2020 Natural Gas Research & Development Program

ANNUAL REPORT

July 1, 2019 – June 30, 2020

Promoting decarbonization, lower costs, and increased safety for California

Letter To California

California Energy Commission
Vice Chair Janea Scott

The California Energy Commission (CEC) is a proud leader in statewide efforts in achieving California's ambitious clean energy and climate goals. Driven by landmark policies, like Executive Order B-55-18 and Senate Bill (SB) 100 (De León, Chapter 312, Statutes of 2018), California is working toward renewable energy and zero-carbon resources supplying 100% of retail electricity sales by 2045. Meeting these climate and energy goals will require deep decarbonization across all sectors.

Focused, actionable research is foundational to achieving the state's decarbonization goals. The CEC's Natural Gas Research and Development (R&D) Program invests $21.6 million annually in science and technology advancements that help improve public health and safety, decarbonize end uses in buildings and industry, develop fuel alternatives, and reduce environmental impacts. As we transition to a decarbonized energy system, there are a few key priorities driving and defining research questions.

First, it is imperative to keep existing natural gas infrastructure safe and reliable. Natural Gas R&D Program investments are advancing technologies for predicting and detecting infrastructure threats with greater speed and precision; developing affordable, high-resolution mapping tools to enhance safety; and identifying large methane leaks for mitigation.

Second, the program is assessing alternatives that have the potential to use existing infrastructure, meet difficult-to-electrify needs in industrial and commercial applications, and support medium- and heavy-duty transportation. Natural Gas R&D funds are helping unlock the commercial potential of zero- and near-zero-carbon fuel substitutes including synthetic natural gas, renewable gas, and renewable hydrogen.

Third, all Californians should reap the benefits of a transition to a decarbonized energy sector, and this transition must not place additional financial or public health burdens on our most vulnerable residents and communities. To that end, since Fiscal Year (FY) 2016-2017, some 65 percent of Natural Gas R&D funds are invested in low-income and/or disadvantaged community project sites with the aim of bringing economic, environmental, and health benefits to the forefront.

While COVID-19 and the resulting economic uncertainties have made 2020 a challenging year, the CEC remains committed to maintaining steady, science-driven progress toward a safer, cleaner, more modern energy system. More than ever, California's climate leadership and can-do spirit continue to help propel the state to a clean energy future built on public-interest energy research.

Sincerely,

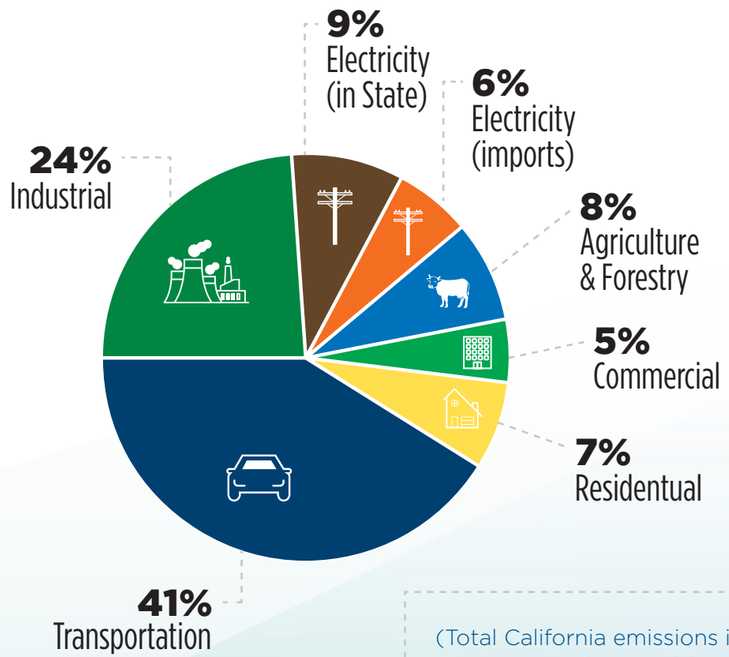
Janea A. Scott

Vice Chair
California Energy Commission

Introduction

State policies have put California on a path to completely decarbonize its energy sector by 2045. Under SB 100, the electricity sector is expected to play a major role in achieving the state's greenhouse gas (GHG) reduction goals by supplying electricity generation that is 100-percent or near 100-percent renewable. Complementing the supply-side strategy, the state has charted a path to additional deep GHG reductions by decarbonizing end uses. Some end uses can easily and cost-effectively electrify. While the path is well paved for new home construction and programs and incentives are in place to electrify light-duty vehicles, more must be done to decarbonize other end uses. Research and development to enable increased electrification is being conducted under the Electric Program Investment Charge (EPIC). However, significant built infrastructure now depends on natural gas, and a transition strategy is evolving and adapting. In the meantime, large GHG reductions can be made in natural gas use through increased efficiency. Other strategies to decarbonize traditional uses of natural gas include solar thermal for heating, technologies to capture and use biogas, and reduction of methane leaks from gas infrastructure. Meanwhile, the development of renewable gas use, including hydrogen, as an alternative to fossil fuel use in the transportation sector, especially medium- and heavy-duty, is an important strategy for lowering emissions and improving air quality.

2018 California Emissions by Economic Sector



(Total California emissions in 2018 = 425.3 million metric tons carbon dioxide (CO_2) equivalent. Source: California Air Resources Board, https://ww2.arb.ca.gov/ghg-inventory-data)

Introduction Continued

A 2018 CEC-funded study* by Energy + Environmental Economics (E3) examined the priority, near-term decarbonization strategies to achieve California's 2030 and 2050 GHG-reduction goals. The study found that electrification is a promising pathway to decarbonization, but also noted that natural gas is an important fuel now and that a transition strategy is needed to guide policy and tailor research. Therefore, the natural gas public-interest research is focused on strategies to keep the aging infrastructure safe, reduce use of natural gas, and pursue development of alternatives to natural gas like green hydrogen and renewable gas. The research is conducted with a conscious commitment to equity and achieving public benefits of GHG reduction, improved air quality, safety, and affordability.

*https://ww2.energy.ca.gov/2018publications/CEC-500-2018-012/CEC-500-2018-012.pdf

The Natural Gas R&D Program

Assembly Bill (AB) 1002 (Wright, Chapter 932, Statutes of 2000) created the program, recognizing natural gas as a vital energy resource for California. AB 1002 directed the California Public Utilities Commission (CPUC) to impose a surcharge on all natural gas consumed in California. This surcharge funds a range of public-interest R&D activities in energy efficiency, renewable energy and advanced generation, and energy infrastructure. The CEC has administered natural gas R&D in the public interest since 2004. SB 1250 (Perata, Chapter 512, Statutes of 2006) updated the program, changing how the natural gas research funds are encumbered and managed.

The CPUC established that the CEC's Natural Gas R&D projects must:

- Focus on energy efficiency, renewable technologies, conservation, and environmental issues.
- Support state energy policy.
- Offer a reasonable probability of providing benefits to the public.
- Consider opportunities for collaboration and co-funding with other entities.

Each year the CEC is required to submit to the CPUC a proposed program plan and funding request for the Natural Gas R&D Program. When creating the budget plan and developing the research portfolio, the CEC receives input from experts in energy research, including the state's investor-owned gas utilities, state and federal agencies, industry experts, academic researchers, and other interested parties. Each year the CEC holds a workshop to explore research initiatives across all natural gas technical subject areas considered for the next funding cycle. Other workshops are held throughout the year to gather input on various research areas and topics. These workshops help avoid research duplication; generate new research ideas; create the best research industry practices; and bring together utilities, researchers, manufacturers, end users, and policy makers from state and federal agencies, such as the California Air Resources Board (CARB) and the United States Department of Energy (DOE), respectively.

The California Legislature has made clean energy equity—ensuring that the benefits from our programs are equitably shared, especially by those in the most vulnerable communities—a policy priority. The CEC has committed to a 35-percent target of Technology Demonstration and Deployment funding under its EPIC program to be allocated to projects sited in disadvantaged and low-income communities, and the Natural Gas Program has kept pace, investing an estimated 65 percent of natural gas R&D funds since FY '16-'17 in projects located in either a disadvantaged community, low-income community, or both.

CEC Research and Development Strategy for Natural Gas

For the natural gas sector to support the state in meeting California's multiple energy and environmental policy goals, challenges must be addressed strategically. The CEC Natural Gas R&D Program enables the natural gas sector to support California's energy and environmental goals by advancing technology innovation and scientific breakthroughs across four strategic objectives:

1 Reduce vulnerabilities and fugitive methane emissions in the natural gas infrastructure.

High-profile events such as the San Bruno pipeline explosion (2010) and Aliso Canyon gas storage facility leak (2015) demonstrated the vulnerabilities of the natural gas system, intensifying the need to research and improve its safety and integrity. Moreover, environmental events like the state's prolonged drought, extensive tree mortality, climate-change-related subsidence, and sea level rise have broadened the research necessary for the natural gas sector to be able to adapt to climate change and contribute to the state's GHG-reduction goals.

2 Drive large-scale customer adoption of efficient and low-carbon technology solutions for natural gas end uses, especially for those that are difficult to electrify.

To reach California's energy and climate change goals, energy efficiency is essential for all sectors. However, current technologies do not always meet acceptable payback periods necessary to drive large-scale market adoption of energy-efficiency upgrades without policy changes. In addition, the invasive nature of some energy-efficiency upgrades that require occupants to temporarily vacate, combined with high customer acquisition costs and low equipment turnover, create a limited window for when customers are receptive to installing these upgrades. New technology advancements and strategies are critical to overcome these market barriers.

3 Improve the cost-competitiveness of renewable gas.

Under E3's high electrification scenario, the largest remaining source of GHG emissions will be from non-combustion emissions, including methane from agriculture and from waste such as wastewater treatment, landfills, and municipal solid waste. Capturing and converting this methane for energy purposes will become a critical strategy for meeting the 2050 GHG emission reductions targets, both by reducing GHG emissions from non-combustion emissions and decarbonizing natural gas supplies. "[Renewable gas] does not face the same type of customer adoption and building retrofit challenges as a building electrification strategy." However, the cost of renewable gas from agriculture and waste is several times greater than traditional fossil fuel natural gas supplies.

4 Minimize air quality impacts from gas use with zero- or near-zero-emission technologies.

Large portions of California, most notably Southern California and the San Joaquin Valley, are in air quality non-attainment zones. These are areas considered to have air quality worse than California ambient air quality standards. Industrial and goods movement is a key economic sector of these regions and major producer of air pollution emissions. As these industries move from diesel and natural gas to alternative and renewable energy resources such as biomethane and hydrogen, opportunities exist to also reduce air pollution emissions from these sectors.

California's Investment In Groundbreaking Natural Gas Research

Natural Gas R&D Program Investment Areas†:

Resiliency, Health, & Safety
$76 million invested

The CEC's Natural Gas R&D Program helps Californians create a reliable, resilient, and safe energy system through state-of-the art research on pipeline storage and safety, climate and weather risk, indoor air quality and health, and forest biomass usage that reduces fossil-fuel reliance and wildfire risk.

Building Decarbonization
$55 million invested

The program invests in novel energy technologies to improve the energy efficiency, affordability, health, and comfort of California's homes and businesses.

Natural Gas System Decarbonization
$22 million invested

As California approaches decarbonization policy goals, this program supports a safe, healthy, and equitable transition to more renewable and low-carbon resources through leading-edge studies on fugitive methane emissions, natural gas infrastructure decommissioning, and decarbonized pipeline gas.

Industrial & Agricultural Innovation
$75 million invested

California's industrial and agricultural sectors have helped the state become the fifth largest economy in the world. The CEC's Natural Gas R&D helps develop and scale technology solutions that decrease natural gas use, carbon emissions, and waste while increasing production of goods, like renewable fuels, such as biofuels from dairy digesters or wastewater treatment plants.

Low-Emission Transportation
$50 million invested

The program advances new technology solutions to increase the efficiency and clean operation of natural gas vehicles, as well as promote hydrogen fuel advancements, particularly in the medium- and heavy-duty vehicle sector.

†Time frame for totals by investment area is from program inception in 2004.

By The Numbers

Through the years, modest investments yield revolutionary benefits that matter for Californians.

INVESTMENTS

$278+ MILLION in Natural Gas R&D Program funds invested to date on **more than 270 projects**

$4.4+ BILLION in private investment received by awardees after being selected for a Natural Gas R&D Program award

~65% OF NATURAL GAS R&D FUNDS invested in projects located in either a disadvantaged community, low-income community, or both*

BENEFITS

20+ PROJECTS informed codes, standards, proceedings, or protocols (adopted or under consideration), providing on average an **estimated $65* million** per year in energy cost savings**

30+ COMMERCIALIZED TECHNOLOGIES or products resulting from Natural Gas R&D projects and many more moving toward commercialization***

9,030+ CITATIONS in publications referencing research results from CEC-funded natural gas projects (through June 2020)

**For projects started in FY '16-'17 or later | **For example, CEC-funded projects on high-efficiency hot water systems in commercial food service, and if the recommendations are implemented by 12% of the food service facilities, that could result in an annual energy reduction of about 23 million therms, with an associated reduction of 133,000 tons of CO_2. The annual energy cost reduction translates to about $23 million. | ***For projects started in 2009 or later*

Investment Areas & Related Portfolio Topics Align To State Policies And CPUC Proceedings

Natural Gas R&D Program Investment Areas & Topics	Key State Policies, Guidance, & Plans
Resiliency, Health, & Safety • Pipeline & Storage Safety • Climate and Weather Risk & Resiliency • Indoor Air Quality • Forest Biomass **CPUC Proceedings** R.11-02-019 | R.13-11-006 R.18-04-019 | I.17-02-002	SB 887 (Pavley, Chapter 673, Statutes of 2016) issued requirements to ensure the safety and integrity of natural gas storage facilities. SB 1371 (Leno, Chapter 525, Statutes of 2014) requires the CPUC to determine whether existing practices are effective at reducing methane leaks and promoting public safety, and whether alternative practices may be more effective. SB 380 (Pavley, Chapter 14, Statutes of 2016) determines the feasibility of minimizing or eliminating the use of the Aliso Canyon natural gas storage field in Los Angeles County while maintaining energy and electric reliability for the region. SB 901 (Dodd, Chapter 626, Statutes of 2018) directs revisions to fuel or feedstock procurement requirements for generation from bioenergy projects intended to reduce wildfire risks.
Building Decarbonization • Space & Hot Water Heating • Cooking Equipment & Appliances • Advanced Building Envelopes **CPUC Proceedings** R.19-01-011 | R.13-11-005 D.19-12-021	SB 350 (De León, Chapter 547, Statutes of 2015) establishes targets for statewide energy efficiency savings and demand reduction that will achieve a cumulative doubling of statewide energy efficiency savings for retail customers by 2030. 2019 California Energy Efficiency Action Plan addresses existing buildings, low-income barriers to energy efficiency, agriculture, industry, newly constructed buildings, conservation voltage reduction, and electrification. Integrated Energy Policy Report assesses major energy trends facing California's electricity, natural gas, and transportation fuel sectors and provides policy recommendations.
Natural Gas System Decarbonization • Biomethane Cleanup & Injection • Natural Gas Infrastructure Decommissioning • Hydrogen Generation & Pipeline Injection • Fugitive Methane Emissions **CPUC Proceedings** R.13.02-008 | R.20-01-007 R.15- 01-008	SB 1383 (Lara, Chapter 395, Statutes of 2016) requires reductions in statewide emissions of methane by 40 percent, hydrofluorocarbon gases by 40 percent, and anthropogenic black carbon by 50 percent below 2013 levels by 2030. AB 1496 (Thurmond, Chapter 604, Statutes of 2015) requires the state to monitor methane hotspots. Short-Lived Climate Pollutant Reduction Strategy recommends actions to reduce emissions of short-lived climate pollutants, including from dairies, organics disposal, and wastewater. SB 32 (Pavley, Chapter 249, Status of 2016) requires California to reduce greenhouse gas (GHG) emissions to 40 percent below 1990 levels by 2030.
Industrial & Agricultural Innovation • Low-Carbon Process Heating • Waste Heat Utilization, Including Combined Heat and Power (CHP) • Waste-to-Energy **CPUC Proceedings** R.17-06-015 | D.15-10-049 R.08-06-024 | R.18-07-003	AB 1613, the Waste Heat and Carbon Emissions Reduction Act (Blakeslee, Chapter 713, Statutes of 2007) requires an electrical corporation to purchase excess electricity from CHP systems that comply with sizing, energy efficiency, and air pollution control requirements. SB 1122 (Rubio, Chapter 612, Statutes of 2012) requires the CPUC to direct the electrical corporations to collectively procure at least 250 megawatts from eligible bioenergy projects, including projects using biogas (biofuel produced from decomposition of organic waste) from wastewater treatment plants, municipal organic waste diversion, food processing, and codigestion; dairy and other agricultural bioenergy; and bioenergy using by-products of sustainable forest management.
Low-Emission Transportation • Near-Zero-Emission Natural Gas Vehicles • Hydrogen Fuel **CPUC Proceedings** R.11-03-012 | R.13-11-007 R.18-12-006	Sustainable Freight Action Plan establishes targets to improve freight system efficiency by 25 percent by 2030, deploy more than 100,000 freight vehicles and equipment capable of zero-emission operation, and maximize near-zero freight vehicles and equipment powered by renewables by 2030. Mobile Source Strategy reduces emissions from the heavy-duty truck sector with cleaner combustion engines, renewable fuels, and zero-emission technology to meet GHG-reduction targets and attain federal health-based air quality standards for ozone and particulate matter. Low Carbon Fuel Standard reduces the full fuel-cycle carbon intensity of the transportation fuels pool used in California by encouraging the transition to fuels that have a lower carbon footprint.

2019–2020

YEAR IN REVIEW

Natural Gas R&D Program

Making Essential Headway on a Safer and Healthier System for Californians

700+

number of high-accuracy-mapping (HAM) units deployed nationally in 2019 for excavation damage prevention and emergency response

300

estimated number of natural gas pipeline damage events from excavation per year that HAM technology could help avoid if fully deployed in California

High-Accuracy Mapping for Safe Operations, Excavation Damage Prevention, and Emergency Response

Natural gas operators have been known to use manual, paper-based methods for asset mapping and documentation; these methods are time-consuming, error-prone, and delay-creating. Traditional digital systems fail to truly automate data capture and cannot create high-accuracy maps with traceability data or provide near-real-time data access. With CEC funding, the Gas Technology Institute (GTI) developed and demonstrated a high-accuracy-mapping (HAM) technology solution: a prototype system to create and display high-accuracy maps using advances in mobile, geographic information system, and global positioning system technologies. This system offers gas utilities a viable option to map more than 90 percent of their underground assets within a 6-inch accuracy at about half the cost of systems with similar accuracy. The HAM system has been used by several utilities, including PG&E, who recently used it in the reconstruction of the fire-stricken town of Paradise, and plans to expand usage to distribution gas construction crews.

1-2 CM PER YEAR

average subsidence rate for some of the levees in the Sacramento-San Joaquin Delta, compounding the growing risk that sea level rise and storms could cause some levees to fail, exposing natural gas pipelines to damage

High-Resolution Measurement of Levee Subsidence Related to Energy Infrastructure in the Sacramento-San Joaquin Delta

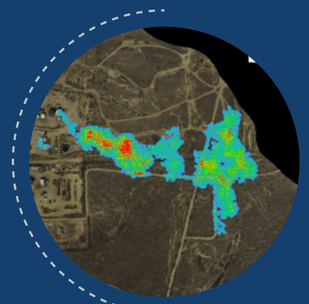
In 2020, the CPUC required utilities to conduct climate vulnerability studies every four years, including sea level rise, subsidence, and other impacts identified in California's Fourth Climate Change Assessment and subsequent assessments. SB 1320 (Stern, Chapter 136, Statutes of 2020) requires California climate change assessments every five years. One of the CEC-funded studies in California's Fourth Climate Change Assessment advanced technology for measuring levee subsidence and applied this technology to improve the accuracy of data on levee subsidence related to natural gas infrastructure in the Sacramento-San Joaquin Delta. Researchers found areas of Sherman Island, including those with natural gas infrastructure, may fail to meet federal levee height standards over time. Of the areas surveyed, the most frequent time of concern is projected between 2040 and 2080 depending on actual sea level rise and 100-year flood stage projections.

$28+ MILLION

estimated value of natural gas discovered leaking from large emitters each year according to the CEC-funded California Baseline Methane Survey*

560+

number of strong methane point sources detected, geolocated, and quantified, spanning all sectors in California



California Baseline Methane Survey: Identifying Large Fugitive Methane Emitters From the Natural Gas Sector

Building on a decade of collaboration among NASA, CARB, and the CEC supporting California's ambitious climate change goals and studying methane emissions from a variety of sectors, including oil and gas, NASA, with funding support from CEC's Natural Gas R&D Program as well as CARB, set out to undertake a comprehensive, multi-sector, statewide survey of methane point sources. This survey helped California to better understand the climate impacts from the natural gas system and informed approaches for continuous monitoring, detection, and mitigation. The field research led to direct identification and mitigation of methane leaks, and a publication in *Nature*. Results were shared with air quality management districts, utilities, and industry stakeholders to help develop a strategic monitoring program for sources of methane leaks. CARB is also using the findings to inform its oil and gas emission regulation and GHG inventory.

**This research estimated point-source emissions for the oil and gas sector in California to be 0.158 terra grams of methane per year.*

2,800+

number of heavy-duty natural gas vehicle deployments in California with near-zero-emission engine technology developed with CEC funding**

CEC Low-Emission Transportation Research

More than a decade of CEC-funded collaborative R&D with partners including the South Coast Air Quality Management District, DOE, Southern California Gas Company (SoCalGas), GTI, Clean Energy Fuels, and Cummins Westport, Inc. culminated in the commercialization of low-NO_X natural gas engines certified to a NO_X level of 90 percent below the current standard. Completion of extensive CEC-funded demonstrations and further deployment accelerated by state and regional incentive programs indicate market acceptance of this technology for fleet types including transit, refuse, port drayage, and regional haul. Availability of low-NO_X natural gas engine technology is considered in CARB and regional air quality management district planning efforts as a bridge technology for meeting near- and long-term air quality and climate change goals. CEC's Transportation Research Program is pivoting its focus to hybrid and hydrogen-powered technologies.

***Number of vehicle purchases supported by the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project as of July 2020*

Natural Gas R&D Program: Project Highlight

Resiliency, Health, & Safety

Integrated Risk Management and Decision-Support System (IRMDSS) for Underground Natural Gas Storage Infrastructure Integrity

Integrated Risk Management and Decision-Support System, or IRMDSS, is a framework tool to proactively manage and reduce natural gas storage risks by taking advantage of the prediction capability of advanced modeling and dynamic data from state-of-the-art monitoring technologies.

> *"IRMDSS…will be designed to enable operators to be more proactive in taking preventive measures early on, instead of fixing a problem after it occurs. Compared to current risk analysis methods, IRMDSS provides a more quantitative, forward-looking analysis with advanced technologies."*
>
> *~ Yingqi Zhang, project principal investigator*

≤1 HOUR

amount of time it takes for the IRMDSS to notify a facility operator of a potential well leak

MONTHS

amount of time a storage well leak could go undetected using traditional, labor-intensive testing methods

8,300+

California households that had to evacuate because of the Aliso Canyon gas leak, the largest methane leak in U.S. history*

$717 MILLION

SoCalGas's cost resulting from the Aliso Canyon gas leak**

2.7 MILLION

the metric tons of CO_2 equivalent to the amount of methane leaked during the Aliso Canyon leak***

*Source: https://www.nytimes.com/2019/05/17/business/porter-ranch-gas-leak.html
**Source: https://www.dailynews.com/2016/10/22/aliso-canyon-1-year-later-how-a-massive-gas-leak-left-its-mark-on-porter-ranch/
***Calculated from an estimated total of 109,000 metric tons of methane (https://ww2.arb.ca.gov/news/aliso-canyon-leak-emitted-109000-metric-tons-methane) and a widely accepted conversion factor of 25 (https://ww2.arb.ca.gov/ghg-gwps)

Many of California's nearly 350 wells for underground natural gas storage were constructed before 1970 for oil and gas production using standards now considered inadequate. The natural gas leak at Aliso Canyon storage facilities underscored the need for comprehensive, upgraded risk assessment and management strategies.

Tackling this need, the CEC enlisted Lawrence Berkeley National Laboratory (LBNL) to develop a risk management tool for gas storage fields. The Integrated Risk Management and Decision-Support System (IRMDSS) will enable facility personnel to manage the ever-evolving risk of storage wells, detect leaks in real time during storage operation, and make decisions using real-time data analysis, all of which are difficult to do with current methods. It leverages the prediction capability of geomechanical models and dynamic monitoring data from modern technologies. Advanced process models integrated with continuous reevaluation and assessment will provide leading indicators of well-integrity threats and other integrity issues from geohazards and field operations.

This breakthrough, recently demonstrated north of Aliso Canyon, will replace ineffective, passive approaches and give California the risk technology upgrade its aging gas system needs. The IRMDSS shows great promise to help prevent failure of natural gas wells and storage infrastructure.

Natural Gas R&D Program: Project Highlight

Resiliency, Health, & Safety

Kitchen Ventilation for Healthy Zero-Net Energy (ZNE) Homes

0

number of previous scientific studies that evaluated the importance of range-hood capture efficiency in reducing unhealthy pollutant exposures from cooking appliances in new California homes

91

approximate percentage of new California homes that would meet health-protective nitrogen dioxide standards* when using range hoods with a 50-percent capture efficiency

99+

percentage of new California homes that would meet health-protective nitrogen dioxide standards* when using range hoods with a 75-percent capture efficiency

23

number of industry groups, agencies, companies, or training events through which stakeholders were engaged and became aware of range-hood capture efficiency's importance to indoor air quality

4

number of peer-reviewed papers published, submitted, or in press resulting from the project

> *"LBNL's research…[helped] to propose a new capture efficiency metric and standard for kitchen ventilation equipment as part of the 2022 update to the California Energy Code."*
>
> *~ Jeff Miller, PE, CEC Lead Engineer for Title 24 Revisions*

**Environmental Protection Agency's outdoor air quality standards for NO_2*

California's Title 24 (T24) Building Code requires home venting range hoods or other kitchen exhaust ventilation to meet standards for airflow and sound but does not directly regulate pollutant -removal effectiveness (capture efficiency). Air pollutants from gas cooking can cause or aggravate cardiovascular and respiratory issues.

Aiming to prevent unhealthy indoor air pollutant exposures, LBNL set out to quantify the impact of current codes and potential code changes. Their work focused on new ZNE homes with natural gas appliances and quantified capture efficiency that can significantly reduce the number of new homes that would exceed health-protective nitrogen dioxide (NO_2) standards*. Roughly 9 percent of new homes exceed health-protective NO_2 standards when using range hoods with 50-percent capture efficiency. When capture efficiency is improved to 75 percent, fewer than 1 percent of new homes exceed those NO_2 standards, even when accounting for current range-hood usage rates.

Supporting state deliberations on stronger kitchen ventilation requirements, LBNL did extensive outreach, engaging agencies and numerous other stakeholders attuned to T24 and American Society of Heating, Refrigerating and Air-Conditioning Engineers' standards. Results show the status quo may inadequately protect Californians from gas-burner combustion pollutants. Standards may also be inadequate for shielding against particulate matter from both gas and electric burner cooking. The good news? California is now equipped to forge healthier kitchen ventilation standards based on pollutant removal.

Natural Gas R&D Program: Project Highlight

Resiliency, Health, & Safety

Earthquake Engineering Assessment Tool for Gas Storage and Transmission Systems

>99%

chance of a 6.7+ magnitude earthquake in California within the next 30 years (U.S. Geological Survey)

100

percentage of geologic hazards, such as landslide, liquefaction, and earthquake, to natural gas infrastructure that will be covered by the seismic risk assessment tool

0

number of existing tools and established methods available to measure seismic risk specific to natural gas infrastructure prior to this project

> *In the event of an earthquake, natural gas pipeline and storage facilities could experience significant damage. It is not hard to imagine the impact that damage of our natural gas system could have on everything from response to recovery efforts.*
>
> *~ UC Berkeley Professor Jonathan Bray, principal investigator of the project*

California is a hot zone of earthquake faults that can rupture without warning, leaving natural gas pipelines and storage systems vulnerable. Examples include the 1994 Northridge earthquake, resulting in a Los Angeles pipeline break and the 1989 Loma Prieta earthquake, resulting in more than 1,000 gas leaks in San Francisco. Unfortunately, current risk assessment approaches can be highly subjective and qualitative, and no quantitative tool exists for reliable and accurate seismic risk estimation and assessment tailored to the fragilities of natural gas systems.

Pacific Earthquake Engineering Research Center is filling this gap with an open source, easily adaptable seismic risk assessment tool built for natural gas utilities and regulators. With leading technology and science, it models all geotechnical threats to gas infrastructure. This tool helps identify and prioritize the most impactful seismic retrofits for California natural gas infrastructure. In 2022-23, the team will validate and demonstrate it at both natural gas pipelines and storage facilities in Northern and Southern California with two major utilities: PG&E and SoCalGas.

This innovative technology anticipates long-lasting impacts by helping regulators and utilities better assess risks and target seismic mitigation to the most at-risk gas system components. To promote and scale up the adoption of this technology, the research team convenes a user panel of utilities, CPUC, and Geologic Energy Management Division (formerly the Division of Oil, Gas, and Geothermal Resources, or DOGGR) in bi-annual meetings and a user workshop and incorporates the collected feedback for tool development.

Natural Gas R&D Program: Project Highlight

Building Decarbonization

Low-Cost, High-Efficiency, Solar-Powered Micro-CHP System for Electricity, Hot Water, and Space Heating

30%

more roof space potentially saved compared to conventional systems combining solar water heaters with solar photovoltaic (PV) panels

1.4-YEAR

payback period per module and payback in 5-8 years for a fully installed system

15%

lower capital cost for system installation

> *"This innovation has the potential to provide both onsite zero-emission electricity generation and hot water for customers in one packaged solution."*
>
> *~ CEC Vice Chair Janea A. Scott*

$10,300

estimated total cost of a solar PV and solar hot water system if purchased and installed individually

$8,700

estimated cost of this micro-CHP system that provides comparable electricity and hot water output

California faces the challenge of reducing natural gas consumption across all buildings to lower energy costs and GHG emissions. Annually, California's buildings consume more than 5 billion therms for space and water heating. Commercially available solar CHP systems combine traditional PV panel architectures with traditional thermal collector models, making them just as expensive per square meter as side-by-side installations of PV panels and thermal collectors.

To solve this problem, UC Merced researchers paired an innovative solar cell packaged in inexpensive glass tubes with low-cost aluminum minichannel technology. Like a car radiator, the aluminum minichannels provide solar water heating, while the solar cells in glass tubes produce electricity for the building. This novel integration keeps the glass tubes cool to enhance electricity production and effectively doubles the energy value without additional installation cost compared to installing two separate PV and solar hot water systems.

This innovation can provide the health, lodging, and food-processing industries with a potentially cost-effective, lightweight, modular, and scalable solar CHP system that can be installed on rooftops and help meet space- and water-heating needs.

Natural Gas R&D Program: Project Highlight

Building Decarbonization

Residential Gas Heat Pump Water Heaters (GHPWH): Demonstration in the Los Angeles Basin

> *I was surprised and amazed by how cool this heat pump technology works. And how my gas bill was over one-third lower.*
>
> *~ John Phibbs, homeowner*

90+ MILLION

therms potential reduction* in annual natural gas use with this technology (equivalent to about 4.5% of the natural gas consumed in residential water heaters annually)

$0

upgrade cost for the water heater gas piping and venting needed to retrofit homes with existing gas storage water heating

54%

energy usage reduced and 49% CO_2 emissions reduced with this system compared to conventional water heaters**

**Assuming 10% residential market penetration*

***Calculated from field data (Remaining figures based on field performance data, then extrapolated in simulation models.)*

More than 95 percent of homes in California use minimum-efficiency natural gas storage water heaters that consume more than 1.7 billion therms annually. Electric heat pumps provide a high-efficiency, low-carbon alternative to traditional natural gas water heaters, particularly in new construction. However, electric heat pump water heaters currently may not be a viable option for all existing building types due to the high cost of electrical panel upgrades.

To provide building owners — who are unable to install an electric heat pump water heater — with a more efficient and low-carbon option to traditional water heaters, GTI is demonstrating a residential gas heat pump water heater (GHPWH) technology. It has the potential to save over $2,200 per unit over a 10-year period, resulting in a 4.5- to 8-year payback period when choosing it over a standard gas storage water heater. This GHPWH results in a 49-percent CO_2 emission reduction compared to conventional natural gas water heaters, in part due to using a refrigerant and absorbent that have a global warming potential of zero. Though they may have higher initial cost than other high-efficiency alternatives, GHPWHs have the lowest estimated total cost of ownership over other advanced natural gas water heaters, aided by zero upgrade costs due to the use of existing venting and piping.

This technology is undergoing refinement to improve the design, but when commercially available, it could provide an option to slash water-heating gas use in half. The technology also has potential to provide hot water and air conditioning in medium to large commercial buildings like restaurants and hotels.

Natural Gas R&D Program: Project Highlight

Building Decarbonization

Decarbonizing Hospitals: High-Efficiency Dehumidification System (HEDS)

90%

reduction in natural gas used for reheat compared to conventional systems*

$1.1 BILLION

and 3,150 gigawatt-hours of electricity potential annual savings in California commercial buildings compared to those using conventional reheat systems**

24%

reduction in cooling load with high-efficiency dehumidification systems compared to conventional systems

5%

reduction in life-cycle costs from lower operation and maintenance costs compared to conventional systems

±15%

of conventional systems' cost for the overall system (depending on the existing baseline system)

> *"The ability to demonstrate HEDS on two hospital units in San Diego would be a breakthrough: the critical nature of hospital loads cannot be understated, and the need for proper RH [relative humidity] control to help eliminate Healthcare Acquired Infections (HAIs) that contribute to the deaths of thousands of patients each year is essential."*
>
> *~ Electric Power Research Institute (EPRI)*

**EPRI proposal to the CEC for GFO-19 504, March 20, 2020.*

***In conventional air handling units designed for dehumidification, air is sub-cooled to draw moisture out, then reheated using a boiler to raise the temperature and lower the RH of the supply air. These systems are commonly used in healthcare facilities.*

Up to 50 percent of hospital energy use is space heating and cooling. Hospitals dehumidify air by cooling it to a very low temperature and then reheating the air back to room temperature using boilers, resulting in extensive natural gas use year-round.

The Electric Power Research Institute and UC San Diego Health will demonstrate a high-efficiency dehumidification system (HEDS) integrated with new air-handling units at Thornton Pavilion Hospital. HEDS is equipped with real-time monitoring (humidity, temperature, fan speed, etc.) to optimize performance while minimizing energy requirements. It uses heat recovery technology that is less complex, lacks moving parts, and requires less maintenance and expense compared to baseline systems. When combined with a heat pump water heater, the system can provide a boiler-free solution in virtually all California climates.

Eliminating boilers and reheat load would reduce wasteful natural gas use, operating costs, and GHG. Using this technology could translate to emission reductions of more than 4.8 million tons of CO_2 and more than 4,400 tons of NO_X from decreasing cooling load and eliminating reheat load. A recent demonstration at a federal lab in Puerto Rico successfully eliminated reheat load with this technology. This breakthrough has at least one manufacturer interested and fully equipped to scale up production.

Natural Gas R&D Program: Project Highlight

Natural Gas System Decarbonization
Cost Reduction for Biogas Upgrading

Mosaic Materials' Thomas McDonald and Zoey Herm demonstrate the ability of their sorbent to selectively adsorb CO_2 over other gases — in this case air. "A time-lapse video of the demo is striking: in 20 minutes the balloon completely deflates as the gas is absorbed by the pellets. These materials absorb more CO_2, and release it more readily, than existing CO_2 separation materials." (*Nature*, Vol. 545, 2017)

<2% CO_2

required purity for renewable natural gas to achieve pipeline quality

38%

operating cost reduction potential using this biogas cleanup technology at commercial scale*

15%

capital cost reduction potential*

**Compared to current industry standard (aqueous amine scrubbing)*

> *"Scientists and entrepreneurs are trying to solve [manufacturing] problems and help make zero-carbon materials that will be affordable around the world. ... Mosaic Materials, for example, is developing new nano-materials that could make … [carbon] capture much more efficient and cost-effective."*
>
> *~ Bill Gates*

An important pathway for California to reach its ambitious climate and environmental goals is increasing use of biogas produced from waste resources, particularly through upgrading it to renewable natural gas to displace fossil fuel-derived natural gas. The high CO_2 content in raw biogas makes removing it the most cost- and energy-intensive step in the upgrading process. Cleaning and upgrading systems need to be simplified and made more affordable and energy-efficient.

Mosaic Materials' reusable, low-cost, low-energy pellets adsorb CO_2 from biogas to the purity required to meet pipeline-quality natural gas standards. When commercially mature, the technology is expected to have a payback period of five years or less for biogas cleanup applications at landfills, wastewater treatment plants, organic waste recycling facilities, and dairy farms.

Building on results of Advanced Research Projects Agency — Energy (ARPA-E), CEC, Cyclotron Road, and other DOE funding, Mosaic Materials' breakthrough CO_2 adsorption pellets are nearing commercial availability for biogas applications. Mosaic Materials is also working with ExxonMobil to explore other CO_2 removal applications. Bill Gates noted the potential of this carbon capture technology to help mitigate climate change in the Netflix series "Inside Bill's Brain: Decoding Bill Gates" and gave the company an online shoutout in a 2019 LinkedIn article.

Natural Gas R&D Program: Project Highlight

Natural Gas System Decarbonization

Strategic Assessment: Natural Gas in a Carbon-Constrained and Water-Efficient Future

500+

views of the high-impact final report of this project just three months after its publication

2

analytical tools developed for this study used by CEC for building decarbonization analyses

7+

instances of media coverage, including an L.A. Times feature (through June 2020)

> *"California needs a 'natural' (fossil) gas transition strategy to shield Californians from sharply higher heating bills, protect workers, and meet the state's climate targets. These are the starkly clear implications of the preliminary findings of a study presented … on the future of gas in the state."*
>
> *~ Pierre Delforge and Merrian Borgeson, Natural Resources Defense Council*

Climate goals have spurred California to reduce carbon emissions from natural gas use in buildings. Few independent analyses exist to determine the optimal approaches for reducing CO_2 emissions from natural-gas end uses. The CEC commissioned a study by E3 to evaluate scenarios achieving an 80-percent reduction in GHG emissions by 2050, focusing on ratepayer and gas system implications.

The study*, published in 2020, finds building electrification a likely long-term strategy with lower cost and risk compared to renewable gas. What's more, electrification leads to compelling improvements in outdoor air quality and public health. In any low-carbon future, the gas demand of buildings is likely to fall because of building electrification or the cost of renewable gas.

The state is working to decarbonize its economy by 2045. This likely means less fossil gas, and that creates a new planning imperative. Without a gas-transition strategy, unsustainable increases in gas rates and energy bills could occur after 2030, burdening customers least able to switch away from gas. E3 noted that this study helped inform the creation of a 2020 CPUC order instituting rulemaking on safe gas systems and long-term gas system planning.**

*https://ww2.energy.ca.gov/2019publications/CEC-500 2019-055/CEC-500-2019-055-F.pdf
**https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M324/K792/324792510.PDF

Natural Gas R&D Program: Project Highlight

Industrial & Agricultural Innovation

Reducing Gas Consumption in the Chemical Industry

UP TO 50%

of industrial energy consumption is lost as waste heat

2-YEAR

payback period with system cost less than $15 per kilowatt-hour-thermal

4,500 TRILLION

British thermal units (Btus) estimated annual process end use energy loss in U.S. industrial sector – heat that could be used given a cost-competitive storage and transport solution

$44 BILLION

industrial waste heat recovery market

80%

reduced cost vs. conventional molten-salt heat storage

> *"Element 16 developed an innovative thermal storage method to capture and use waste heat from vented steam. That stored heat will be used to save natural gas by pre-heating the product in the drying process. The project additionally results in potable water savings, a critical issue in the California Desert. The plans to transform a facility into the first Zero-Net-Energy (ZNE) Industrial Facility will likely make the Element 16 Thermal Storage System essential to achieve ZNE."*
>
> *~ Don Musser, Energy Manager at Searles Valley Minerals*

The industrial sector has overtaken electricity production as the second largest contributor to carbon emissions in California. Industrial process heating accounts for 70 percent of industrial sector natural gas consumption and is the source of highest emissions. Industrial process heating also is a major source of waste heat that, if captured and reused, can bring gains in overall facility energy efficiency. But using waste heat poses unique challenges like recovery, storage, and cost.

Element 16 is helping California find a solution: a unique thermal energy storage system using pressurized, superheated water and elemental sulfur to inexpensively store and transport low-temperature waste heat. Key advantages include ZNE compatibility, small footprint, and the ability to capture heat from steam, store intermittent waste heat sources, and deliver continuous or on-demand supply. The bottom line? Immediate improvements in energy efficiency.

Parker Wells and Hamarz Aryafar, while working as engineering researchers at UCLA, cofounded Element 16 with Professor Richard Wirz. Element 16's recent $1.5-million grant will be for their first installation and demonstration of their unique waste heat recovery and storage system at an industrial facility. The installation at Searles Valley Minerals is projected to result in a 15-percent reduction in natural gas usage at the facility and conserve precious water in the Mojave Desert. With the support of CEC grants, the team grew to seven technical staff members, received its first institutional investment from GINCO Investments, and gained entry into the Techstars Accelerator. CEC-funded projects helped Element 16 achieve its motto of "make every Btu and every kW count."

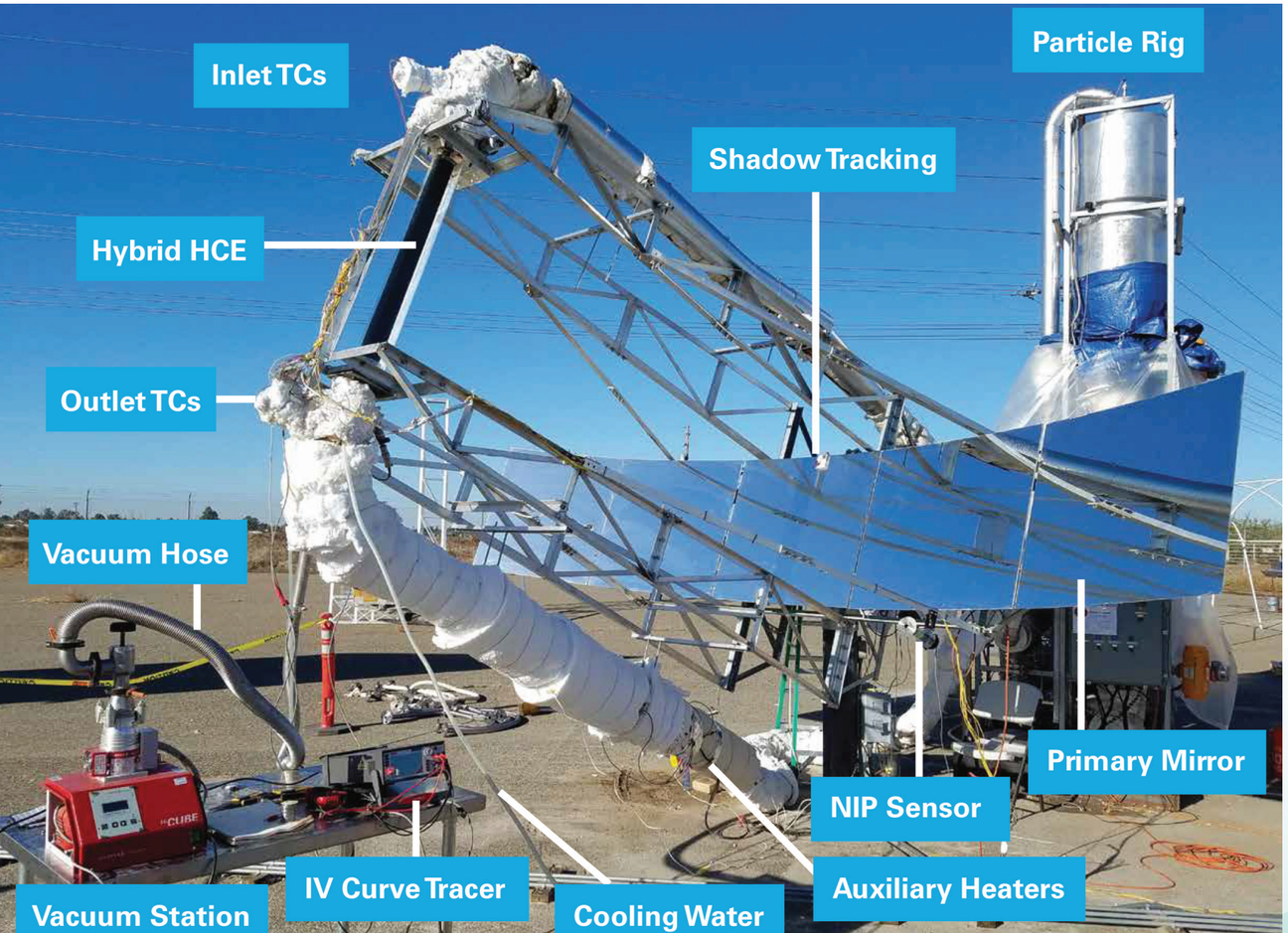
Natural Gas R&D Program: Project Highlight

Industrial & Agricultural Innovation

Integrating a High-Temperature Solar Thermal System With an Industrial Process

GTI's hybrid solar energy system was featured at the 2018 ARPA-E Congressional Showcase. It was one of five projects from across the nation that was invited, a distinguished honor that recognizes its great potential to be transformational.

> *"At ARPA-E, we are focused on advancing and developing innovative technologies, including solar conversion and storage tech. GTI's breakthrough technology can simultaneously generate high temperature and storable heat, potentially reducing natural gas use and enabling a higher penetration of solar energy into the U.S. energy mix. Their industrial plant installation could help to further verify system performance, energy savings, and emissions benefits of the technology for on-demand process heating."*
>
> *~ Rachel Slaybaugh, ARPA-E*



33%

of the natural gas use in California is for the industrial sector

20+%

potential reduction in natural gas use for the industrial sector with GTI's hybrid solar thermal system

70%

of the industrial sector natural gas use in California is for process heating

<5-YEAR

simple payback for the system

Current technologies for reducing natural gas use in industrial processes provide only modest gains in energy efficiency, have long payback periods, and may adversely affect the process. Solar thermal systems (STSs) for process heating are limited to low-temperature applications, not distributable, or not economical.

GTI is demonstrating the integration of a revolutionary, high-temperature STS with an industrial process to deliver cost-effective and on-demand, high-temperature process heat while reducing natural gas use. It holds great promise for growing the market for solar thermal technologies to slash industrial GHG emissions. With the potential for seamless integration into existing infrastructure and controls, the STS enables straightforward installation and reliable operation. The target markets include curing and forming, distillation, fluid heating, drying, heat treating, and preheating, among others. "The STS technology has a compelling value proposition for industrial customers … and could ultimately result in substantial gas savings for California industrial markets," said Dr. Roland Winston of UC Merced.

The prototype system will be installed and monitored at United States Gypsum's (USG's) Plaster City Plant near El Centro (Imperial County), a disadvantaged community under SB 535 (De León, Chapter 830, Statutes of 2012). "[W]e … have the chance to help the state reduce emissions at the same time as helping our company save energy and improve the financial health of our business," said a spokesperson for USG.

Natural Gas R&D Program: Project Highlight

Low-Emission Transportation

Transient Plasma Ignition System for High-Efficiency Natural Gas Engines

$8.5 MILLION

in Series A venture capital funding secured with Kairos Ventures

7+

innovation awards, honors, or nominations, including Automotive News PACEpilot award (2020), Business Green Transport Technology of the Year Finalist (2019), and a *Forbes* spotlight

$1.5 MILLION

in follow-on funding received through the DOE, and CEC cofunded the Natural Gas Vehicle Research Consortium to further advance the manufacturability of the technology to achieve market readiness.

24+

engine tests completed with various industry partners; this project enabled the technology to move from single-cylinder research engine testing to multi-cylinder commercial engine testing.

> *So, in a spark about 1% of the energy goes into actually igniting the fuel/air mixture. In our low temperature plasma, more than 50% of the energy you put in actually goes into the gas in the form of this plasma.*
>
> *~ Dan Singleton, Cofounder of Transient Plasma Systems, Inc, Source: Forbes 2020*

Low-emission natural gas engines are a key bridge technology for improving air quality and decarbonizing California's heavy-duty vehicle fleets that are not yet ready to electrify fully. However, they can be 10–20 percent less efficient than diesel vehicles, eroding some of the associated emissions benefits.

His research at University of Southern California on short, nanosecond-duration, pulsed power generators led Dan Singleton, with his major professor, Martin Gunderson, and colleagues to form Transient Plasma Systems (TPS). The literal garage startup later expanded to an office in Torrance (Los Angeles County) to respond to military and commercial market needs. Applying this technology, the team replaced traditional spark plug systems with modules using short pulses of plasma for ignition, unlocking pathways for cleaner, more efficient combustion with reduced maintenance.

CEC funding enabled TPS to partner with leading engine manufacturer Cummins Westport to demonstrate its technology on a commercial, multi-cylinder engine for the first time. The engine testing demonstrated a 30-percent reduction in smog-forming NO_x emissions, 10-percent reduction in carbon monoxide emissions, and over 2-percent increase in efficiency with potential for an up to 20-percent increase in fuel economy with additional optimization. The project's widespread demonstration results are accelerating commercialization.

Natural Gas R&D Program: Project Highlight

Low-Emission Transportation

Assessing On-Road, In-Use Emissions and Fuel Usage

Instrumental in informing significant policies to reduce air pollution from medium- and heavy-duty vehicles (MHDVs) **including:**

CARB'S

Heavy-Duty Low NO_X Omnibus Regulation

CARB'S

EMission FACtor (EMFAC) Model 202X model update

South Coast Air Quality Management District's (SCAQMD's)

investment strategies, including incentive programs that have funded more than 1,000 near-zero-emission natural gas trucks to date

0

emission rates specific to natural gas heavy-duty trucks existed in the EMFAC model prior to this project, which used diesel truck emission rates despite the unique emission characteristics of natural gas trucks

5

vehicle vocations tested including delivery, goods movement, transit bus, school bus, and refuse

219

unique MHDVs recruited for testing, representing 22 vehicle manufacturers, 9 engine manufacturers, and 25 fleets

> *"This project is one of the largest and most extensive emissions studies of medium- and heavy-duty vehicles to date. CEC provided vital support to make this study possible, which will play a critical role in ensuring the latest natural gas engine technologies are achieving intended emissions reductions."*
>
> *~ Sam Cao, SCAQMD project manager*

Near-zero-emission natural gas engines exceed the most stringent emissions standards in certification lab testing, helping them gain market share across a variety of MHDV types. But do these vehicles achieve such low emissions in demanding, real-world operations? The CEC partnered with SCAQMD, SoCalGas, and CARB to answer this question.

Supporting California's clean air targets, the study is validating the effectiveness of near-zero-emission natural gas engines under actual driving, not lab, conditions. Led by top emissions researchers at UC Riverside and West Virginia University, this comprehensive project collected and analyzed emissions and activity data from more than 200 MHDVs operating in California representing different vehicle types and fuels.

By gathering granular in-use data and assessing performance shortfalls, the project is building a scientific basis for future R&D needs and informing smart policy decisions to reduce MHDV emissions. For example, CARB's use of the data is informing California's official emissions inventories. The CEC is also using the data to shape future R&D investments and develop charging infrastructure and fuel-demand projections.

2021 WHAT'S TO COME

What's Next for the Natural Gas R&D Program?

Future Project Investments Align With California's Climate and Energy Goals, Accelerating Achievement

As the state reduces reliance on fossil natural gas, R&D investments will drive innovations to decarbonize the natural gas system while maintaining resiliency and safety. Since the inception of the program in 2004, research has focused on using natural gas as safely, cleanly, and efficiently as possible. These topics remain important, and the FY '20-'21 budget plan places greater emphasis on research areas that align with the state's current priorities for decarbonization – including strategic natural gas decommissioning and deep efficiency for end uses that can't yet electrify, natural gas alternatives like biomethane and hydrogen, and renewable alternatives for water heating.

FY '20 –'21 Natural Gas Budget Plan Initiatives* Organized by Investment Area:

Resiliency, Health, and Safety

Technologies to Inspect and Prevent Corrosion of Natural Gas Pipelines and Storage Facilities

An estimated 70 to 95 percent of pipeline internal leaks are due to localized corrosion caused mainly by microbiologically influenced corrosion, which costs the gas industry as much as $2 billion per year. Following the Aliso Canyon natural gas leak incident, an independent analysis of the leak identified that microbial corrosion on the well caused the rupture. This new initiative will focus on research, development, and demonstration of innovative technologies that can diagnose and address microbiologically and soil property-influenced corrosion of pipelines and storage facilities in the California natural gas industry.

Building Decarbonization

Examining the Effects of Hydrogen in End-Use Appliances

Hydrogen mixed with natural gas can play a role in meeting California's long-term decarbonization goals. However, the potential effects of adding hydrogen into existing natural gas infrastructure is not well understood, including the effects of varying levels of hydrogen on end-use appliances, such as water heaters, boilers, furnaces, cooktop stoves, ovens, and dryers. This initiative will focus on conducting research to address knowledge gaps and identify key benefits and challenges associated with safely using hydrogen blends in appliances.

Based on CPUC G-3555 Guidance

Accelerating Adoption of Modular Solar Water Heating in Low-Income or Disadvantaged Communities

Water heating accounts for nearly 40 percent of the natural gas used by California households and 32 percent used in the commercial building sector. Solar thermal water heating offers a clean, renewable alternative that can significantly reduce natural gas consumption in the building sector. This initiative will focus on demonstrating modular solar water heating systems in low-income and disadvantaged communities and analyzing their cost-effectiveness.

Development of a Data-Driven, Actionable Tool and Case Studies to Support Strategic and Equitable Natural Gas Decommissioning

Natural gas demand in the building sector is likely to fall due to various decarbonization strategies. With fewer customers and less natural gas demand, the cost of natural gas for remaining retail customers could rise. The prospect of significant reductions in retail customer demand for natural gas creates a planning imperative for the state. A strategic transition is needed to manage equity issues, safety, and cost-effectiveness. This initiative will focus on developing a data-driven, actionable tool to support strategic and equitable decommissioning decisions.

Analytics for Pilot Demonstration of Strategic Decommissioning of Natural Gas Infrastructure

Replacing aging natural gas pipelines can cost $1 million to $5 million per mile. These costs are passed on to natural gas consumers, which raises concerns about ratepayer impact particularly in disadvantaged and low-income communities. This initiative will focus on in-depth analytics to inform a pilot demonstration of pipeline decommissioning in California. It requires a multidisciplinary approach to address interrelated issues, such as identification of the most applicable use cases for demonstrations, technical requirements, short- and long-term cost/benefit analysis for customers and utilities, customer acceptance information, and equity considerations.

Natural Gas System Decarbonization

Decarbonization via Efficient and Cost-Competitive Renewable Hydrogen and Biomethane

Renewable hydrogen and biomethane could replace or reduce natural gas consumption and GHG emissions by providing an alternative for heating fuel and electricity generation and as an additive in natural gas pipelines. The costs of producing low-carbon hydrogen remain high compared to conventional steam methane reforming processes. Existing biogas cleanup technologies need to improve to make biomethane more competitive with fossil natural gas. This initiative will focus on advancing technologies to cost-effectively produce low-carbon hydrogen and high-quality biomethane.

Pilot Test and Demonstration of Hydrogen Blending into Existing California Natural Gas Pipelines

Delivering hydrogen through the existing natural gas pipeline network has been proposed as a promising strategy to increase the percentage of renewable energy, such as solar and wind energy, in the current energy portfolio. Blending hydrogen can cause issues in existing natural gas pipelines including material embrittlement, crack growth, gas permeation, interaction with reservoir caprock, sealant performance, and system leaks. This initiative will focus on conducting a pilot test and demonstration to measure various impacts of hydrogen blending on the integrity of California's existing natural gas infrastructure system.

Natural Gas Budget Plan Initiatives Organized by Investment Area Continued

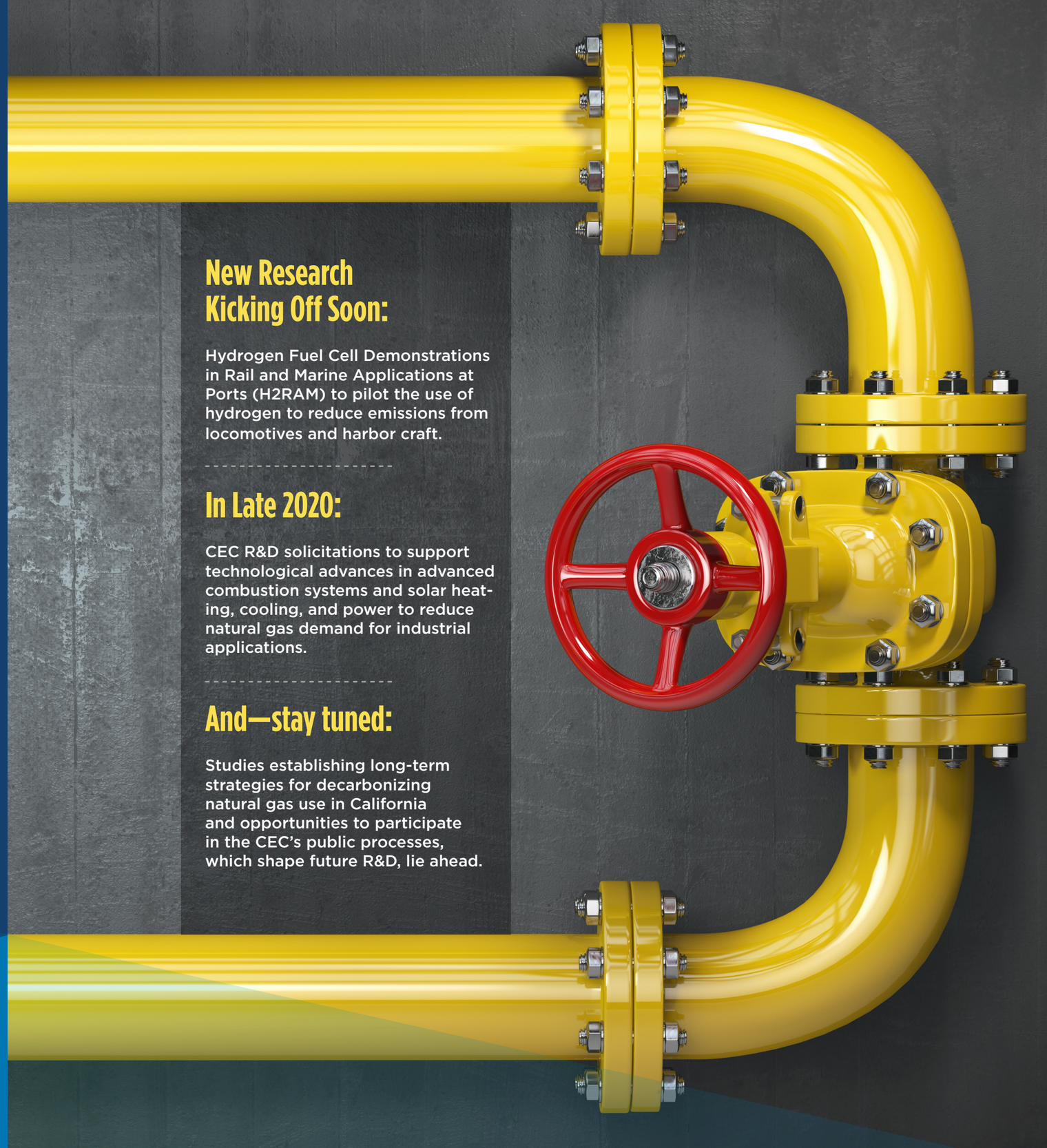
Industrial and Agricultural Innovation

This research area was not addressed in FY ’20-‘21 plan; the FY ’19-’20 plan included an initiative titled “Developing and Demonstrating Advanced Combustion Systems.” The initiative focused on improving industrial natural gas combustion efficiency, reducing NO_x emissions, and better enabling pathways for CO_2 capture.

Low-Emission Transportation

Technology Integration and Demonstration of Hydrogen Fuel-Cell Trucks and Buses

Hydrogen can play a role in decarbonizing the natural gas sector, but it faces several challenges such as high costs, need for lower carbon hydrogen production, and lack of infrastructure. Regulations such as the Low Carbon Fuel Standard, Innovative Clean Transit, and Advanced Clean Truck rule are driving a transition to zero-emission trucks and buses that use renewable fuels. Increasing hydrogen demand in the transportation sector can drive low-carbon hydrogen production at scale. This initiative will focus on advancing heavy-duty fuel-cell electric vehicle and hydrogen fueling infrastructure technologies to reduce costs, improve efficiency, and accelerate vehicle adoption.



New Research Kicking Off Soon:

Hydrogen Fuel Cell Demonstrations in Rail and Marine Applications at Ports (H2RAM) to pilot the use of hydrogen to reduce emissions from locomotives and harbor craft.

In Late 2020:

CEC R&D solicitations to support technological advances in advanced combustion systems and solar heating, cooling, and power to reduce natural gas demand for industrial applications.

And—stay tuned:

Studies establishing long-term strategies for decarbonizing natural gas use in California and opportunities to participate in the CEC’s public processes, which shape future R&D, lie ahead.

Discover The Power Of Energy Innovation

http://innovation.energy.ca.gov/SearchResults.aspx?cat=Program&subj=Natural%20Gas

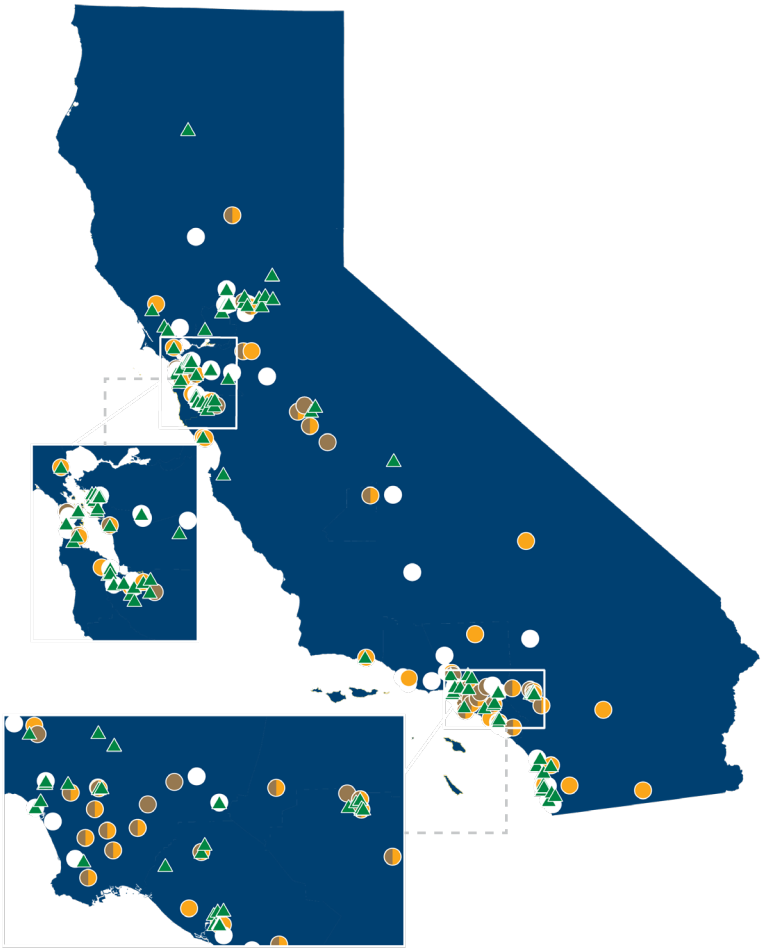
Get additional technical details on the projects highlighted here and learn about many other cutting-edge research projects funded by the Natural Gas R&D Program on **CEC's Energy Innovation Showcase.** There you will find project descriptions, fiscal details, benefits, latest status, and more.

Natural Gas R&D Program Recipient Headquarters and Project Site Locations

Recipient Headquarters

Project Site Locations

- Disadvantaged Community
- Low-Income Community
- Disadvantaged and Low-Income Community
- Neither Disadvantaged Nor Low-Income Community



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