



Energy Innovation

California's energy sector has changed dramatically over the past decade as the state moves to reduce greenhouse gas emissions and advance other clean energy goals. In that short time, the state has seen improvement in almost every metric used to measure progress towards transforming its energy sector and building a clean energy economy. Much of this progress can be attributed to the various policy instruments California's leaders have adopted to accelerate development and adoption of clean energy technologies. "Market pull" policies such as the California Solar Initiative have helped create the necessary market signals for clean energy while "technology push" policies such as the Energy Commission's energy research and development programs have helped push new technology solutions into the market.

To achieve California's ambitious energy policy goals and avoid the most serious impacts of climate change, innovations in clean energy technologies and strategies are needed to help bring existing and new low greenhouse gas technologies to market, lower costs, and encourage widespread adoption. The Energy Commission, through the Electric Program Investment Charge (EPIC) and Natural Gas Research and Development program provides approximately \$162 million annually to accelerate new scientific and technology solutions that will help bring a cleaner, safer, more affordable and more resilient energy system to California.¹

Building a Safe and Resilient Energy System

An aging infrastructure and a changing climate threaten the safety and resiliency of California's energy systems. Climate change impacts have led to significant increases in the frequency, size, and destructiveness of wildfires, while leaks in the natural gas infrastructure have created major safety and environmental concerns. To address these and other challenges, the Energy Commission is supporting new scientific and technological advancements to equip California's stakeholders with the solutions they need to build a safe and resilient energy system.

Operationalizing Climate Science into Energy Planning Decisions

California is a long-recognized leader in supporting science that defines how climate change can impact regional planning, energy use and infrastructure, and public health. However, until recently, there was no readily accessible tool to find and translate the complex results of these scientific studies into easily understandable and actionable information.

In 2011, a team at UC Berkeley launched the Cal-Adapt web tool to synthesize decades of historical data, like average temperature, snowpack and rainfall, with climate projections to see the impacts of climate change in a region.² Cal-Adapt allows users to aggregate high-resolution

¹ The Energy Commission is one of four administrators of the EPIC program – along with Pacific Gas and Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company. The Energy Commission administers 80 percent of the EPIC funding, investing in the areas of applied research and development, technology demonstration and deployment, and market facilitation.

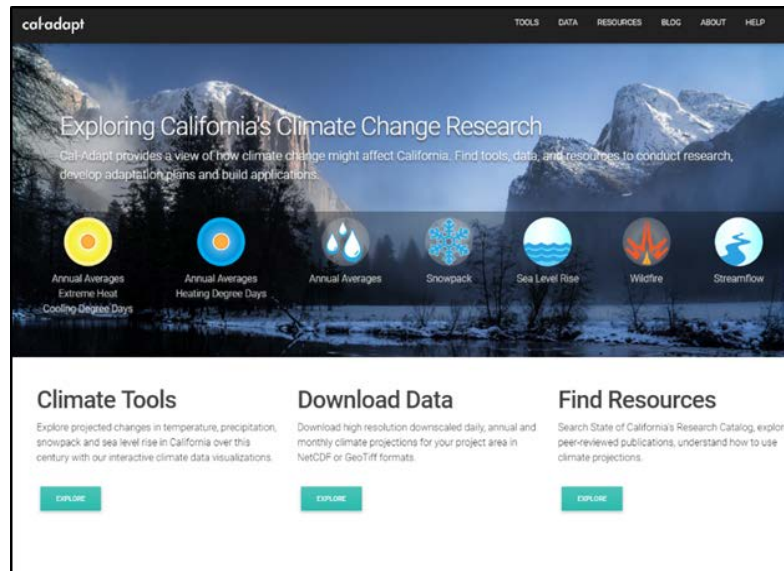
² The Cal-Adapt tool is available at <https://cal-adapt.org/>



climate information by census tract, watershed, climate zones, congressional district, utility service territories, counties, and more. Further, users can upload customized boundary files to allow closer investigation on Cal-Adapt of areas that are specific to a particular user.

Users can now go to the Cal-Adapt website and input the conditions and time frames they are interested in to easily generate images and graphs that can support their planning efforts. **(Figure 1.)**

Figure 1: Cal-Adapt Website Screenshot



Source: Cal-Adapt.org

Cal-Adapt exists because of Energy Commission funding and its continued support to develop enhancements that make it even more useful to key user groups. Cal-Adapt has been adopted as an integral tool by State agencies, including the Governor's Office and California Natural Resources Agency, to decipher and mitigate climate impacts at the local level for practitioners ranging from local planners to utilities. Cal-Adapt has also been adopted by the Office of Planning and Research and included in the 2017 General Plan Guidelines as a tool to help cities and counties examine potential climate impacts in their communities.³

Utilities are using Cal-Adapt to identify parts of the energy system that are at the greatest risk to climate impacts, like many more days of extreme heat in a particular area, and how those impacts will affect energy demand and the life and operation of equipment. In 2017, San Diego Gas and Electric (SDG&E) described how it is using Cal-Adapt for initiatives to support resilient infrastructure, including revisions to SDG&E's Design Standards and to explore climate change implications of system hardening projects.⁴

Cal-Adapt is an evolving tool with new functionality added regularly. In 2017, Cal-Adapt 2.0 was released which dramatically expanded the capabilities of the initial tool including adding new climate projections, enhanced visualizations, and improved access to data. Cal-Adapt will continue to be updated and enhanced as new data and research become available.

³ Governor's Office of Planning and Research, 2017 General Plan Guidelines http://opr.ca.gov/docs/OPR_COMPLETE_7.31.17.pdf .

⁴ https://cal-adapt.org/blog/media/gif-opr-energy-sector-workshops/wilhelm_energy_sector_examples_091217.pdf.



Maintaining Critical Operations and Services during Grid Outages, Extreme Weather Events

Wildfires and other natural disasters have highlighted the need for new technology solutions capable of maintaining power to critical operations and services during electric grid outages. Critical facilities – such as hospitals and emergency response shelters – as well as first responders, have traditionally relied on back-up diesel generators to maintain power. Microgrids are one tool that allows for continued operation in the face of a grid outage, utilizing on-site renewable generation and energy storage, and offering a clean source of back-up power. Other tools may include establishing resilient zones that would remain energized in the event of utility de-energization or deploying mobile battery energy systems to power command centers in an emergency.⁵

Widespread deployment of microgrids, however, has been limited by several factors. Microgrids require sophisticated control systems that must respond accurately and quickly during a grid outage. Furthermore, because microgrids are new solutions, much of the technological advancements needed to reduce costs and overcome challenges involved with designing, installing, and operating these systems -- and supporting their replication -- are still in their infancy. For more information, see the Tracking Progress report titled [EnergyStorage](#).

Since 2015, the Energy Commission's R&D program has awarded 19 projects to deploy and demonstrate microgrids across a variety of use-cases. Once such project is a grant to Blue Lake Rancheria – a federally recognized tribal government and community – to install and demonstrate a campus microgrid capable of providing power to the local American Red Cross evacuation center in Humboldt County.⁶ **(Figure 2)** Humboldt County is a

natural disaster-prone region of California with a majority of power generation assets in the coastal tsunami zone and constrained transmission from the greater California electric grid. There are only two major electrical connections to the larger electric grid, and the electric transmission capacity that connects Humboldt County to the larger grid is approximately 70

Figure 2: Blue Lake Rancheria Microgrid



Credit: Blue Lake Rancheria

⁵ Additional topics on climate adaptation and resiliency were discussed at a joint agency workshop held on August 2, 2018. More information can be found at https://www.energy.ca.gov/2018_energy/policy/documents/#08022018.

⁶ More information about the project can be found at <http://innovation.energy.ca.gov/SearchResultProject.aspx?p=30077&tks=636676049561995664>.



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megawatts (MW), less than half of the County's 170 MW peak electrical demand. Additionally, natural gas enters the county through a single pipeline from the larger natural gas grid and petroleum-based transportation fuels are primarily imported to the county by barge.⁷

These constraints make energy resiliency a serious concern to the local community, and planning efforts have emphasized the need to expand sources of longer-term backup energy generation at critical facilities.

Shortly after being installed, the microgrid was put to the test. On October 8, 2017, a wildfire started about a quarter mile from the Blue Lake Rancheria campus. This caused the power to go out from 4:37 p.m. until 5:55 p.m., leaving approximately 1,900 customers without power. The microgrid detected the outage, automatically isolated itself from the statewide grid, and prevented blackout. At 5:55 p.m. the microgrid automatically reconnected to the grid when grid power was restored. This was all done as part of the standard operation of the microgrid. Meanwhile the Rancheria was being used as an emergency response and staging center for the fire crews. The outage went unnoticed by the Rancheria until the operational logs were reviewed, demonstrating how a microgrid can provide seamless operation to a facility in an emergency.

The microgrid has provided benefits beyond reliable backup power. Blue Lake Rancheria has been able to reduce its electricity costs by 25 percent and carbon footprint by 158 metric tons carbon dioxide equivalent (CO₂e) in 2017. In addition, the microgrid has increased tribal employment by 10 percent while also bringing national attention to the Blue Lake Rancheria community, receiving the Federal Emergency Management Agency's 2017 Whole Community Preparedness Award and POWERGRID's International Project of the Year (2018) award for Distributed Energy Resource Integration, marking the first time that a non-utility has won the award. The successful deployment and demonstration of this research project illustrates the vast potential to increase the resiliency of the electric grid.

Addressing Vulnerabilities in the Natural Gas Infrastructure

Damage to natural gas pipelines caused by digging, grading, trenching, and boring is one of the main challenges to safe pipeline operations. The U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration reported that excavation damage is the root cause of about 26 percent of gas transmission and distribution pipeline serious incidents and approximately 50 percent of these were caused by third-party excavators.⁸ One-call centers are established by pipeline infrastructure owners and operators to coordinate with third party excavators to ensure that excavation is performed safely and prevents damage to underground

⁷ RePower Humboldt A Strategic Plan for Renewable Energy Security and Prosperity
http://www.schatzlab.org/docs/RePower_Humboldt_Strategic_Plan.pdf.

⁸ <https://www.phmsa.dot.gov/data-and-statistics/pipeline/national-pipeline-performance-measures>



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facilities. However, these existing practices do not mitigate all incidents as many accidents result from failure to follow these existing notification practices prior to digging.

In 2016, the Energy Commission awarded funding to the Gas Technology Institute to develop a platform solution that provides real-time visibility and notification to utilities and heavy-equipment operators when construction work is being conducted near natural gas pipelines.⁹ The Global Positioning System (GPS) Excavation Encroachment Notification System integrates a small hardware unit installed on the excavation equipment with geospatial tools and custom-developed algorithms and machine learning capabilities that together provide a rich visual display on excavator status and location in relation to the natural gas pipelines. This provides excavator operators with much better situation awareness regarding the location of underground pipelines so that they can better avoid accidentally hitting them while digging. (**Figure 3.**)

As part of the Energy Commission funded project, Gas Technology Institute developed, installed, and tested the hardware device on 150 excavation equipment units owned by Pacific Gas & Electric, the Southern California Gas Company, and third-party excavation contractors. The device and dashboard are integrated with the utilities' geographic information system network. Such implementation provided high-accuracy GPS location of excavation equipment, which can overlay the utility's geographic information system map services, one-call boundaries, or custom geo-fences around the pipeline right of way. It also displayed real-time indications of the activities of the geospatially-located excavators and sent instant alerts in the form of sound and light signals in the device, plus graphical and text message alerts to the utility's operators. The system was validated by matching actual field observations against the excavators predicted activities of idle, digging, and driving which were about 87 percent, 80 percent, and 85 percent accurate, respectively. In deploying these technologies, the initial goal is to reduce

Figure 3: GPS Device on Excavator and Utility Monitoring Dashboard



Credit: Gas Technology Institute

⁹ Final Report available at: <http://www.energy.ca.gov/2018publications/CEC-500-2018-014/CEC-500-2018-014.pdf>



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about 12 percent of the non-fatal and non-injury incidents in California that are caused by first- and second-party excavators and save an estimated \$1,564,500 annually.

Further deployment of the technology to third-party contractors in areas where gas pipeline systems exist, is anticipated in the following few years through the commercialization of the technology. Such deployment will target a 43 percent reduction of non-fatal and non-injury excavation incidents that are caused by excavators, backhoes, and trenchers. More savings can be achieved if the telecommunication, electrical, water, and agriculture industries adapt the excavation safety technology to their application.

Improving the Affordability, Health, and Comfort of California's Communities

Energy plays a critical role in the affordability, health, and comfort of California's residential customers and the communities they live in. However, rising energy costs burden low income communities disproportionately since residents in these communities typically spend a larger share of their income on energy than other households. Increasing the capacity for communities to generate local renewable energy reduces the need for fossil fuel generation and helps reduce greenhouse gas emissions. Similarly, advances in energy efficiency technologies can not only save residents' money, but can also increase the comfort of homes by more efficiently controlling heating and cooling. (For more information, see the Tracking Progress reports on [Renewable Energy](#) and [Energy Efficiency](#).)

Empowering Action at the Local Levels

The role of communities in transforming California's energy sector is becoming increasingly important. Local governments have several policies for driving greater deployment of clean energy technologies in their jurisdictions. However, in 2008 the idea of a community taking control of its energy needs using local renewable resources was still a novel concept and few local jurisdictions were willing or able to dedicate limited staff and budgetary resources to such as risky undertaking. Because of this, few case studies and lessons learned existed to guide local governments interested in pursuing clean energy projects. Rural communities in particular lacked the tools, expertise, and capacity needed to develop and implement a feasible energy procurement strategy. The Energy Commission launched the Renewable Energy Secure Communities (RESCO) program to address issues with the deployment and integration of renewable energy at the community scale. RESCO projects focused on technical solutions that enable communities to rely primarily on locally-available renewable resources to provide electricity at competitive rates. This increased reliance on indigenous renewable resources minimizes vulnerability to interruptions and emergencies affecting imported energy, thereby increasing local grid security. The Energy Commission awarded 13 RESCO projects, one of which was to Humboldt County which, as discussed above, faces geographic isolation and constrained transmission of electricity and natural gas.

In 2009 the Energy Commission awarded funding to The Redwood Coast Energy Authority to pilot a planning process for developing Humboldt County's local renewable energy resources. The project developed a comprehensive strategic plan which included an assessment of

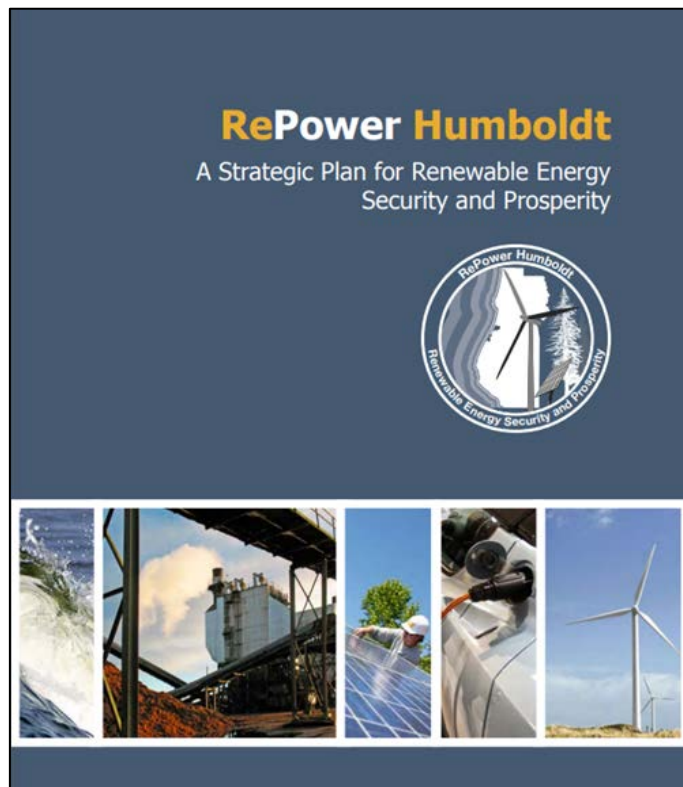


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resource and technology options and an economic analysis that considered costs as well as job and economic stimulus opportunities. The study concluded that Humboldt County’s goal of meeting 75 percent or more of its electricity needs and a large portion of its heating and transportation energy demand is feasible and would require using a mixed portfolio of local renewable energy resources. (Figure 4.)¹⁰

Since the project completed, Humboldt County and many of its cities have enacted the plan to pursue further local clean energy projects including installing microgrids at the Blue Lake Rancheria campus, as discussed above, and Arcata airport and establishing a Community Choice Energy program that allows customers to purchase up to 100 percent renewable energy. Within the community choice service territory, 688 customers have elected to purchase the 100 percent renewable energy power option, including the City of Arcata and the City of Blue Lake which have switched all their city facilities and operations requiring electricity to this 100 percent renewable energy program. Throughout the pilot process, the Redwood Coast Energy Authority documented the lessons learned and incorporated them into a tool for other rural communities to use.

Figure 4: Cover of Humboldt County Strategic Plan



Source: Schatz Energy Research Center

Bringing New Clean Energy Technology Solutions and Their Benefits to Disadvantaged and Low-Income Communities

Housing affordability is a top concern for residents in California’s disadvantaged and low-income communities. Housing and energy costs can account for more than 50 percent and 16 percent of their income, respectively. To reduce their living expenses, residents of these communities need affordable housing that does not sacrifice energy efficiency. However, affordable housing developers must typically adhere to smaller, tighter budgets which limits their ability to install higher energy-efficient appliances. Effectively sealing the home’s envelope – including the roofs,

¹⁰ The full study is available at: <http://www.schatzlab.org/projects/policyanalysis/repower.html>.



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walls, and floors – can go a long way towards improving the energy efficiency and comfort of a home without the need for more expensive, efficient HVAC appliances. Sealing the envelope, a process typically involving caulk, spray foam, weather stripping or other materials can be difficult, labor-intensive, and not always effective.

In 2012, the Energy Commission awarded funding to the UC Davis Western Cooling Efficiency Center to further develop a portable automated process for sealing gaps and tightening a building's envelope.¹¹ Now called AeroBarrier, the system sprays a cloud of waterborne acrylic sealant droplets into a pressurized room. The pressure forces air to escape through leaks, and the sticky particles follow the air flow to the leaks, where the particles are flung from the airstream due to their inertia, coagulating around a leak until they seal it. A computer controls the temperature, pressure, humidity, and distribution of the sealant, and technicians are able to monitor the progress in real time. In less than three hours, a two-person team was able to reduce the air leakage of a 2,200 square-foot, three-bedroom house by an additional 68 percent over what was accomplished by traditional sealing methods that required more than 20 hours of labor. Tests showed that AeroBarrier can seal holes as tiny as a human hair and as large as a half inch across, and tests show it can reduce leakage by up to 90 percent in new buildings.

The process is GREENGUARD Gold certified, meaning it meets or exceeds low emissions standards for volatile organic compounds in indoor spaces. AeroBarrier was awarded the 2018 Most Innovative Building Product and Best in Show by the National Association of Homebuilders' in January 2018. It has been called the decade's most disruptive energy efficiency product.¹²

Successful early demonstrations of AeroBarrier in California homes proved its effectiveness and drew the attention of home builders and designers. AeroBarrier hit the commercial market in January 2018, after five years of research and development supported by the Energy Commission's Public Interest Energy Research Program and the Department of Energy's Building America program. During this period, AeroBarrier was tested in new and retrofit single family and multifamily buildings, including homes built by Habitat for Humanity and retrofits to improve multifamily buildings in disadvantaged communities. Most recently, AeroBarrier was used in new homes built by Beazer in Sacramento.

Creating New Opportunities for Residential Energy Savings

The California Title 24 Building Energy Efficiency Standards are designed to ensure new and existing buildings achieve energy efficiency while preserving indoor environmental quality. Since 1978, energy efficiency standards have made buildings more comfortable, lowered energy costs and reduced greenhouse gas emissions. Standards ensure that builders use the most energy efficient technologies and construction. California's Appliance Efficiency Regulations were

11 More information available at https://wcec.ucdavis.edu/wp-content/uploads/2013/01/WCEC_Case-Study-AeroSeal_2010-10.pdf.

12 The 2018 Most Innovative Building Product Goes to AeroBarrier, <https://www.prnewswire.com/news-releases/the-2018-most-innovative-building-product-goes-to-aerobarrier-300581832.html>.



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established in 1976 and are updated periodically to allow consideration and possible incorporation of new energy efficiency technologies and methods.

The Energy Commission's energy efficiency research program invests funds to promote efficiency technologies and strategies. The research provides the data and testing needed to inform updates of the Building and Appliance Energy Efficiency Standards. Between 2005 and 2015, 18 research agreements were directly responsible for or contributed to 15 changes to energy efficiency codes. The research contributed to energy efficiency standards for televisions, external power supplies, battery chargers, computers and monitors, and commercial lighting. Research also contributed to energy code changes in residential roofing materials that reduce the cooling load of homes; heating, ventilation, and cooling system improvements; and residential hot water pipe insulation.

The Energy Commission invested about \$28 million in building and appliance efficiency research that contributed to these efficiency standards and code changes which are estimated to have saved ratepayers an estimated \$12.1 billion in savings between 2005 and 2025.^{13,14} This amount consists of energy savings minus compliance costs. More than 90 percent of the energy savings during this period will accrue to electricity ratepayers.

Supporting California's Local Economies and Businesses

California is the fifth largest economy in the world and the energy sector is a vital contributor to providing the necessary goods, products, and services that have helped achieve that status. Furthermore, the global, national, and regional markets for clean energy are creating new economic opportunities for California's technology companies and entrepreneurs. To help maintain California's global competitiveness and assert our leadership to promote low carbon opportunities, the Energy Commission is supporting California's businesses in their efforts to develop and adopt the next-generation of clean energy technology solutions.

Building a Statewide Energy Innovation Ecosystem to Support Clean Energy Entrepreneurship

Entrepreneurs are the seeds of innovation. In 2016, the Energy Commission launched the California Energy Innovation Ecosystem to create a statewide network of technology incubators, investors, universities, non-profits and corporate partners to foster and support clean energy entrepreneurship across the state.

13 Sotero, Maria. 2013. Public Interest Energy Research 2012 Annual Report. California Energy Commission, Energy Research and Development Division. Publication Number: CEC-500-2013-013-CMF p. 12.
<http://www.energy.ca.gov/2013publications/CEC-500-2013-013/CEC-500-2013-013-CMF.pdf>.

14 <http://www.energy.ca.gov/2016publications/CEC-400-2016-026/CEC-400-2016-026-FS.pdf>.



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The Innovation Ecosystem is comprised of four regional innovation clusters responsible for recruiting promising start-up companies that focus on energy technologies.¹⁵ The cluster connects these start-up companies to a suite of free services and resources, such as access to laboratory equipment and facilities, business plan development, connections to investors and industry stakeholders, and guidance on protecting intellectual property. Such guidance helps clean energy entrepreneurship focus limited time and resources on the most critical activities for developing their technology and business.

The Innovation Ecosystem also includes the California Sustainable Entrepreneur Development Initiative or CalSEED.¹⁶ CalSEED provides a recurring opportunity for entrepreneurs to apply for up to \$150,000 in seed funding to move their invention through the proof-of-concept stage. Entrepreneurs selected for CalSEED also receive technical consulting and are eligible to compete in a business plan competition for additional funding to move from proof-of-concept to prototype development. Through these two stages, CalSEED helps clean energy entrepreneurs demonstrate the early technical merits and commercial potential of their technology.

To date 109 start-up companies have received funding and entrepreneurial assistance from the Ecosystem. These companies have attracted \$28 million in private investment, and \$6 million in public funding. In addition, the organizations that make-up the Ecosystem have been able to use their Energy Commission funding to attract \$3 million in federal funding to expand the services they provide to entrepreneurs within the state. The program is intended to grow innovation seeds to mature technological advancements that will become fully adopted in the energy marketplace, fostering economic growth of businesses and advancing California's clean energy market.

Developing Scalable Technology Solutions for the Industrial and Agricultural Sectors

California is America's top wine producing state, making 90 percent of all wine in the country and employing more than 300,000 people in the state with a \$61 billion annual economic impact. A key part of winemaking involves removing tartrates, tiny crystals that form when tartaric acid and potassium bind together. To remove tartrates, producers have traditionally used an energy-intensive and time-consuming process called cold stabilization.

A new process developed in Europe eliminates costly refrigeration by removing tartrates through electrodialysis via a process called the Selective Tartrate Removal System (STARS). Winesecrets™ created a mobile STARS unit with a \$309,000 grant from the Energy Commission. The STARS unit was demonstrated in California wineries to document the costs and benefits and the effects of the technology on wine quality. Winesecrets showed winemakers how the product would more than pay for itself by saving wineries energy, water, and business expenses, while preserving wine quality.

¹⁵ The four regions and cluster programs are: Bay Area (<http://www.cyclotronroad.org/>), Central Valley (<http://bluetechvalley.org/>), Los Angeles (<http://www.energize-ca.org/>), and San Diego (<http://cleantechsandiego.org/sdrein/>).

¹⁶ More information at <http://calseed.fund/>.



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Winesecrets estimates the process uses up to 95 percent less electricity than the traditional cold stabilization process. Natural gas is also saved because there's no need to warm wine back up for bottle labeling. Winemakers are saving money by eliminating the weeks-long cold stabilization process and operational costs.

In the decade since the Energy Commission funded the demonstrations, Winesecrets has deployed the STARS system to more than 60 wineries in California's Central Valley, Central Coast, and North Coast, including vintners Fetzer and and Domaine Chandon. The technology has also been deployed to about 20 wineries outside California. As of 2016, more than 17 million gallons of wine was processed annually using STARS in California with the potential to increase to 21 million gallons in the near future.¹⁷ California wine makers using the Winesecrets system are estimated to have saved about \$6.5 million through 2015 in reduced energy and water costs.¹⁸

Energy Commission funding was critical to obtaining these benefits. According to co-founder and co-owner of Winesecrets, Domingo Rodriguez, "We came out of nothing with support from the [Energy Commission] and have rolled out in a major development with utility companies across North America." Energy Commission funding was needed because, "private funds were not enough to fund prolonged start-up of business to sell electro dialysis. Without the matching grant we would not have been able to establish the business."¹⁹

Advancing Energy Efficiency Solutions in Commercial Buildings

Lighting constitutes one third of California's commercial electricity use, costing commercial operators more than \$5 billion a year. Much of this electricity is wasted when occasionally occupied areas such as hallways remain brightly lit all day, or when areas with multiple light sources, such as offices, provide more light than occupants require. Professor Charlie Huizenga, from the UC Berkeley Center for the Built Environment, recognized that lighting electricity use could be greatly reduced in existing buildings by making entire lighting networks respond intelligently to occupancy and light sensors. Because the electrical rewiring was often a cost barrier, Huizenga introduced a novel strategy of installing low-cost controllers in each fixture that used wireless communications to "break the connection between how lighting is wired for power and how it is controlled."²⁰ After testing four prototypes, Professor Huizenga competed for and received a \$75,000 Energy Commission grant in 2004. The grant funded development of a wireless lighting control network and allowed Professor Huizenga to patent

17 Staff estimates from Draft *The Public Interest Energy Research Program Report: Electricity Funding and Accomplishments 1997-2015*.

18 Ibid.

19 Mirviss, Lillian. 2014. Public Interest Energy Research 2013 Annual Report. California Energy Commission, Energy Research and Development Division. Publication Number: CEC-500-2014-035-CMF. p. 52 <http://www.energy.ca.gov/2014publications/CEC-500-2014-035/CEC-500-2014-035-CMF.pdf>.

20 Huizenga, as cited in: "Lighting It Up, Efficiently." University blog. *University of California Research: Explore Stories*, November 4, 2011. <http://research.universityofcalifornia.edu/stories/2011/11/adura.html>.



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the technology.²¹ Building on the successful results of this small grant, Professor Huizenga and two graduate business students formed Adura to market the technology.

The successful demonstration of the technology allowed Adura to secure more than \$25 million in venture capital to scale-up the technology. In 2013, Adura was purchased by Acuity Brands Lighting, Incorporated, which now sells the product nationwide as Adura® XPoint™ Wireless. The Xpoint™ lets customers configure lights to respond optimally to daylight and other lights, occupancy cues, user schedules, and/or demand response agreements to save energy and money during peak periods. By summer 2014, Adura/Acuity wireless controllers were installed in 9 million square feet of California building space, saving Californians more than 17 million kilowatt hours (kWh) a year and an estimated \$1.3 million a year above product and installation costs.²²

Since Adura's XPoint Wireless was developed and introduced to the market, other major lighting companies focused on networked lighting controls. One of them was Enlighted, started by one of the Adura's co-founders. Enlighted launched a lighting-as-a-service-program for networked smart lighting which allows customers to install lighting upgrades with lower upfront costs and pay for operation of the lighting system through a subscription service. In February 2016, Enlighted reported more than 100 million square-feet of installations in U.S. Fortune 500 companies, including Google, AT&T, and HP.²³ In April 2016, Enlighted announced the addition of Bluetooth 4.x radio to its Intelligent Lighting Control sensors, adding capability for Bluetooth beacons for location-specific communications and color tuning.²⁴

Enabling a More Decarbonized and Decentralized Electric Grid

California's energy and climate change policies envision a significantly more decarbonized and decentralized electric grid than the one that developed a century ago. Increasing deployment of renewable energy generation will lead this transformation, but widespread use of renewables requires innovations in a host of other technologies to enable its integration into the legacy transmission and distribution infrastructure. Advancements in storage and grid management

21 Queen, Robert. San Diego State University Research Foundation. 2011. Energy Innovations Small Grant Program: 2003 Independent Assessment Reports. California Energy Commission. Publication number: CEC-500-2012-004. <http://www.energy.ca.gov/2012publications/CEC-500-2012-004/CEC-500-2012-004.pdf>. Pages 114-121.

22 All estimates are in real 2014 dollars and assume an 8.06 percent discount rate, a two percent inflation rate, and a conservative ten-year product lifetime. Product values come from kWh saved (14 cents per kWh in 2014, 16.4 cents per kWh in 2020, and intermediate values). Maintenance and peak savings follow the proportions volunteered in the Energy Technology Assistance Program (ETAP) study described below, with peak reduction valued at the capacity residual value of \$118 per square foot. Product costs come from early ETAP and from an example given by a manufacturer's sales representative in 2014, with interpolated costs between 2011 and 2014, and 2014 costs staying constant through 2020.

23 Enlighted. February 29, 2016. IoT Leader Secures \$25 Million in Equity Financing to Expand Software Solutions. <http://www.enlightedinc.com/iot-leader-secures-25-million-in-equity-financing-to-expand-software-solutions/>.

24 Enlighted. April 25, 2016. Enlighted Extends Leadership with Release of Fourth Generation of Intelligent Sensors. Press release. <http://www.enlightedinc.com/enlighted-extends-leadership-with-release-of-fourth-generation-of-intelligent-sensors/>.



technologies will allow greater proliferation of renewables onto the grid, while innovations that help reduce costs will provide economic incentives for investments in renewable generation technologies.

Addressing Product Gaps in the Energy Storage Market

The rapid growth of renewable energy sources like photovoltaic solar and wind generation is driving the need for cost-effective energy storage to capture energy during periods of peak generation, so it can be used during peak demand. Lithium ion batteries are a market leader in storage technology, driven largely by the growth of the consumer electronics and electric vehicle market. Also, there is a growing market for deploying lithium ion batteries that were used in electric vehicles for “second life” applications on the grid.

Flow batteries are one alternative to lithium ion that have the potential to address the large-scale storage needs of the grid. Flow batteries are designed to convert the chemical energy of two electrolytes, often separated by a membrane, to electricity. The use of these electrolytic fluids allows the battery to be discharged and recharged rapidly by changing the direction of flow of the liquids. In comparison to lithium ion batteries, flow batteries have no loss of performance over time or with extensive cycling of the battery. As a result, they can be sized for long-term use and do not need to be oversized, like lithium ion, to ensure the battery meets performance requirements throughout its life. Flow batteries also have very little ongoing maintenance and do not suffer from fire safety issues as do lithium ion. Although, some electrolytic fluids can pose environmental or human health concerns, lithium ion technology also poses similar environmental and human health risks.

Primus Power recognized the value of flow batteries for these applications and with a \$95,000 grant from the Energy Commission in 2006, successfully tested the feasibility of a novel flow battery based on zinc-chlorine chemistry, which is non-toxic and environmentally safe.²⁵ The Primus Power test demonstrated improved performance, longer storage time, and reduced maintenance costs compared to typical lithium-ion batteries. For example, for the same size system operating under similar circumstances, Primus Power flow

Figure 5: Primus Power Flow Battery Installed at Marine Corps Air Station Miramar



Credit: Primus Power

25 Sotero, Maria. 2013. Public Interest Energy Research 2012 Annual Report. California Energy Commission, Energy Research and Development Division. Publication Number: CEC-500-2013-XXX. pp.73-74. http://www.energy.ca.gov/business_meetings/2013_packets/2013-03-20/2013_03_20_Item_3_PIER_Annual_Report.pdf.



batteries can last five hours, while a lithium ion battery lasts two hours. They can operate in a wider operating temperature band and because the Primus system has eliminated life-limiting components, the ongoing maintenance is even lower than other flow batteries. As a result, Primus Power secured substantial private equity financing from Chrysalix Energy Venture Capital. In November 2009, Primus Power received a \$14 million award from the US Department of Energy as part of an overall \$47 million project to commercialize, deploy and monitor a 25 MW energy storage system as part of the Department of Energy's Smart Grid Demonstration Program. Since then, Primus has been awarded contracts for its energy storage technology with the Marine Corps Air Station Miramar and the Rialto Resilient Clean Power Microgrid – both in the EPIC program. (**Figure 5.**) Primus Power has experienced tremendous growth and seen global interest in its products. It now has a workforce of 50 employees, holds 34 patents and has 26 additional patents pending.

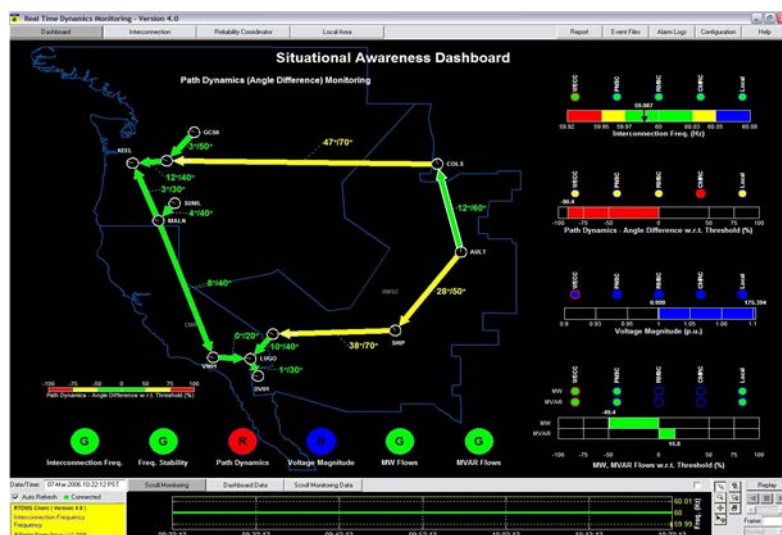
For more information on these and other energy storage technologies and how they can be used to help advance California's clean energy goals, see the Tracking Progress report titled [Energy Storage](#).

Using Big Data to Improve Grid Operations

Increasing amounts of energy from renewables is comprised of variable and unpredictable photovoltaic (PV) and wind generation. (For more information, see the Tracking Progress page titled, [Resource Flexibility](#).) Transmission and distribution circuits and substations were not designed to handle these unpredictable sources, which can lead to grid outages if not properly monitored and controlled. Grid operators and engineers did not have the monitoring technology needed to enable them to take corrective actions before potential problems developed.

Traditional monitoring uses information from the System Control and Data Acquisition (SCADA) system which takes time. It is too slow to keep up with the rapidly changing dynamics from using variable renewable electricity generation. Synchrophasors (synchronized phasor measurements) complement existing SCADA systems by providing the high sub-second resolution while continuing to use existing SCADA infrastructure for local monitoring and control.

Figure 6: Situational Awareness Dashboard Used By California Independent System Operator



Credit: Consortium for Electric Reliability Technology Solutions



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Synchrophasors are a method of electrical wave measurements for voltage and current, (they measure phase angles) taken at the exact same time at two or more places on the grid. They are fast acting and can be used by grid operators to take action rapidly in a changing grid system. Synchrophasors directly measure the system instead of estimating it. As measurements are reported 20-60 times per second, synchrophasors can track grid dynamics in real time. Synchrophasor systems now provide a tool for power system operation by providing real-time, accurate, time-stamped measurements from across the system. Using synchrophasors, the time frame of information has been reduced from minutes, to microseconds.

Time synchronization is not a new concept or a new application in power systems. However, it was not until the 1990s that advancements in computer processing and the availability of GPS signals made the development of synchrophasors practical. Since 1998, the Energy Commission has been funding research to develop and demonstrate applications for synchrophasor technologies. These applications have sharply decreased the risk of a major customer power outage. Initial research developed and applied a synchrophasor-based software platform to make grid status measurements faster and more precise. That platform is used by the California Independent System Operator to visualize system operation information in real time. A collaboration, led by Southern California Edison, used synchrophasor data to develop new load models that help warn the grid operator when voltage problems might arise and help reduce the length of time a system experiences voltage sags and prevent power outages.

Research successes with synchrophasors led to their inclusion as a feature by commercial relay manufacturers such as Schweitzer Engineering Laboratories (SEL), making the technology extremely low cost and widely available. This has resulted in greater adoption by electrical grid operators for both transmission and distribution use. For example, synchrophasors on the San Diego Gas & Electric Company (SDG&E) distribution system provide improved situational awareness, voltage profiles, and load monitoring over the use of SCADA alone. They are also used to detect bad voltage sensors and provide a quantitative assessment of the operational health of the system under current conditions. A new use for distribution synchrophasors is the detection and isolation of falling or broken power lines. This can happen, for instance, when a car strikes a utility pole. This was pioneered by SEL and SDG&E and can detect and de-energize a falling power line before it touches the ground. This increases public safety and reduces fires caused by falling lines. By 2020, synchrophasors will save Californians an estimated \$210 million to \$360 million annually by improving system reliability and reducing the risk of costly power outages.²⁶

Reducing the Cost of Renewable Generation

The declining cost of solar PV generation technologies has been one of the energy sector's biggest success stories of the past decade. Despite this progress, further cost reductions are

26 Kandel, Adrienne, 2016. Benefits and Costs of PIER Research Enabling Synchrophasor Applications. California Energy Commission, Energy Research and Development Division. Publication Number: CEC-500-2016-036. <http://www.energy.ca.gov/2016publications/CEC-500-2016-036/CEC-500-2016-036.pdf>.



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needed to continue to accelerate the growth of the solar PV market. Tracker systems that follow the sun's path could significantly improve the economics of solar PV generation over traditional fixed-tilt systems. However, conventional solar PV trackers – which rely on motors and gearboxes with hundreds of moving parts and wear surfaces coupled to heavy steel structures – have higher installation and operation and maintenance (O&M) costs compared to their fixed-tilt counterparts.

In 2015, the Energy Commission awarded funding to a California start-up company called Sunfolding to conduct a field validation of its *AirDrive™* solar PV tracking system. The *AirDrive™* solar PV tracking system uses robust and reliable air-based components instead of mechanical components to track the sun throughout the day. This system has the potential to reduce structural components by 10 times, resulting in costs savings on multiple fronts including a 65 percent reduction in labor hours for installation, a 7 percent reduction in O&M costs, and a 2.63 percent reduction in the levelized cost of electricity.

As part of the Energy Commission award, Sunfolding tested its system against three critical metrics for tracker systems: tracker accuracy, component failure, and availability. The system passed the validation on all three metrics. These test results have helped Sunfolding make the first sales of the *AirDrive™* technology for a 3 MW project at several agricultural sites in California's Central Valley.

Advancing Low-Carbon Transportation Technologies

The transportation sector accounts for roughly 38 percent of the state's greenhouse gas emissions – and accounts for about 50 percent when including refinery emissions – with heavy-duty vehicles as the second largest contributor in the transportation sector. Motor vehicles are by far the largest source of air pollution that harms human health, accounting for nearly 80 percent of nitrogen oxide (NOx) emissions and 90 percent of diesel particulate emissions. The Energy Commission is supporting innovations in alternative fuel options that can maximize environmental and air quality benefits for heavy-duty vehicles include advanced near-zero emission natural gas engines. Natural gas represents a low carbon transition fuel for heavy-duty vehicles and a near-term solution to California's air quality issues when used to power near-zero emission natural gas engines.

Reducing Air Pollution from Heavy-Duty Vehicles to "Near Zero" Levels

Reducing NOx emissions is critical for controlling ambient air concentrations of harmful ozone and fine particulate matter, especially in the South Coast and San Joaquin Valley air basins. Prolonged exposure to high concentrations of NOx contribute to the development of asthma and increases susceptibility to respiratory infections. Seven of the nation's top 10 most ozone-polluted cities are in California and more than 90 percent of the state's population is living under at-risk levels of ozone pollution. Medium- and heavy-duty vehicles account for more than 40



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percent of NO_x emissions in the air basins.^{27, 28} Drastic decreases in emissions from these vehicles are needed to address air quality concerns.

In 2013, the Energy Commission partnered with the South Coast Air Quality Management District and Southern California Gas Company to challenge natural gas engine manufacturers to develop a low NO_x natural gas engine that would reduce NO_x emissions to levels 90 percent below the 2010 California Air Resources Board (CARB) emission standards. In response to this challenge Cummins Westport, Inc. (CWI) was successful in upgrading its existing 8.9-liter natural gas engine with improved controls, closed crankcase ventilation, and a modified three-way catalyst to meet the emission objectives of the research without sacrificing performance. In October 2016, CWI's 8.9-liter ISL G near zero engine was commercially offered with an emissions certification at CARB's lowest optional low NO_x standard of 0.02 grams per brake horsepower hour (g/bhp-hr), 90 percent below the U.S. EPA standard. (**Figure 7.**)

Los Angeles Metro purchased 360 new transit buses equipped with the 8.9-liter near-zero emission engine and committed to buying an additional 395 engines over the next three years. The City of San Diego is converting its refuse truck fleet from diesel to natural gas with 92 trucks equipped with the near-zero emission engine. By adopting the near-zero emission engine, these two fleets alone can see NO_x reductions of 108 and 34 annual metric tons, respectively.

Based on the innovations developed for the 8.9-liter engine, advanced 6.7-liter and 12-liter engines are being developed as part of additional Energy Commission projects. These new engines will widen the availability of low-NO_x natural gas engines to other vehicle applications such as school buses, port yard trucks, and regional haul vehicles. Successful large-scale deployment of low NO_x natural gas engines will result in significant air quality improvements in California. With a projected growth of 5 percent per year in market share for transit buses and refuse trucks, deployment of the near-zero engine in these markets is expected to reduce NO_x emissions by up to 2.2 tons per day in the South Coast Air Basin.

Figure 7: Cummins Westport's Near Zero Engine



Credit: Cummins Westport, Inc.

27 San Joaquin Valley Air Pollution Control District. 2016 Ozone Plan for 2008 8-hour Standard. http://valleyair.org/Air_Quality_Plans/Ozone-Plan-2016/b.pdf.

28 South Coast Air Quality Management District. 2016 Air Quality Management Plan. Appendix III: Base and Future Year Emission Inventory. <http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2016-air-quality-management-plan/final-2016-aqmp/appendix-iii.pdf?sfvrsn=6>.



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Next Update:

August 2019 with updates provided annually