuel.

Twelve's electrochemical reactor — a membrane electrode assembly (MEA) — is designed to be fully integrated into existing industrial processes, allowing a more seamless deployment into supply chains. Twelve's system can enable industrial facilities to quickly ramp up production capacity to take advantage of low-cost renewable overgeneration that is currently curtailed, reducing costs to the industrial producer.

The technology behind Twelve was developed by Dr. Etosha Cave and Dr. Kendra Kuhl at the Jaramillo Group at Stanford University. They cofounded their company in 2012 along with fellow Stanford graduate Nicholas Flanders. EPIC funding has supported the company at key stages of the development and growth, initially through CalSEED and more recently through the CalTestBed program. Twelve was also awarded a RAMP^{POB} (Realizing Accelerated Manufacturing and Production for Clean Energy Technologies) award in 2021 to build out the initial manufacturing line for its MEA technology in Berkeley, California. Since receiving the RAMP award, Twelve has received more than \$180 million in private investment and is currently working with major manufacturers and the military to produce a wide range of low-carbon industrial products — spanning car parts, detergent, sunglasses, and a jet fuel alternative.

By the Numbers

365: Number of days of renewable curtailment in California in 2022. Chemical manufacturer customers can take advantage of affordable renewable overgeneration with Twelve's technology.

50%: The share of industrial emissions that can be reduced by replacing fossil feedstocks through Twelve's technology.

5+: The number of major corporations who have officially partnered with Twelve, including Shopify, Alaska Airlines, and Microsoft.

275: Number of people Twelve plans to employ by the end of 2023, growing from four people in 2016 at the time of its CalSEED award.

Figure 7: Etosha Crave and Twelve's Reactor



Caption: Etosha Crave, cofounder and chief scientific officer of Twelve, holding the company's reactor.

Credit: Twelve

CHAPTER 4:

Looking Ahead: EPIC Opportunities in 2023

The CEC's statutory mission for EPIC is to fund projects that benefit electric ratepayers and lead to technological advancements and breakthroughs for achieving the state's statutory energy policy goals. The state's world-leading energy policy goals — including 100 percent renewable and zero-carbon electricity by 2045 — provide not only a vision of the future energy sector, but also guidance and direction for future EPIC investments. In 2023, the CEC will continue to invest EPIC funding in new and emerging science and technology topics that enable California to realize its goals at a lower cost and on an accelerated timeline. Priority investments planned for 2023 include:

- Developing and demonstrating **advanced prefabricated zero-carbon homes** that can be quickly and affordably deployed in underresourced communities.
- Developing new designs for **floating offshore wind mooring lines and anchors** and **environmental monitoring technologies** that are critical for successful offshore wind development off the coast of California.
- Advancing methods to improve the **valuation of investments in grid resilience** to weather-related events and outages, including in underresourced communities.
- Demonstrating new technology advancements in **emerging nonlithium long-duration energy storage** and associated benefits in underresourced communities.
- Supporting the state's clean energy entrepreneurs through the next round of cohorts for **CalSEED, CalTestBed, and RAMP**.
- Conducting objective analysis to inform the **roll out of renewable hydrogen in California** and the intersection of renewable hydrogen with the electricity sector.
- Continuing to build out California's circular battery economy and increase supply chain security by scaling up **novel lithium-ion battery recycling and reuse processes**.
- Developing a new generation of **efficient, high-power electronic devices** that can enable EVs across all market sectors to better serve customer and grid needs.
- Improving the energy efficiency and cost-competitiveness of electric technology options for **decarbonizing the industrial sector**, including concrete manufacturing.

For information on current and completed EPIC projects, visit the Energize Innovation Showcase at <https://www.energizeinnovation.fund/projects>.

GLOSSARY

Term	Definition
AB	Assembly Bill
ARPA-E	Advanced Research Projects Agency-Energy – a United States Department of Energy Program advancing high-impact energy technologies by providing funding, technical assistance, and market readiness
CAL FIRE	California Department of Forestry and Fire Protection
California ISO	California Independent System Operator
CaISEED	California Sustainable Energy Entrepreneur Development Initiative
CARB	California Air Resources Board
CEC	California Energy Commission
CO ₂	Carbon dioxide
CPUC	California Public Utilities Commission
Disadvantaged community	A community that scores at or above 75 percent in the version of CalEnviroScreen that was available at the time of project application.
EPIC	Electric Program Investment Charge
GW	Gigawatt
MW	Megawatt
RAMP	Realizing Accelerated Manufacturing and Production for Clean Energy Technologies
SB	Senate Bill
TDD	Technology deployment and demonstration
USDOD	United States Department of Defense
USDOE	United States Department of Energy

APPENDICES

The following appendices are available as a separate volume (Publication Number CEC-500-2023-012-APA-B-CMF):

- Appendix A: CEC EPIC Reporting Requirements and Budget Information for Calendar Year 2022
- Appendix B: CEC EPIC Projects Awarded through 2022 with Fiscal and Diversity Details