SoCalGas

Innovation with Impact

RESEARCH, DEVELOPMENT, AND DEMONSTRATION 2024 ANNUAL REPORT

projects

SoCalGas Research, Development, and Demonstration (RD&D) identifies and supports projects and technologies with the potential to save energy, reduce greenhouse gas (GHG) emissions, improve air quality, and increase the safety, reliability, and affordability of energy for all SoCalGas customers.

$9.8M
TOTAL DOLLARS SPENT ON RD&D PROJECTS

42
PROJECTS INITIATED

70
PROJECTS COMPLETED

226
ACTIVE PROJECTS

community engagement

SoCalGas strives to deliver benefits to people in Environmental and Social Justice (ESJ) Communities through the RD&D projects it supports and its diverse supplier network.

NUMBER OF RD&D PROJECTS LOCATED IN ESJ COMMUNITIES **41**

$1.08B

TOTAL SOCALGAS DOLLARS SPENT WITH DIVERSE BUSINESS ENTERPRISES (DBES)

608 **TOTAL NUMBER OF DBES THAT SOCALGAS DID BUSINESS WITH IN 2024**

IMPACT / 2024 AT A GLANCE

benefits

Number of active SoCalGas RD&D projects designed to

IMPROVE AFFORDABILITY

95

IMPROVE AIR QUALITY

117

INCREASE OPERATIONAL EFFICIENCY

111

REDUCE GHG EMISSIONS

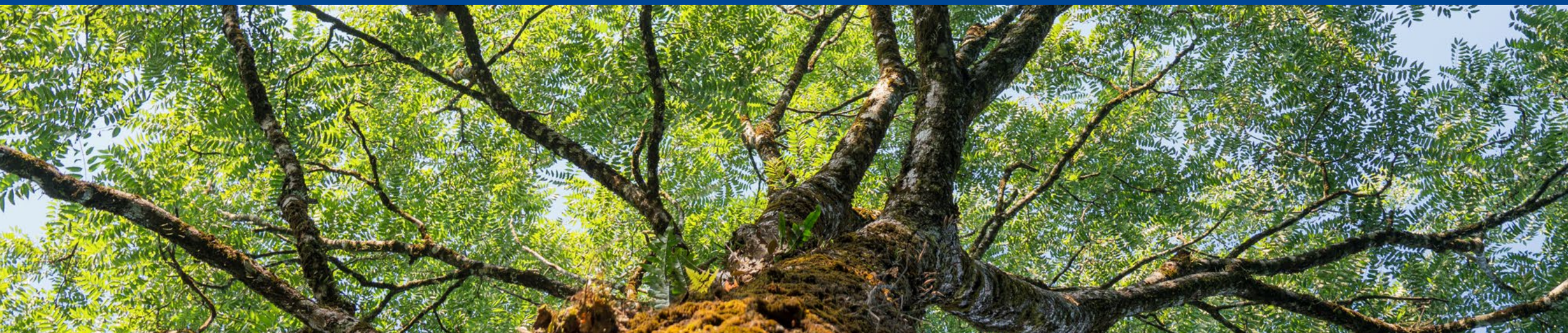
145

IMPROVE RELIABILITY

137

IMPROVE SAFETY

124



amplifying ratepayer value

On average, every dollar of RD&D funds expended in 2024 was matched by $7.10 of co-funding from other sources, including the US Department of Energy, the California Energy Commission, and out-of-state research consortia.

$309M IN TOTAL CO-FUNDING FOR ALL ACTIVE RD&D PROJECTS

AWARDED TO RD&D PROJECTS FROM THE CALIFORNIA ENERGY COMMISSION **$9.4M**

$5M AWARDED TO RD&D PROJECTS FROM THE US DEPARTMENT OF ENERGY

AWARDED TO RD&D PROJECTS FROM STATE AND FEDERAL AGENCIES **$14.4M**

IMPACT / 2024 AT A GLANCE

knowledge sharing & commercialization

SoCalGas RD&D presented the results of the projects it supported at numerous industry events and in many different articles, reports, and technology briefs to share knowledge and benefit even more stakeholders.

15

INDUSTRY EVENTS WHERE SOCALGAS RD&D PROJECTS WERE PRESENTED

$860M

IN FOLLOW-ON FUNDING AWARDED TO RD&D ALUM

32

PROJECTS FEATURED IN ARTICLES, REPORTS, AND TECHNOLOGY BRIEFS

Contents

“Californians need energy to be safe, affordable, reliable, and increasingly decarbonized. Renewable natural gas, hydrogen, and other technologies have tremendous potential to reduce greenhouse gas and nitrogen oxide emissions, particularly in communities of concern. These technologies are proven and are getting better—and more affordable—all the time.”

—MARYAM BROWN
CHIEF EXECUTIVE OFFICER
SOCALGAS

Introduction

Innovation is helping decarbonize California's gas system. Around the state and across the country, scientists and engineers at national laboratories, research consortia, universities, and private organizations are pursuing research, development, and demonstration (RD&D) projects exploring technologies and cleaner fuels that can lower emissions and improve air quality, while continuing to provide the safe, reliable, and affordable energy that ratepayers demand.

California and its residents are already experiencing the impacts of the changing climate, including observable shifts in the frequency and severity of extreme weather events, such as heat waves and wildfires, more variable precipitation, floods, and droughts (California Climate Adaptation Strategy, 2025).

According to the World Meteorological Organization (WMO), 2024 was the hottest year on record, with the global average temperature reaching 1.55°C above pre-industrial levels (WMO, January 2025). In California, the average temperature, as measured in August, has risen from 71.3°F to 77.2°F since 1900 (National Centers for Environmental Information, 2025).

California is actively trying to reverse these trends by pursuing a broad range of decarbonization strategies, including electrification, carbon capture, and increasingly decarbonized fuels, such as renewable natural gas (RNG) and clean, renewable hydrogen.

The cost of this energy transition is not trivial, with many of the new technologies and fuels costing significantly more than their traditional fuel counterparts. Unfortunately, the greatest impacts of these higher costs often fall on people from California's ESJ communities (CPUC ESJ Plan, v.2).

Fortunately, the state's natural gas system—which is highly interdependent with its electric system—can help mitigate this cost impact and provide energy reliability and resiliency. Natural gas is a flexible resource, enabling deeper

> "The attainment of public policy goals at tolerable cost to society frequently requires technological breakthroughs. Many experts assert that making the transition to a low-carbon future at an affordable cost, for example, will demand such breakthroughs. Pertinent to the utility sector, R&D is essential for advancing long-term policy objectives mentioned earlier, namely, safety, reliability, cheaper energy, improved energy efficiency and a cleaner environment."
>
> —KEN COSTELLO
>
> PRINCIPAL RESEARCHER,
> ENERGY AND ENVIRONMENT
> NATIONAL REGULATORY
> RESEARCH INSTITUTE

penetration of renewable energy through its peak smoothing and energy storage attributes. Any plan to decarbonize the world's economy also includes a transitional role for domestically abundant and affordable natural gas.

Hundreds of such projects are underway. At Caltech, engineers are developing a hybrid electrochemical, catalytic approach for generating compressed hydrogen on demand. At sites in Europe and the United States, researchers conducted field tests of advanced obstacle location technology for use in horizontal directional drilling, demonstrating impressive improvements in safety and affordability by eliminating the need for costly digging when installing new underground infrastructure. And at Oak Ridge National Laboratory, a team successfully retrofitted a cooking range and oven with a flameless radiant burner technology that can safely operate on 100% hydrogen or hydrogen-natural gas blends—all without the emissions of nitrogen oxides (NOx).

SoCalGas RD&D Shepherds Technology from Laboratory to Market

With more than 21 million consumers served and one of the nation's largest networks of natural gas transmission, storage, and distribution infrastructure, SoCalGas can play a significant role in the ongoing decarbonization of the energy industry. Importantly, SoCalGas also actively supports projects and technologies on the forefront of the energy transition.

SoCalGas RD&D—a department within SoCalGas—is tasked with identifying and supporting projects and technologies with the potential to save energy, reduce GHG emissions, improve air quality, and increase the safety, reliability, and affordability of energy for all SoCalGas customers, including those in ESJ communities.

Driven by scientific research and collaboration with subject matter experts (SME) from universities, national laboratories, public agencies, private industry, and research consortia, RD&D staff is committed to accelerating the energy transition to affordable, increasingly decarbonized fuels and to educating policymakers, industry, and the public about the many opportunities and technological pathways to achieve that goal.

"California's energy system is undergoing a period of profound change... The pressing question for California is how we can manage this transition to minimize societal costs and unfair burdens on the remaining gas customers, while also ensuring GHG emission reductions, air quality improvements, and equitable outcomes among California's communities."

—GRIDWORKS

CALIFORNIA'S GAS SYSTEM IN TRANSITION

Over the years, SoCalGas RD&D has contributed funding for thousands of projects and technologies. In 2024, RD&D staff provided $9,751,204 in support of 226 projects developing exciting new approaches to the challenges of decarbonizing the gas supply, energy delivery and storage, and end-use applications such as power generation, commercial heating, and air conditioning.

Over time, this support has paid off, with numerous technologies in the RD&D portfolio moving from the laboratory to pilot-scale demonstrations to commercial deployments. Other projects supported by SoCalGas RD&D have influenced state and federal policies and regulations. Significantly, one project even catalyzed the growth of California's industry-leading RNG market (Spotlight: Success).

"Beyond the cost and performance of individual elements in the energy system, decision makers will also need to consider the full system implications and tradeoffs of technology investment choices for reliability, affordability, the environment, and equity."

—AN OVERVIEW OF CALIFORNIA'S ENERGY TRANSITION

CALIFORNIA COUNCIL ON SCIENCE & TECHNOLOGY

Our Values

The values of SoCalGas RD&D align with SoCalGas' mission:

Safe, Reliable, and Affordable energy delivery today.

Ready for tomorrow.

Equity

We champion technologies that support affordable access to cleaner, safe, and reliable energy for all Californians.

Science

Our experts in science, engineering, and policy work with the world's finest researchers in universities, national laboratories, and industry to seek answers to some of today's most pressing energy questions.

Synergy

We bring value to our ratepayers by pooling knowledge and funding with researchers, utilities, and research consortia throughout California and across the United States.

Ratepayer Benefits

IMPROVED AFFORDABILITY RD&D drives innovations that lower energy costs and expand access to increasingly decarbonized, affordable energy for all Californians, including those in ESJ communities.

IMPROVED AIR QUALITY By advancing technologies that reduce harmful pollutants like carbon monoxide, particulate matter, and nitrogen oxides, RD&D improves the air Californians breathe, promoting healthier communities.

OPERATIONAL EFFICIENCY RD&D enhances energy systems to deliver peak performance while utilizing minimal resources, reducing waste and energy consumption, and lowering costs for ratepayers.

REDUCED GHG EMISSIONS RD&D advances renewable natural gas, increasingly clean, renewable hydrogen production, and advanced leak detection technologies, which could significantly reduce GHG emissions from customer-owned equipment as well as SoCalGas facilities.

RELIABILITY As Californians face increased threats posed by climate change—from wildfires to increasingly powerful storms—RD&D is developing technologies to ensure ratepayers have an adequate, secure, and resilient supply of energy, even during Public Safety Power Shutoffs.

SAFETY RD&D develops advanced technologies to protect gas pipelines and the Californians who live, work, and recreate near them while also enhancing safety in behind-the-meter systems and emerging gas applications.

2024
IN REVIEW

"The potential gains from adaptation of new technologies and business approaches to a 'mature' industry are large, and studies indicate the potential consumer benefits from RD&D outweigh the costs by up to 5:1 multiples."

—ENERGY REGULATION QUARTERLY
SHOULD RATEPAYERS FUND INNOVATION

Financial Highlights

Updates on the 2023 Research Plan

On June 15, 2022, SoCalGas submitted its 2023 RD&D Research Plan through Advice Letter (AL) 5991-G, seeking approval for a spending level of $16,874,000. Pending a Commission Resolution on AL 5991-G, SoCalGas ceased entering into new agreements for RD&D projects on January 1, 2023. During 2023, SoCalGas maintained its ongoing RD&D activities for multi-year programs previously approved by the CPUC, including project agreements entered during 2022 and prior.

On November 30, 2023, the Commission issued Resolution G-3601, which partially approved and modified SoCalGas AL 5991-G, setting the funding level for the 2023 RD&D Plan at $16,874,000, with program administration capped at 10 percent of the total budget. SoCalGas was further authorized to spend its approved 2023 RD&D funding in calendar year 2024. SoCalGas was also ordered to reallocate $7,301,717 of its 2023 Gas RD&D funding from several subprograms within the Low Carbon Resources (LCR), Clean Generation (CG), and Customer End-Use Applications (CEUA) programs, as well as from all four subprograms in the Clean Transportation (CT) program.

In compliance with Resolution G-3601, SoCalGas submitted a revised 2023 Research Plan (AL 6273-G) incorporating the modifications required by the CPUC. On April 10, 2024, the CPUC's Energy Division approved the revised 2023 Research Plan as submitted.

In 2024, all new projects were initiated under the approved 2023 revised Research Plan.

226

TOTAL **ACTIVE PROJECTS** IN 2024

TOTAL **PROJECTS INITIATED** IN 2024

42

TOTAL **PROJECTS COMPLETED** IN 2024

70

"Putting together the resources for the Oakview Science Camp is not cheap. We have projects involving small solar panels, electric motors, wind turbines, LED lights, and water electrolysis. SoCalGas RD&D provided the financial resources we needed so that when the kids arrived, they could go to work with the supplies they needed."

—DR. ROBERT FLORES

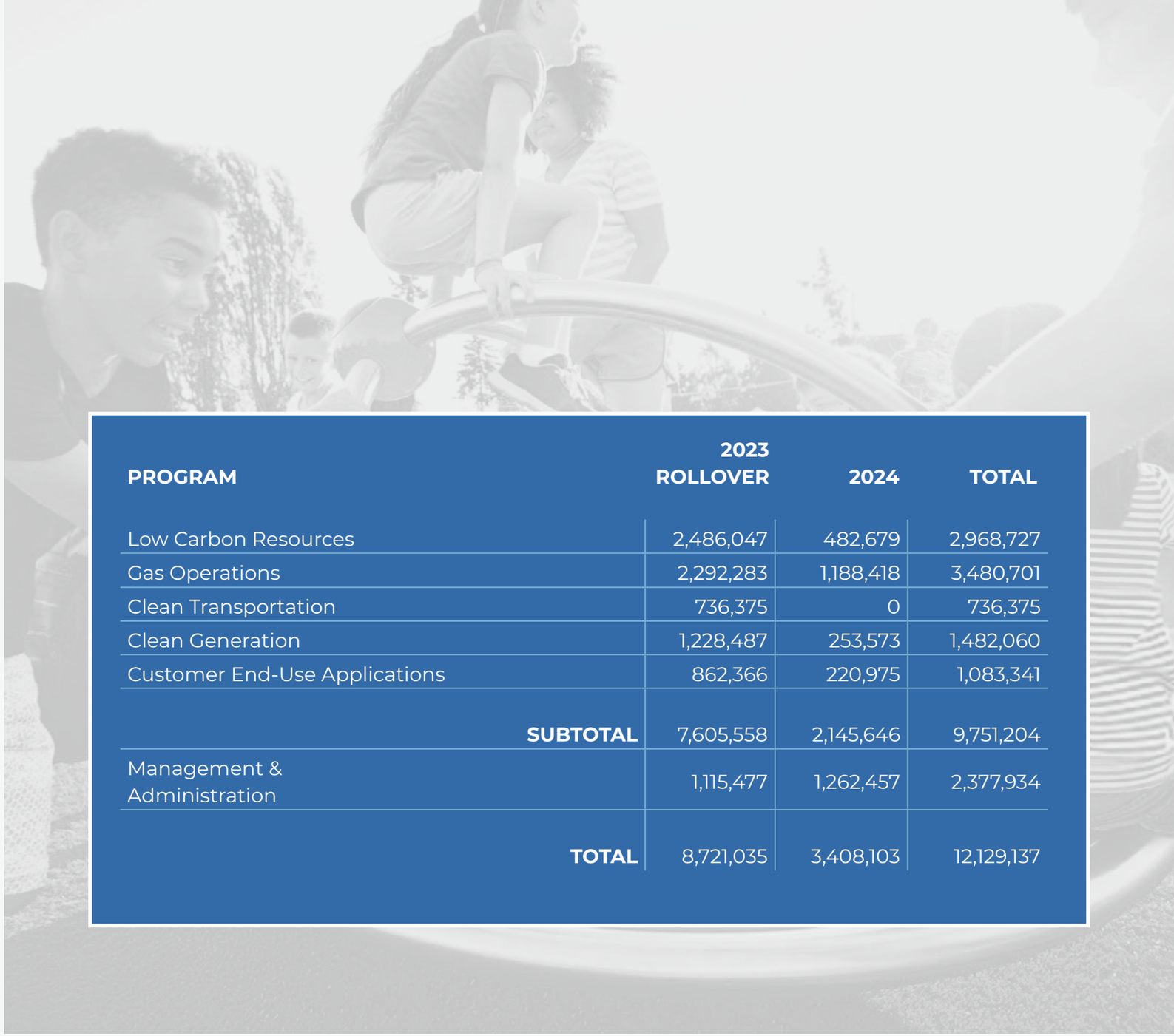
SENIOR SCIENTIST
CLEAN ENERGY INSTITUTE
UNIVERSITY OF CALIFORNIA, IRVINE

2024 Funds Expended

In 2024, SoCalGas differentiated expended funds as: 1) 2023 roll-over funding and 2) 2024 expenditures per the 2024 General Rate Case, including labor.

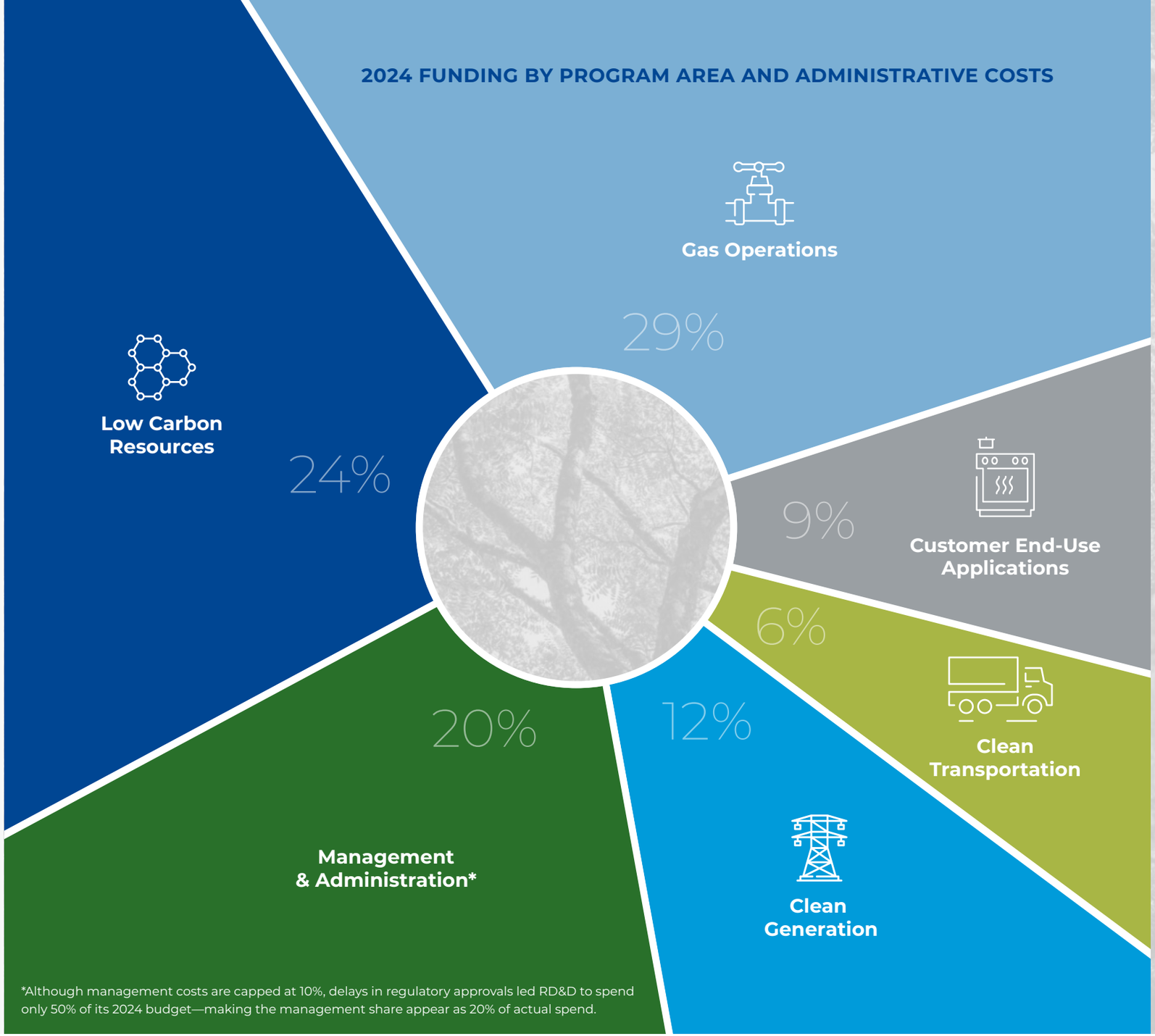
SoCalGas maintained its ongoing RD&D activities for multi-year programs previously approved by the CPUC, including agreements entered during 2023 and prior. As authorized by the CPUC in the approved AL-6273-G, it also spent funds closing out projects within five retired subprograms. In addition to rollover funds from 2023, SoCalGas RD&D incurred labor costs associated with supporting existing projects and programs in two retired subprograms, as well as program administration costs in 2024.

In 2024, SoCalGas RD&D provided $9,751,204 in funding to numerous projects across the gas value chain, with an additional $2,377,934 going to program management and administration. Collectively, the 226 active projects in the RD&D portfolio have leveraged or will leverage $309,444,735 in co-funding over the project lifetimes from businesses, research consortia, the California Energy Commission (CEC), the United States (U.S.) Department of Energy (DOE), and other participating organizations. On average, every dollar of RD&D funds committed was matched by $7.10 of funding from other sources in 2024.



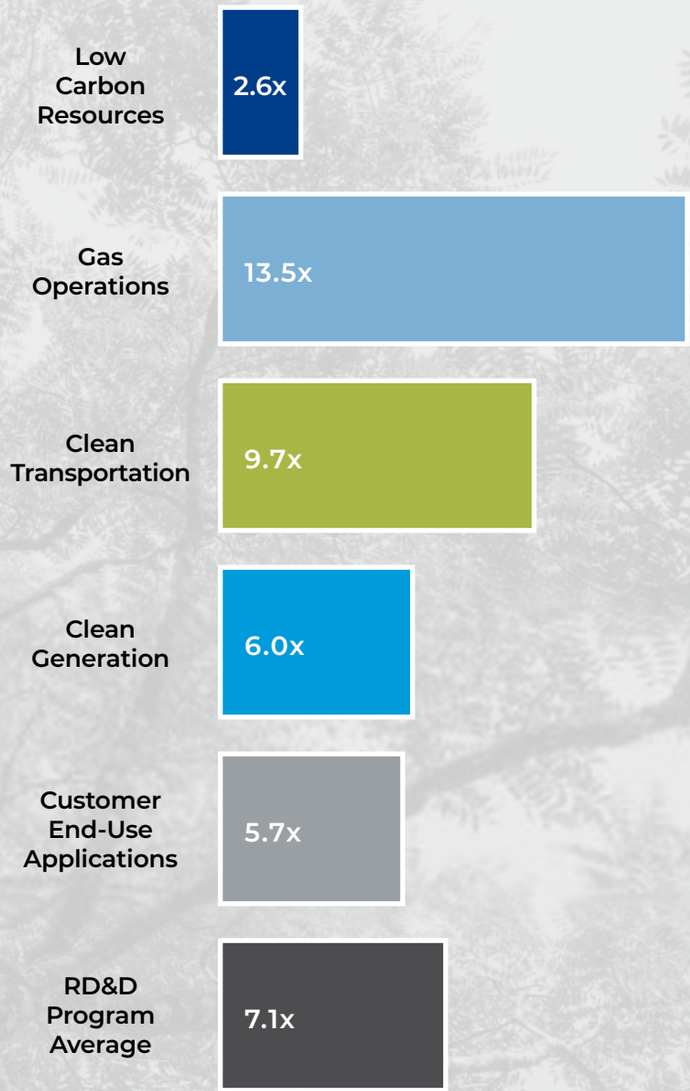
PROGRAM	2023 ROLLOVER	2024	TOTAL
Low Carbon Resources	2,486,047	482,679	2,968,727
Gas Operations	2,292,283	1,188,418	3,480,701
Clean Transportation	736,375	0	736,375
Clean Generation	1,228,487	253,573	1,482,060
Customer End-Use Applications	862,366	220,975	1,083,341
SUBTOTAL	7,605,558	2,145,646	9,751,204
Management & Administration	1,115,477	1,262,457	2,377,934
TOTAL	8,721,035	3,408,103	12,129,137

2024 FUNDING BY PROGRAM AREA AND ADMINISTRATIVE COSTS



*Although management costs are capped at 10%, delays in regulatory approvals led RD&D to spend only 50% of its 2024 budget—making the management share appear as 20% of actual spend.

RATIO OF OUTSIDE FUNDING TO SOCALGAS FUNDING FOR ALL RESEARCH PROJECTS ACTIVE IN 2024



SoCalGas catalyzes RNG market growth

A 2010 demonstration project in the City of Escondido, California, helps drive new legislation, regulation, and reductions in GHG emissions.

SPOT LIGHT on Success

Collaborators:
City of Escondido, Burns & McDonnell, Xebec Adsorption

Project Benefits:

IMPROVED AIR QUALITY

REDUCED GHG EMISSIONS

SoCalGas helped catalyze the growth of California's RNG market through its support for a demonstration project at the Hale Avenue Resource Recovery Facility in the City of Escondido.

The Challenge

Today, renewable natural gas (RNG) is a decarbonized fuel characterized by its ultra-low or negative carbon intensity (CI) and "drop-in" compatibility with existing natural gas infrastructure and end uses. It is widely used across California in transportation, power generation, and heating applications. Primarily made from biogas—a mixture of gases produced through the breakdown of organic matter in anaerobic digesters—RNG is the only commercially available fuel to frequently boast a negative carbon intensity, meaning that its use can effectively remove carbon from the atmosphere, depending on the feedstock and production methods. A negative CI score brings additional benefits, enabling producers to take advantage of monetary incentives such as federal Renewable Energy Credits (REC) and California's Low Carbon Fuel Standard (LCFS).

In 2010, the landscape was quite different. California produced a fraction of today's RNG volumes. And,

SPOT LIGHT on Success

although researchers had demonstrated RNG injection into a natural gas pipeline on a small scale, no one had done so at a level inspiring confidence it could be done across California's extensive natural gas system. Furthermore, many project developers doubted it was even technically possible or financially feasible to upgrade biogas to pipeline-quality standards, such as SoCalGas Rule 30 (SoCalGas, 2024).

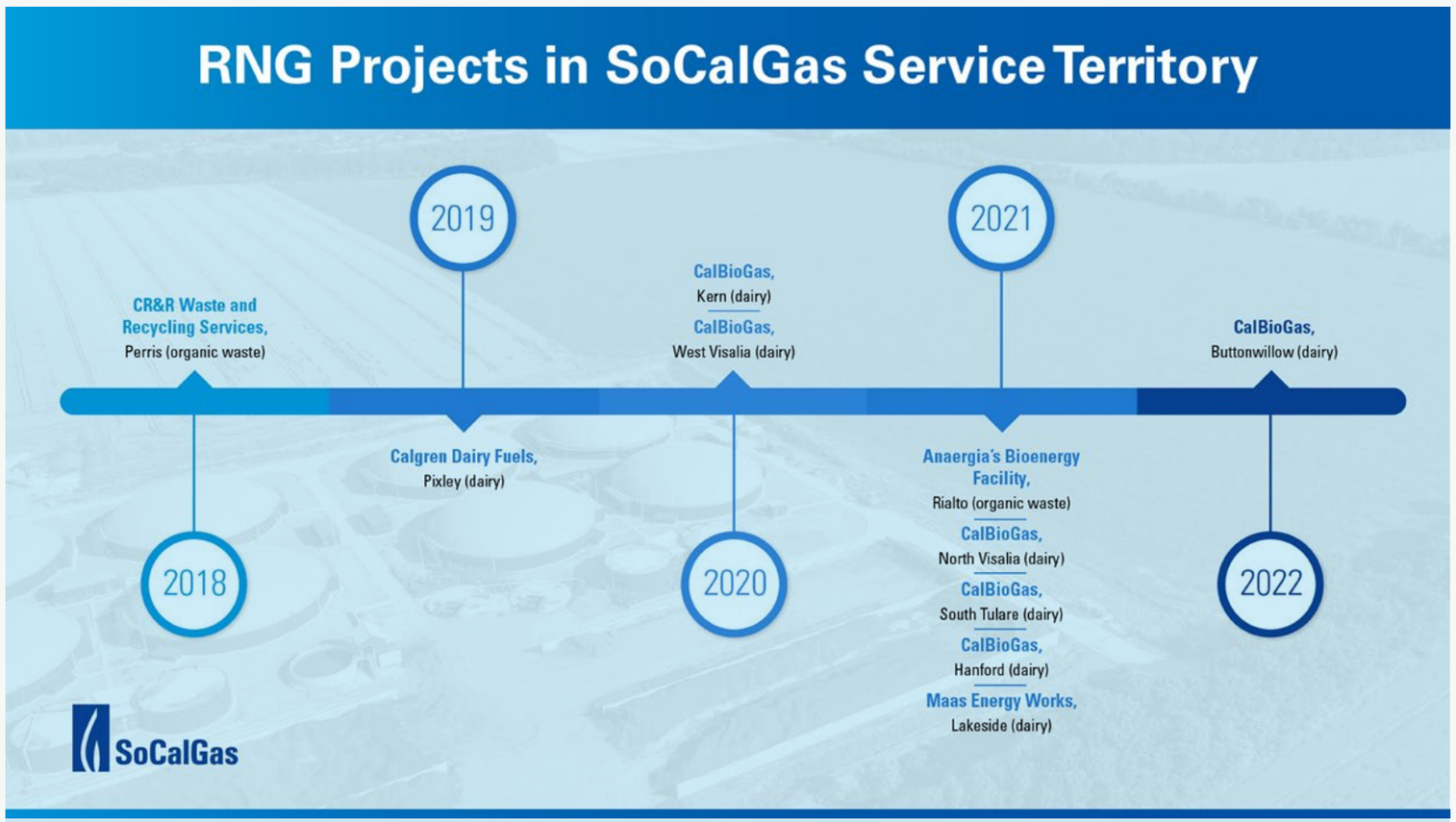
Without a viable end-use for biogas, organic waste is frequently disposed of in landfills, where it decomposes, emitting significant quantities of methane into the atmosphere. In many cases, landfills, dairies, and wastewater treatment plants that possess anaerobic digesters regularly flare the biogas they produce for lack of a better option.

The Solution

In response to these challenges, in 2010, SoCalGas RD&D conducted a demonstration project at the Hale Avenue Resource Recovery Facility (HARRF) located on the grounds of the City of Escondido Wastewater Treatment Plant. At that time, the HARRF flared raw digester gas at a rate of roughly 175 cubic feet per minute, enough to satisfy the natural gas demand for nearly 1,200 homes.

"We were inspired by the realization that a significant amount of biogas was being wasted through flaring near natural gas pipelines," said Ron Kent, former Manager of Advanced Technologies, Strategy, and Development at SoCalGas RD&D. "And, because the project was situated next to low-income housing, we recognized the potential to enhance air quality and benefit the surrounding families by eliminating biogas flaring."

Working closely with engineering firm Burns & McDonnell and equipment manufacturer Xebec Adsorption, SoCalGas RD&D sought to demonstrate the feasibility of conditioning raw digester biogas into pipeline-quality RNG. Project goals included designing, manufacturing, and installing a pressure swing adsorption (PSA) gas conditioner and demonstrating it for 12 months. As part of the demonstration, SoCalGas sought to evaluate, validate, and improve both the feasibility of the PSA gas separation technology and the efficacy of related digester gas sampling, analysis, and monitoring instruments and protocols.



SoCalGas RD&D's work on the City of Escondido project helped catalyze the RNG market in California and helped lead to the development of many new RNG projects.

SPOT LIGHT

on Success

SoCalGas broke ground in August 2010 and began testing the new technology in the fourth quarter of that year. At the heart of the system was Xebec's advanced PSA, which separates methane from other digester gas constituents—such as carbon dioxide, water vapor, nitrogen, and silicon compounds—producing one stream of low-energy "tail gas" and another stream of high-energy, methane-rich "product" gas that met Rule 30 specifications.

"I was impressed by the scale of the HARRF project, a field demonstration at an operational biogas producer," said Matt Gregori, Technology Development Manager for Customer Solutions at SoCalGas RD&D, who served as an intern at SoCalGas RD&D during the project. "Our objective was to demonstrate the feasibility of conditioning and upgrading biogas to meet rigorous RNG standards for pipeline injection in a real-world application." The HARRF project demonstrated that SoCalGas could upgrade biogas to the company's stringent gas quality standards and that the City of Escondido could reduce the amount of gas that it flared by more than 90 percent.

The project demonstrated that SoCalGas could upgrade biogas to the company's stringent gas-quality standards.

Early Success Catalyzed Market Growth

"In response to the success of the HARRF project, the California Public Utilities Commission (CPUC) required the state's major gas investor-owned utilities (IOUs) to conduct demonstration projects at dairy digesters throughout the state," said Gregori. Promising results on those projects led to the passage in 2018 of Senate Bill (SB) 1440, establishing an RNG procurement program for California's natural gas IOUs. By 2023, approximately five percent of the natural gas delivered by SoCalGas was sourced from RNG (SoCalGas Newsroom, March 2024).

"The City of Escondido project undoubtedly made an impact on the RNG sector," said May Lew, Principal Engineer at SoCalGas. "I've engaged in discussions and presentations with numerous transmission and distribution peers and consultants regarding our RNG specifications. As a result, elements of our project have been incorporated into pipelines or tariffs across the country."

"It is only appropriate that California adopt policies to encourage the use of renewable methane molecules

SPOT LIGHT

on Success

just as it pioneered the development of requirements for renewable electrons with renewable portfolio standards," said Jim Lucas, Commercial Development Manager for RNG at SoCalGas. "Moving to renewable energy of all kinds not only helps address climate change but also supports the creation of a more sustainable society in which all waste is reused, recovered, and recycled."

Project developers also took notice of the project's success. In fact, all of the RNG producers in the California market today can be traced back to this early RD&D project. "This was the most important project for RNG market development in California," said Lucas. "At that time, project developers had real doubts about being able to meet the gas quality specifications. The HARRF project showed, with hard data, that it could be done. Its success gave the industry confidence to start investing in commercial projects."

Conclusion

Equally as important, the project demonstrated the value of RD&D. "The projects that we support require patience," said Gregori. "They rarely have an immediate, measurable impact. But over time—sometimes as long as a decade or more—they can lead to dramatic changes in how we generate power, harness and transport energy, and use heat in industrial applications such as cement and steel production. It just takes patience."

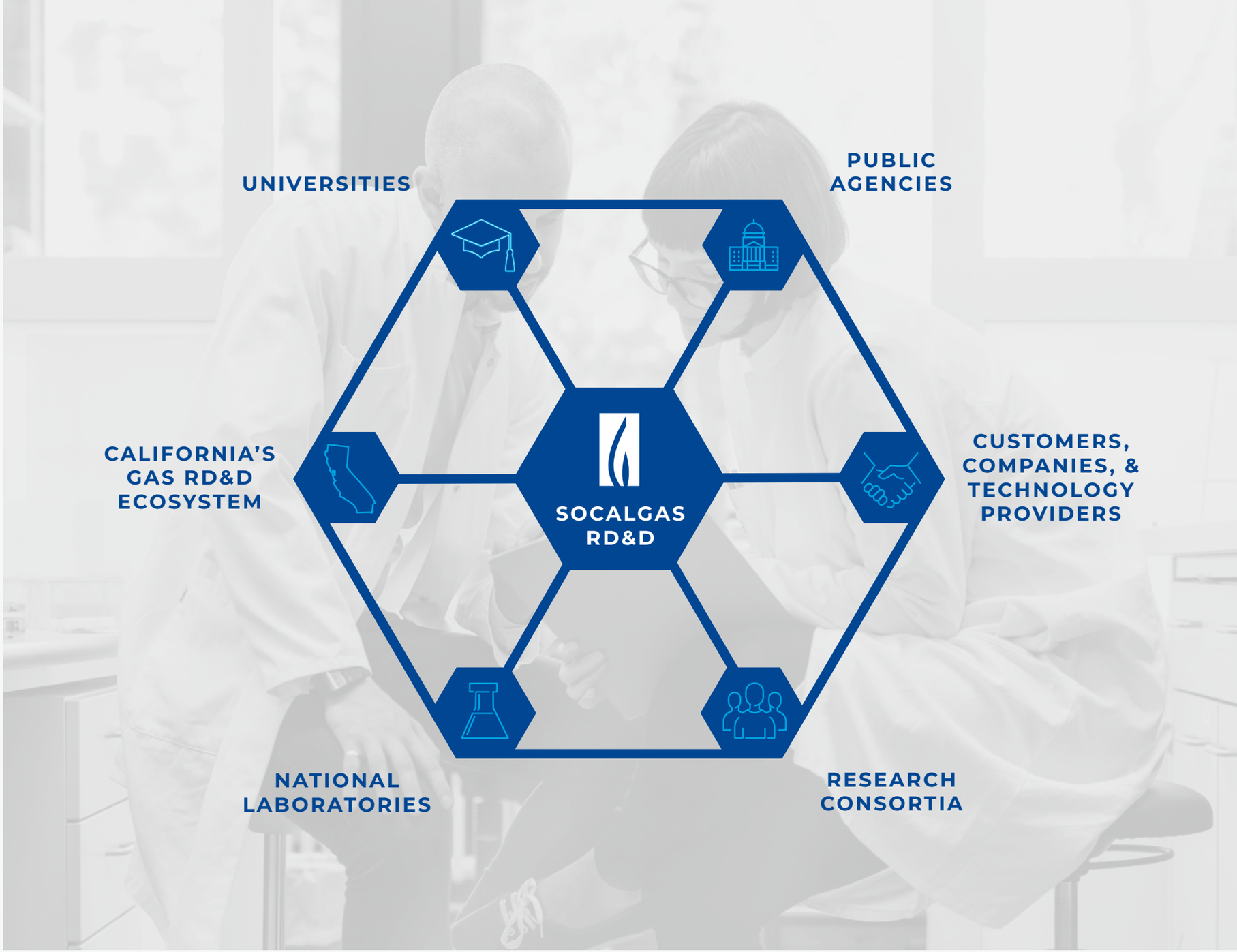
That patience paid off with the HARRF project. According to the California Energy Commission, California now has 27 dairy farms, five wastewater treatment plants, and five landfills that produce RNG from organic wastes, with many more making beneficial use of the biogas they produce (CEC, 2023).

"That, in turn, has resulted in the injection of approximately 4.2M Therms of RNG into the SoCalGas and San Diego Gas & Electric network," said Gregori. "That's the equivalent of taking approximately 52,000 gas-powered cars off the road in one year and taking more than 222,000 metric tons of carbon dioxide out of the atmosphere."

Beyond emissions reductions, the expansion of RNG production also brings economic and air quality benefits to ESJ communities, where many waste processing facilities and transportation corridors are located, helping to create local jobs and improve public health by reducing exposure to harmful pollutants.

2024 Research Collaborators

SoCalGas RD&D is a vital element of a much larger technology funding ecosystem that includes universities, national laboratories, public agencies, businesses, gas industry research consortia, and California's robust Gas R&D ecosystem. SoCalGas RD&D staff work with professionals and subject matter experts from these organizations to maximize the impact of their investments in promising technologies and products with clear commercialization pathways.



Universities

SoCalGas collaborates with scientists, engineers, and other academics at some of our nation's most prominent universities. These professionals perform fundamental scientific work on a variety of critical energy topics, including fuel cell development, hydrogen production and energy storage, and carbon capture and use.

National Laboratories

The U.S. National Laboratories and Technology Centers form a system of facilities and laboratories overseen by DOE to advance science and technology. Researchers and scientists at the 17 national labs tackle the critical scientific challenges of our time and possess unique instruments, equipment, and testing facilities.

Gas Research Consortia

SoCalGas RD&D staff have developed ties with several research consortia focused on the natural gas industry. The membership of many of these organizations consists of utility companies across North America and the world. Typically, these consortia serve member utilities by facilitating technical collaboration and pooling of financial and technical resources to collectively address ongoing or anticipated challenges in the gas industry. SoCalGas can also learn from consortia how to prepare from an operational and safety perspective for scenarios—such as a deep freeze—that do not occur frequently in its service territory. By working closely with these and other similar organizations, RD&D staff can share knowledge, avoid needless duplication of work, and develop and execute impactful projects.

Importantly, by pooling funding with other consortia members on projects addressing challenges faced by California gas utilities, SoCalGas RD&D magnifies the impact of its funding manyfold. In 2024, for every dollar provided by SoCalGas RD&D to projects managed by research consortia, other consortia members—most of which are from outside California—provided $16.57.

See Appendix for more information.

Public Agencies

At local, state, and federal levels, public agencies play a key role in driving the RD&D process, from disseminating project solicitations related to regulatory policy objectives to serving as thought leaders that help shape broad energy strategies. RD&D staff regularly work with numerous agencies to reduce many of the risks associated with deploying staff and resources on untested products and technologies.

Customers, Companies, & Technology Providers

At its core, SoCalGas RD&D is about developing and promoting practical applications to overcome challenges facing the energy sector, in alignment with California's decarbonization goals. To ensure the new technologies and products supported by SoCalGas advance to real-world applications and markets, RD&D staff leverage their connections, knowledge, and expertise by working closely with leading equipment manufacturers, start-ups, global technology developers, and SoCalGas customers to demonstrate new technologies in large-scale and/or long-term pilot demonstration projects under real-world conditions in response to actual business needs.

California's Gas R&D Ecosystem

To further share knowledge, avoid duplication of work, and develop and execute impactful projects, representatives of SoCalGas RD&D meet with their counterparts from Gas R&D programs at the California Energy Commission and two investor-owned utilities (IOUs), Pacific Gas and Electric Company (PG&E) and Southwest Gas

Helping all Californians participate in the energy transition

Researchers drive down capital and operating expenses associated with clean renewable hydrogen production.

SPOT LIGHT on Affordability

Program:
Low Carbon Resources

Collaborators:
EVOLOH, Caltech

Project Benefits:

- AFFORDABILITY
- OPERATIONAL EFFICIENCY
- IMPROVED AIR QUALITY
- REDUCED GHG EMISSIONS

On a project exploring reducing hydrogen compression costs, Caltech Staff Scientist Mason Jang uses a tube furnace to synthesize the molybdenum carbide catalyst.

California has a statutory goal of reducing anthropogenic emissions by at least 85% below 1990 levels and achieving carbon neutrality by 2045 (CARB, 2022). The California Air Resources Board's 2022 Scoping Plan anticipates that scaling up renewable hydrogen will play a role in that transition for hard-to-electrify end uses.

"By supporting promising technologies, we hope to drive down operational and production costs for increasingly decarbonized fuels such as renewable natural gas (RNG) and hydrogen," said Dr. Ethan Simonoff, Project Manager—Technology Development at SoCalGas RD&D.

Recently, SoCalGas RD&D supported two projects that could, if advanced to full commercialization, significantly reduce both the capital and operating expenses associated with the production and consumption of hydrogen. The first, led by technology developer EVOLOH, sought to enhance

SPOT LIGHT

on Affordability

the manufacturing process for electrolyzers used to produce hydrogen. In the second, Caltech researchers explored a novel production technology that could reduce compression costs—a major expense in hydrogen production systems.

New technology cuts costs significantly

The industry standard in electrolyzers uses a proton exchange membrane (PEM), which efficiently produces high-purity hydrogen, but relies upon rare and costly minerals—such as iridium and platinum—whose relative scarcity can lead to unpredictable price fluctuations. These electrolyzers are also difficult to manufacture, transport, and install, further increasing costs. A competing technology, the alkaline electrolyzer, performs well and is relatively affordable, but is complex and massive, and cannot produce hydrogen at high pressures. Neither system has been optimized for manufacturability.

Finding a way to bring down electrolyzer costs is critical to the growth of an increasingly clean, renewable hydrogen ecosystem. “Low-cost electrolyzer supply already cannot meet demand,” said Dr. Jimmy Rojas, CEO of EVOLOH. “Current technologies are struggling to scale due to expensive, complex balance-of-plant, vulnerable supply chains, and slow manufacturing—at a time when demand for cleaner hydrogen at or below $2 per kilogram is huge. That number is still out of reach. The whole industry is just stuck.”

EVOLOH's megawatt-scale advanced liquid alkaline electrolyzer stack.

In collaboration with SoCalGas RD&D, EVOLOH sought to develop a solution that addressed the limitations of current electrolyzer technology. “We have combined the good stuff from alkaline and PEM systems to create a hybrid solution that reduces the capital costs of manufacturing electrolyzers significantly,” said Rojas. “Our Nautilus™ series electrolyzer stack utilizes 100% domestically available earth-abundant minerals, is designed for easy integration into low-cost balance-of-plants, and relies on commercially available and scaled-up anion exchange membrane (AEM) that operates in an alkaline environment.”

“We developed a high-speed, roll-to-roll manufacturing process for every component of the electrolyzer stack,” said Rojas. “This is the same technology used to make solar cells, battery electrodes, and even newspapers. We just adapted it to a new technology.” Roll-to-roll manufacturing reduces costs by

SPOT LIGHT on Affordability

enabling continuous, high-speed fabrication, which minimizes material waste and reduces labor and energy inputs.

EVOLOH also designed its stack for easy system integration. “Typically, technology developers design an electrolyzer stack and then go through a process of figuring out how to integrate balance-of-plant components—such as power systems or heat exchangers—with the stack,” said Rojas. “We turned that approach on its head and talked to manufacturers of all major system components so that we could build a stack that integrated easily with the most affordable and widely available options out there.”

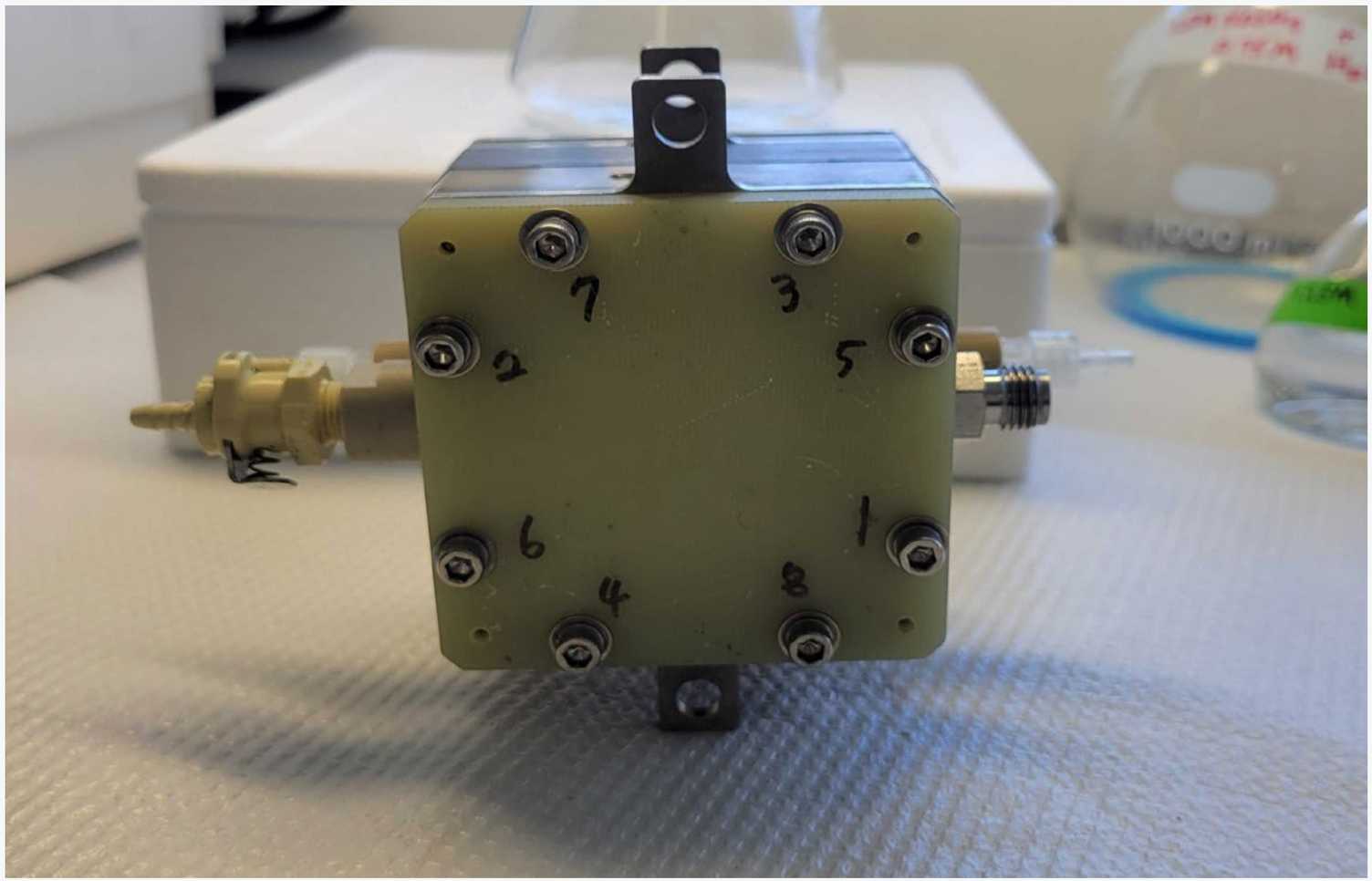
“That enabled us to completely change our business model because now we only need to make stacks,” said Rojas. “We don’t need to raise hundreds of millions of dollars just to put pipes and wires together. Somebody else can do that.” The EVOLOH stack also uses only commodity materials such as steel, aluminum, and plastic from 100% domestic sources.

“In comparison to the incumbent technologies, our systems will have significantly lower costs,” said Rojas. “We estimate that our enhancements to the electrolyzer manufacturing process and technology could drastically reduce capital costs and lower operational costs through improved system durability and efficiency—both of which reduce the levelized cost of hydrogen.”

Novel compression technology lowers hydrogen compression costs by an order of magnitude

Where the EVOLOH project sought primarily to lower capital costs, Caltech researchers developed a process by which they can produce hydrogen at the high pressures required by most applications without need for costly and unreliable mechanical compression.

“Many production processes can produce hydrogen at or slightly above atmospheric pressure quite affordably,” said Simonoff. “They then use mechanical compressors to achieve end-use pressures of 350 or 700 bar. Spanning that pressure difference can be



The 25-cm² electrolyzer used at Caltech for benchtop testing.

SPOT LIGHT

on Affordability

extremely expensive—in some cases costing more than the hydrogen production."

With support from SoCalGas RD&D, researchers at Caltech sought to close this pressure difference by optimizing hydrogen production for specific end uses through development of a batch-mode catalytic compression system that eliminates the need for costly mechanical compression. "The concept was very novel," said Chengxiang Xiang, Research Professor at Caltech. "It also had a lot of advantages, including low cost, no moving parts, and scalability."

The technology operates similarly to a flow cell battery, storing energy in an intermediate charged vanadium solution rather than relying on high-pressure systems. "At the anode, we use water oxidation to generate oxygen, protons, and electrons," said Xiang. "These protons move through a membrane to the electrolyte, where they help convert vanadium ions into a stable, energy-rich form. This stored energy can then be used in a separate step to produce hydrogen at high pressures, offering a more cost-effective alternative to conventional mechanical compression."

"The ability to store energy at ambient temperature and pressure is quite useful," said Xiang. "This enables the system to load-follow, for example, storing excess renewable energy at a solar farm and then producing clean renewable hydrogen when it is needed."

At that point, the charged vanadium electrolyte is pumped through a catalytic reactor, where a catalyst facilitates the production of hydrogen. "We essentially flow the electrolyte through a catalyst in a controlled system," said Xiang. "As hydrogen is generated, the system regulates pressure, allowing for a steady release at high pressures—offering a more efficient alternative to conventional compression methods."

"We proved that the science works in batch mode," said Xiang. "When you compare our system with those that use mechanical compression, we are roughly an order of magnitude lower in cost." In 2025, Xiang and his team plan on building a continuous-flow system. "Support from SoCalGas enabled our team to conduct our project in a very rigorous way. Ultimately, if we can prove this technology at commercial scale, it could bring down costs across the hydrogen value chain."

Passing Cost Savings to Ratepayers

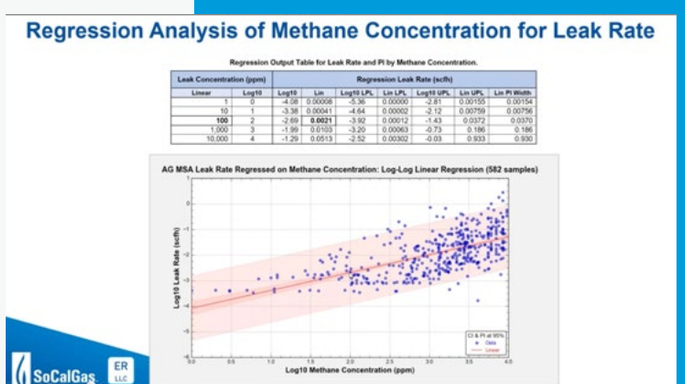
"One of the things we evaluate through our program and the projects we fund is how to support the availability of affordable, cleaner hydrogen and ensure that cost reductions from advancements in hydrogen production technologies contribute to broader energy affordability," said Simonoff. "Lower-cost hydrogen can help gas utilities transition more effectively toward meeting the State's climate goals."

Caltech graduate student Ryan J. Benavides assembling batch mode reactor for testing .

Stakeholder Engagement

2024 QUARTERLY NEWSLETTERS

Each quarter, SoCalGas RD&D increases transparency by sharing updates on its latest projects, collaborations, and events via a quarterly newsletter sent to more than 3,000 people and organizations in the energy industry.



RESEARCH WEBINARS

Impact of H2 Blending on an 18L Rich-Burn NG Engine with NSCR Catalyst

September 26, 2024: SoCalGas and Colorado State University discussed the impact of hydrogen (H2) blending on natural gas engines. Interest in H2 fuels is growing, with the industry planning to produce it with stranded or excess energy from renewable sources to reduce greenhouse gas emissions. This work explores the impact that H2-natural gas blends would have on "rich burn" (stoichiometric) engines with non-selective catalytic reduction, or 3-way, catalysts. Results indicate a significant reduction in GHG emissions up to 30 vol% H2 concentrations.

Company-Specific Emission Factors for Customer Meters

May 23, 2024: SoCalGas and Element Resources discuss company-specific leak-based natural gas emission factors (EFs) for distribution customer meter facilities. These new EFs are more robust and comprehensive than those developed under prior industry studies, with greater precision and statistical confidence. The approach developed by the SoCalGas research team under the SB 1371 program is also structured to take advantage of historic system data for trend analysis from past benchmark-year baselines.

PUBLICATIONS, PATENTS, AND CITATIONS

In 2024, 32 projects co-funded or otherwise supported by SoCalGas RD&D were featured in articles, reports, and technology briefs. Additionally, one technology supported by RD&D received a patent from the US Patent and Trademark Office.

See Appendix for more information.

Research Continuity

3 PROJECTS
WON A TOTAL OF
$14.4M
FROM FEDERAL AND
STATE AGENCIES

PUBLIC FUNDING AWARDS

One of the ways that SoCalGas seeks to reduce ratepayer costs is through identifying and securing co-funding for the projects that it supports. In 2024, RD&D staff supported four winning proposals that applied for public funding from both state and federal sources. These projects were awarded $14,392,968 in research funding, including $5,000,000 from federal sources, bringing valuable funds from Washington D.C. to California for the benefit of SoCalGas ratepayers.

Lead Investigator	Research Program*	SoCalGas RD&D Cash Funding Committed	Project Funding Awarded	Awarding Agency
Enchanted Rock	CG	$235,000	$2,142,968	CEC
Lawrence Berkeley National Lab	LCR	$400,000	$3,000,000	CEC
Noble Thermodynamic Systems	CG	$750,000	$5,000,000 $4,250,000	DOE CEC
	TOTAL	**$1,385,000**	**$14,392,968**	

**LCR (Low Carbon Resources) CG (Clean Generation)*

Research Continuity

FOLLOW-ON FUNDING

Numerous companies that received early support from SoCalGas RD&D highlight the program's success in identifying innovative early-stage technologies and accelerating their journey to market. By fostering partnerships, securing demonstration opportunities, and attracting additional public and private funding, these companies have achieved major milestones, such as proving technology viability, scaling up deployment, and advancing toward manufacturing and commercialization. In 2024, eight companies received follow-on funding totaling **$862,432,049**, further emphasizing SoCalGas RD&D's pivotal role in driving progress and market readiness.

8 RD&D ALUMNI RECEIVED MORE THAN

$860M

IN FOLLOW-ON FUNDING IN 2024

» **Brimstone:** The DOE's Office of Clean Energy Demonstrations awarded an up-to $189-million award to co-produce portland cement, a second concrete ingredient, and alumina from U.S.-sourced rocks. The new plant may be the first new American source of alumina—a critical mineral essential for defense, aerospace, transportation, and energy—in a generation.

» **Electrochaea GmbH:** Electrochaea, Carbonaxion Bioénergies, and Énergir received $345,000 from provincial and federal governments to develop an innovative Power-to-Gas project in Québec, Canada. The project will deploy Electrochaea's market-ready bio-methanation technology to convert renewable electricity into renewable methane.

» **Emission Free Generators:** Emission Free Generators received a total of $580,000 from Caltech's Rocket Fund, a corporate partner, and a high-net-worth individual to continue technology development and complete its Minimum Viable Product.

» **GTI Energy:** The DOE's Industrial Efficiency and Decarbonization Office awarded GTI Energy $3,252,049 to support the design and demonstration of a scaled, fuel-flexible adaptable omnivore combustion system with ultra-low NOx emissions. GTI Energy also won $7,000,000 from the DOE's National Energy Technology Laboratory for engineering-scale testing of the ROTA-CAP carbon dioxide capture system on real flue gas conditions at U.S. Steel's Edgar Thomson Steel Works.

» **RockeTruck:** RockeTruck received a $4-million grant from the CEC and a $1,150,000 award from the DOE to develop a solid-state transformer, DC power distribution network, and direct DC fast chargers for electric truck charging at the Ports of Los Angeles and Long Beach.

» **Twelve:** Twelve announced $645 million in funding, a mix of capital including $400 million in project equity led by TPG Rise Climate, $200 million in Series C financing, and an additional $45 million in credit facilities from leading funders in the renewable energy sector, marking this as one of the largest financing rounds to date in the e-fuels space. The funding will accelerate Twelve's plans to transform carbon dioxide into jet fuel and e-chemicals. Twelve also received a $2.1-million award from the Biden-Harris Administration for measuring surface ocean carbon.

» **Upstart Power:** In 2024, this growth-stage company raised an additional $25.5 million from its existing investors for further development and scaling of its high-performance, solid oxide fuel cell technology.

» **University of Wisconsin, Madison:** The DOE's Hydrogen and Fuel Cell Technologies Office awarded the University of Wisconsin, Madison, a $10-million grant to explore the use of clean renewable hydrogen to decarbonize steel production.

Research Continuity

DEPLOYED TECHNOLOGIES

A major goal of SoCalGas RD&D is to advance technology from the laboratory or pilot scale to deployment on SoCalGas infrastructure or the commercial market. SoCalGas and organizations across California and the nation regularly deploy products and technologies for real-world use that received support from SoCalGas RD&D. In 2024, SoCalGas RD&D supported the deployment of numerous new technologies, including:

- **Brimstone's Green Cement:** SoCalGas RD&D supported early-stage development of Brimstone's technology to convert carbon dioxide in the air into low-cost cement without process emissions. Brimstone has successfully scaled up this technology and is building a commercial-scale production facility in Oakland, California, in part with funds from the DOE. This technology has the potential to benefit ratepayers through reduced GHG emissions and improved air quality.

- **Intero's Pipe Explorer 20/26:** In the early 2000s, SoCalGas RD&D participated in research, development and demonstration for the Explorer robotic in-line inspection (ILI) tool, leading to its commercialization in 2011. Since then, SoCalGas RD&D has continued to support RD&D activities that have led to a series of advancements, improving the performance and efficiency of the Explorer ILI robot. Additionally, SoCalGas RD&D is supporting the demonstration of Explorer robots for improved pipeline mapping and to investigate energy harvesting systems that would extend robot operational life. These advancements will enhance pipeline integrity management, reduce inspection costs, and improve safety and reliability for California ratepayers. SoCalGas Integrity Management Program now both uses this robotic inspection platform and identifies and supports ongoing improvements.

- **Susteon's Catalytic Non-thermal Plasma (CNTP) Technology:** After its original development at NASA's Jet Propulsion Laboratory, SoCalGas worked closely with Susteon to scale and commercialize this technology. In 2025, SoCalGas RD&D plans to help demonstrate a CEC-funded bench-scale system at a biogas facility in California. This technology has the potential to benefit ratepayers through reduced GHG emissions and improved air quality.

- **University of California, Irvine's Solid Oxide Electrolysis Cells (SOEC) for Green Steel Production:** In 2021, SoCalGas RD&D provided $550,000 to help UCI design and develop a laboratory-scale zero-emission prototype for the direct reduction of iron (DRI) with hydrogen produced from an SOEC system. In 2024, the DOE awarded $10M of follow-on funding to support the development and deployment of the technology at Cleveland Cliffs Toledo DRI Plant. This technology has the potential to benefit California ratepayers through reduced GHG emissions, improved air quality, and increased operational efficiency.

- **Zero Emission Industries' (ZEI) FTcase Technology:** SoCalGas RD&D supported early efforts by ZEI to develop and demonstrate a portable hydrogen refueling application for mobile applications, including a harbor craft powered by a hydrogen fuel cell demonstrated by ZEI in the San Francisco Bay and Long Beach Harbor. ZEI has since received significant private investment to make this technology commercially available. This technology has the potential to benefit California ratepayers through reduced GHG emissions, improved air quality, and increased operational efficiency.

Events

Program staff spoke or presented at 15 events throughout the state and nation in 2024, sharing knowledge about the projects they supported and lessons learned.

2024 AIChE Annual Meeting

A representative from SoCalGas RD&D co-chaired this conference and also moderated a plenary session titled “Chemical Engineering Reimagined: Creating Ideas That Get to the Marketplace.” During this and another session, SoCalGas RD&D also presented information about some of the technologies and technology developers it has supported, including carbon-negative building composites and Twelve, which converts carbon dioxide into useful products.

2024 EPIC Symposium and Other EPIC Workshops/ Conferences

At the annual symposium, two SoCalGas RD&D staff members joined clean energy professionals, researchers, grantees, policymakers, industry leaders, technology developers, and entrepreneurs in learning about the latest innovations and advancements driven by the EPIC program. Representatives from SoCalGas RD&D also collaborated with other IOUs at other EPIC workshops throughout the year.

California Desert Air Working Group

A representative from SoCalGas RD&D served as a keynote speaker at this annual event, introducing SoCalGas RD&D, discussing some of its benefits, and highlighting eight RD&D projects focused on a variety of technologies, including ultra-low-NOx forced air residential furnaces, direct solar conversion of biogas to hydrogen, and low-cost catalyst and electrolyzer development.

Cleantech Forum North America

Three SoCalGas RD&D personnel attended this premiere annual event in sustainable innovation, meeting fellow innovators, highlighting one of the program's startup projects, and learning about key cleantech topics and investment trends. One moderated a panel titled “Hardtech is Hard, Scaling is Even Harder.” The panel highlighted innovators creating solutions to accelerate the scale-up of clean energy technologies.

Institute of Electrical and Electronics Engineers Power & Energy Society General Meeting

At this meeting, a SoCalGas representative introduced the RD&D program, discussed hydrogen integration into the grid, spoke about clean generation RD&D projects, and featured five projects.

Events

PG&E Innovation Summit

Three members of the SoCalGas RD&D team gathered with more than 800 leaders, innovators, and utility partners to collaborate on solutions that bridge to California's clean energy future, including RD&D projects focused on gas operations. The theme of the summit was artificial intelligence (AI).

Western Energy Institute Operations Conference

A representative from SoCalGas RD&D introduced SoCalGas RD&D to conference participants, spoke about the role of RD&D in decarbonization planning, and featured three projects focused on an ultra-efficient combined heat and power technology; the integration of metal hydride storage with renewable energy and fuel cells; and the demonstration of a mobile hydrogen fuel cell generation system, respectively.

Low-Carbon Resources Initiative Tech Week

This workshop highlighted low-carbon research, pilot testing, and demonstration activities in a series of sessions to promote technology transfer of research results and facilitate conversations among participants on how to address challenges with deploying low-carbon technologies. A representative from SoCalGas spoke about hydrogen infrastructure and gave a presentation on community engagement in SoCalGas' Angeles Link hydrogen hub project.

Hydrogen Annual Merit Review and Peer Evaluation

In 2024, SoCalGas RD&D sent four representatives to this annual event where hydrogen and fuel cell projects funded by DOE are presented, and projects and programs are reviewed for their merit. RD&D staff attended to support two of its projects led by the National Renewable Energy Laboratory, interact with other researchers, and stay informed about research in the hydrogen ecosystem.

2024 Community Engagement Activities

In 2024, SoCalGas RD&D undertook two major activities to build capacity in ESJ communities and help develop the next generation of innovators.

OAKVIEW SCIENCE CAMP

Working with graduate students from the University of California, Irvine's Clean Energy Institute, SoCalGas RD&D hosted approximately 30 pre-K to sixth-grade students for an afternoon of fun science experiments, including water electrolysis and solar-powered fans.

SOCALGAS SPENT

$1.08B

WITH **608** DIVERSE FIRMS IN 2024

SOCALGAS RD&D SUPPORTED

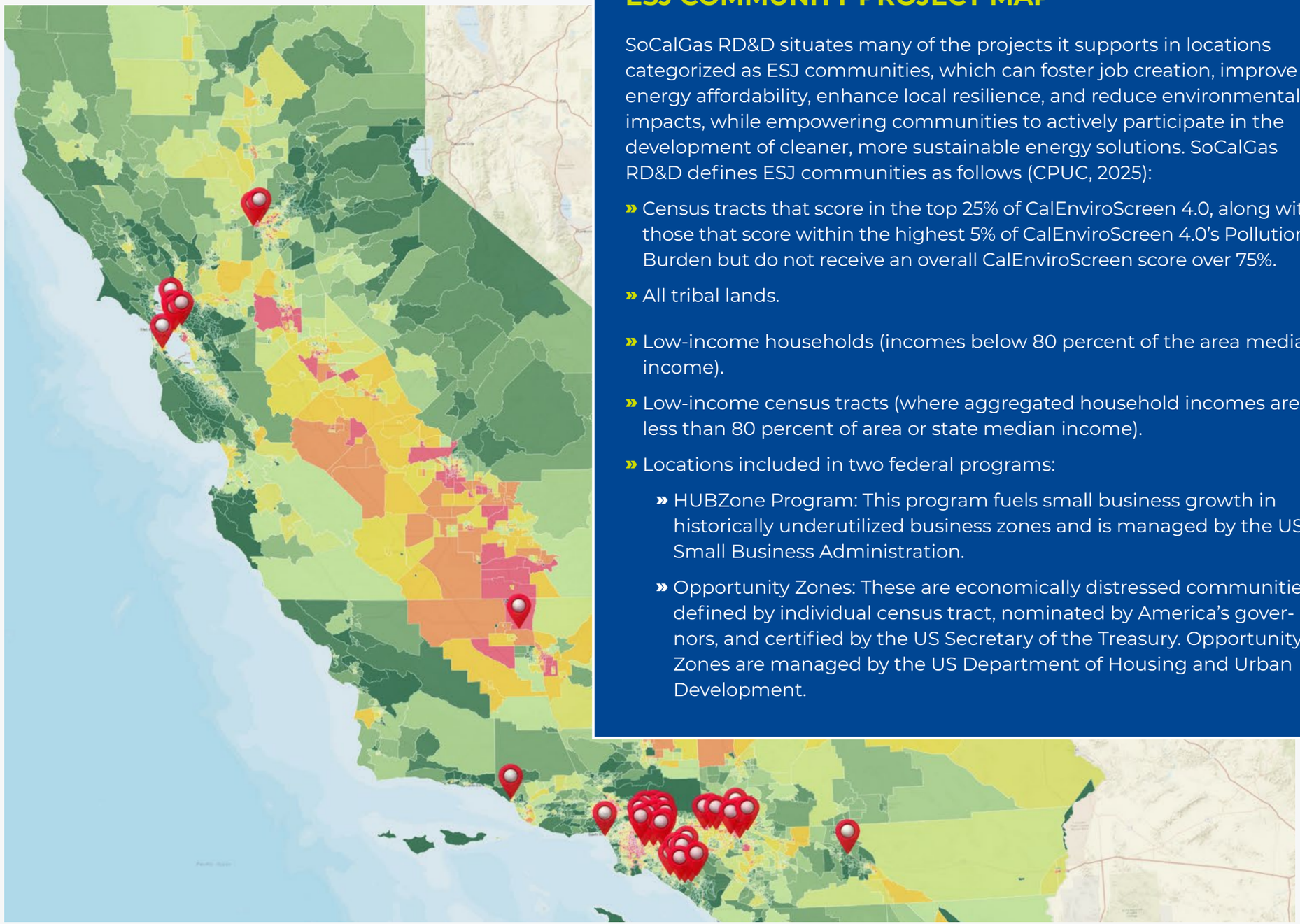
41

PROJECTS LOCATED IN ESJ COMMUNITIES IN 2024

HYDROGEN GRAND PRIX

SoCalGas RD&D collaborated with Horizon Educational to sponsor 10 high school teams at five Title I high schools throughout Southern California in the Hydrogen Grand Prix (H2GP). One of the teams made it as far as the 2024 H2GP World Finals held in Anaheim, California. A representative from SoCalGas RD&D served as a judge at the H2GP California State Finals and at the H2GP World Finals.

2024 Community Engagement Activities



ESJ COMMUNITY PROJECT MAP

SoCalGas RD&D situates many of the projects it supports in locations categorized as ESJ communities, which can foster job creation, improve energy affordability, enhance local resilience, and reduce environmental impacts, while empowering communities to actively participate in the development of cleaner, more sustainable energy solutions. SoCalGas RD&D defines ESJ communities as follows (CPUC, 2025):

- Census tracts that score in the top 25% of CalEnviroScreen 4.0, along with those that score within the highest 5% of CalEnviroScreen 4.0's Pollution Burden but do not receive an overall CalEnviroScreen score over 75%.
- All tribal lands.
- Low-income households (incomes below 80 percent of the area median income).
- Low-income census tracts (where aggregated household incomes are less than 80 percent of area or state median income).
- Locations included in two federal programs:
  - HUBZone Program: This program fuels small business growth in historically underutilized business zones and is managed by the US Small Business Administration.
  - Opportunity Zones: These are economically distressed communities, defined by individual census tract, nominated by America's governors, and certified by the US Secretary of the Treasury. Opportunity Zones are managed by the US Department of Housing and Urban Development.

Oakview Science Camp sparks curiosity and learning

Researchers improve trust—and ultimately data quality—in a disadvantaged community by introducing kids to STEM activities in fun and creative ways.

SPOT LIGHT

On Community Engagement

"The Oakview Science Camp is one of the most successful ways we have ever used to build relationships with community members. It has also been incredibly heartwarming and fulfilling work."

—DR. ROBERT FLORES
SENIOR SCIENTIST
CLEAN ENERGY INSTITUTE
UNIVERSITY OF CALIFORNIA, IRVINE

Dr. Robert Flores is a senior scientist at the Clean Energy Institute (CEI), located at the University of California, Irvine (UCI). "We are focused on research for a clean California hydrogen ecosystem," said Flores. "My specific area of research is in energy systems optimization."

Recently, CEI collaborated with the National Renewable Energy Laboratory (NREL) and SoCalGas RD&D on a project seeking to develop fuel-cell-based, grid-forming inverters. These devices can stabilize power grids by enabling a steady flow of electricity from intermittent renewable sources. "By managing the flow and balance of electricity, grid-forming inverters powered by fuel cells can provide stable, continuous power," said Flores. "This can reduce the need for expensive battery systems and lower

SPOT LIGHT

On Community Engagement

costs for utilities and ratepayers, which is particularly important for those with low to moderate incomes."

A critical part of the project involved analyzing existing energy systems in the environmental and social justice (ESJ) community of Oakview in Huntington Beach, California. "Many of the models we use to predict electrical loads and demand on the grid as electrification accelerates rely on data from medium- to high-income populations," said Flores. "The data does not capture what is going on in ESJ communities very well at all."

That missing link is critical. "Getting California to zero carbon absolutely has to take into account what is happening in ESJ communities," said Flores. Yet, even those researchers who acknowledge this challenge often struggle to gather comprehensive data. "These communities are skeptical of research efforts and reluctant to participate in data gathering activities, primarily because they rarely get anything in return. All of the value in the relationship flows to the researchers."

On this project, CEI sought to gather data on the community's 310 buildings, which are served by six electric distribution systems and two main gas pipelines. "At one point, I spent an entire week walking around the community, looking at individual buildings, and documenting what I saw," said Flores.

Flores and his team also looked for a tangible way that they could give back to the community. "On a past project in Oakview, we had already built some strong relationships, including with the local librarian," said Flores. "She suggested that we do science experiments with children from the community—a suggestion that ultimately led us to develop the Oakview Science Camp."

The camp kicked off in the summer of 2019 at the Oakview branch of the Huntington Beach library and—after a three-year hiatus due to COVID—resumed in 2023. Each year, approximately 30 children from pre-K to sixth grade attend up to four 90-minute sessions, learning clean energy and physics concepts through a variety of fun activities, such as egg drops, making paper airplanes, and building bridges from marshmallows and spaghetti.

"Although I led development of the camp, our graduate students are the ones who are responsible for its success," said Flores. "They engage the kids in exciting experiments and provide an extremely positive environment and lots of hands-on assistance." Many of the graduate students come from backgrounds similar to those of the kids.

"I grew up in Bakersfield, California, and did not have a lot of exposure to science, technology, engineering, and math (STEM) until I was older," said Esmeralda Ramirez, who studies high-temperature fuel cell electrolysis systems at CEI. "With the camp, our goal is to introduce STEM topics in a fun and creative way to help the kids understand that they can make science their future if they want."

Ramirez particularly enjoys serving as a role model for young girls, who make up at least half of the

SPOT LIGHT

On Community Engagement

camp attendees. “It’s heartwarming to serve as an example that women can succeed in STEM fields,” said Ramirez.

SoCalGas RD&D has provided valuable assistance in running the camps. “Putting together the resources for the Oakview Science Camp is not cheap,” said Flores. “We have projects involving small solar panels, electric motors, wind turbines, LED lights, and water electrolysis. SoCalGas RD&D provided the financial resources we needed so that when the kids arrived, they could go to work with the supplies they needed.” SoCalGas also provided input on experiment selection.

In 2024, several SoCalGas staff volunteered at one of the sessions, helping the children with water electrolysis and solar-powered fans. “Once the formal session was over, many of the kids stayed late and experimented with different ways to wire their projects,” said Flores. “In one case, a group worked with a volunteer from SoCalGas to connect several solar panels in parallel to get more power. I would say that was our most successful class, although the children would disagree. They really liked the marshmallow and spaghetti bridges.”

“These kids are so smart,” said Flores. “When they get a chance to do hands-on experiments—like splitting water molecules into oxygen and hydrogen—they are naturally inquisitive. They want to learn what is going on and how things work. You can see the gears turning in their heads.”

“I love the science camp that CEI organized,” said Joe Leiva, MBA, Technology Development Project Manager at SoCalGas RD&D. “It’s such an incredible thing to host and inspire our future scientists and engineers. The most rewarding part of volunteering was witnessing their curiosity and watching their eyes light up once they got their experiments working.”

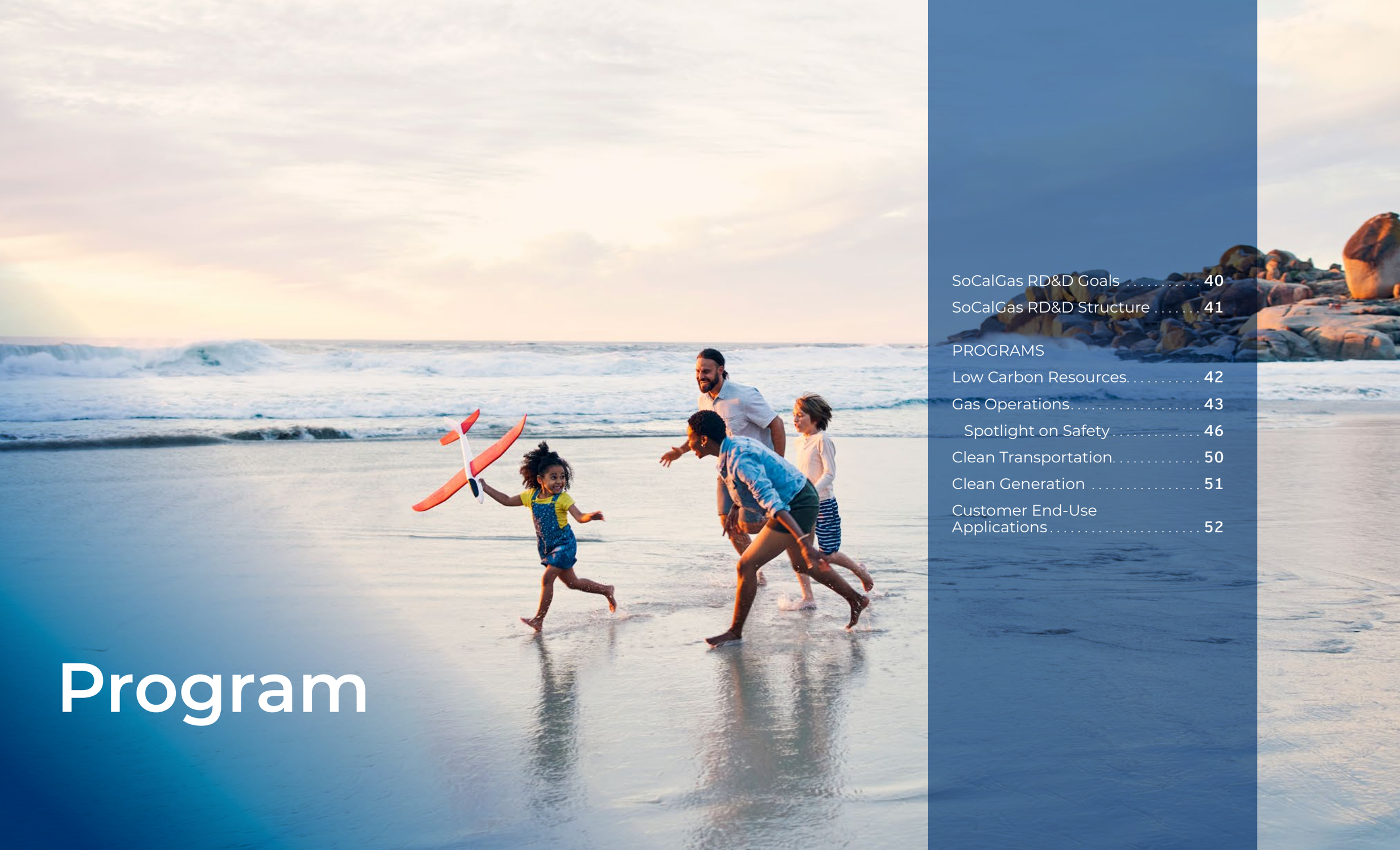
“Communities might not see the benefit of a research project for many years,” said Ramirez. “We need to show them something tangible that is benefiting people in their community now. The Oakview Science Camp is one of the most successful ways we have ever used to build relationships with community members. It has also been incredibly heartwarming and fulfilling work.”

“This is 100% a project we will continue in the future,” said Flores. “It is so positive for everyone involved that we are planning on pursuing it indefinitely. Everyone has benefited. The kids have a great time and gain exposure to both science and to young professionals in the field who can serve as examples.”

“Today, when we visit the community, people smile when they see us,” said Flores. “More often than not, it’s the parents who attended camp with their children. There has definitely been a change in the relationship.” The camps have also strengthened CEI’s relationship with the librarian. “She knows everyone in the community, including the local nonprofit housing groups. She helped get us inside some of the community’s buildings so we could talk to the residents about their concerns. You only get that kind of access when you have a relationship with people in the community who are trusted.”

> “With the camp, our goal is to introduce STEM topics in a fun and creative way to help the kids understand that they can make science their future if they want.”
>
> —ESMERALDA RAMIREZ
> GRADUATE STUDENT RESEARCHER
> CLEAN ENERGY INSTITUTE
> UNIVERSITY OF CALIFORNIA, IRVINE

Program



SoCalGas RD&D Goals

The goals of SoCalGas RD&D are to identify, test, and commercialize transformational new energy technologies that will reduce GHG and criteria air pollutant emissions, maintain the energy affordability that natural gas has historically provided, and advance the safety, operational efficiency, and reliability of California's gas delivery networks and systems in an ever-changing operational environment.

Concurrent with the pursuit of these goals, SoCalGas RD&D seeks to advance decarbonization by enabling the replacement of conventionally-sourced natural gas with increasingly higher amounts of RNG. SoCalGas is also exploring the potential of leveraging hydrogen technologies to benefit its customers and support California in the achievement of its ambitious climate goals.

Consistent with the framework established in Public Utilities Code Section 740.1, program staff consider multiple factors when selecting projects to support. These factors include ratepayer benefits, input from knowledgeable industry stakeholders, equity, corporate policy and goals, and regulatory and policy drivers.

SoCalGas RD&D Structure

In 2024, SoCalGas RD&D allocated funding across five program areas: Low Carbon Resources, Gas Operations, Clean Transportation, Clean Generation, and Customer End-Use Applications. See *Updates on the 2023 Research Plan* (p. 14) and *2024 Funds Expended* (pp. 15) for more information about program structure.

**Subprogram has been retired. Allocated costs include close-out costs as approved by the CPUC.*

PROGRAM:

LOW CARBON RESOURCES

The Low Carbon Resources program seeks to decarbonize the gas supply while improving its affordability and reliability. To achieve this goal, program staff members develop, promote, and advance new technologies aimed at increasing and expanding the production and use of clean, renewable hydrogen and RNG. In 2024, the Low Carbon Resources program also included active projects in the Carbon Capture, Utilization, and Sequestration subprogram, which was retired in CPUC Resolution G-3601 (see *Updates to the 2023 Research Plan* for more information). Per the terms of Resolution G-3601, SoCalGas RD&D was allowed to track the completion of projects in this sub-program that were fully funded before the resolution but not to initiate any new projects.

Carbon Capture, Utilization, and Sequestration (Retired)

This sub-program focused on carbon management—a vital component in the fight against climate change. More than half of the excess CO_2 released into the atmosphere by human activity is absorbed by plants and the world's oceans (US DOE, 2025).[5] Carbon management technologies seek to remove the remainder of the excess CO_2 from the atmosphere and the ocean; capture carbon emissions from point sources; convert carbon into useful products such as plastics, cement, or biofuels; and sequester CO_2 in subsurface geologic formations.

The goals of this sub-program were to offset emissions from conventional natural gas use by capturing, converting, and/or permanently removing atmospheric GHG emissions through carbon management approaches.

Renewable Gas Production

This sub-program focuses on the safe, reliable, and cost-effective production of renewable gaseous fuels—specifically RNG and clean, renewable hydrogen—from various feedstocks and multiple technological pathways.

The goals of this sub-program are to increase the availability of renewable gas and to promote pipeline decarbonization solutions by advancing production technologies that diversify renewable gas feedstocks and pathways.

PROGRAM:

GAS OPERATIONS

The Gas Operations RD&D program supports transmission, distribution, and storage operations through innovations that enhance pipeline, public, and employee safety, maintain system reliability, increase operational efficiency, and minimize GHG impacts to the environment. The program also facilitates technology development driven by emerging regulatory requirements. Its primary goals are to develop, test, and introduce new gas operations technologies that are beneficial to ratepayers, public safety, and the environment.

Each project within this program was evaluated for its potential to provide ratepayer benefits appropriate to its technology readiness level (TRL). The TRL is a systematic framework used to assess the maturity and readiness of technologies for practical application.

TRLs 1-3 span projects conducting basic technology research to those performing

analytical and laboratory studies to physically validate earlier analytical predictions. Projects at TRLs 4-6 bridge the gap between pure scientific research and demonstrating technologies at scale. These projects cover laboratory-scale component and system validation through pilot-scale demonstrations in relevant environments. TRLs 7-9 take technologies from full-scale demonstrations demonstrated in relevant environments through completion of system development and operation under the full range of operating mission conditions. These final three TRLs develop projects and technologies to the point where they can be advanced to market in support of pipeline safety, integrity, system reliability, and energy decarbonization.

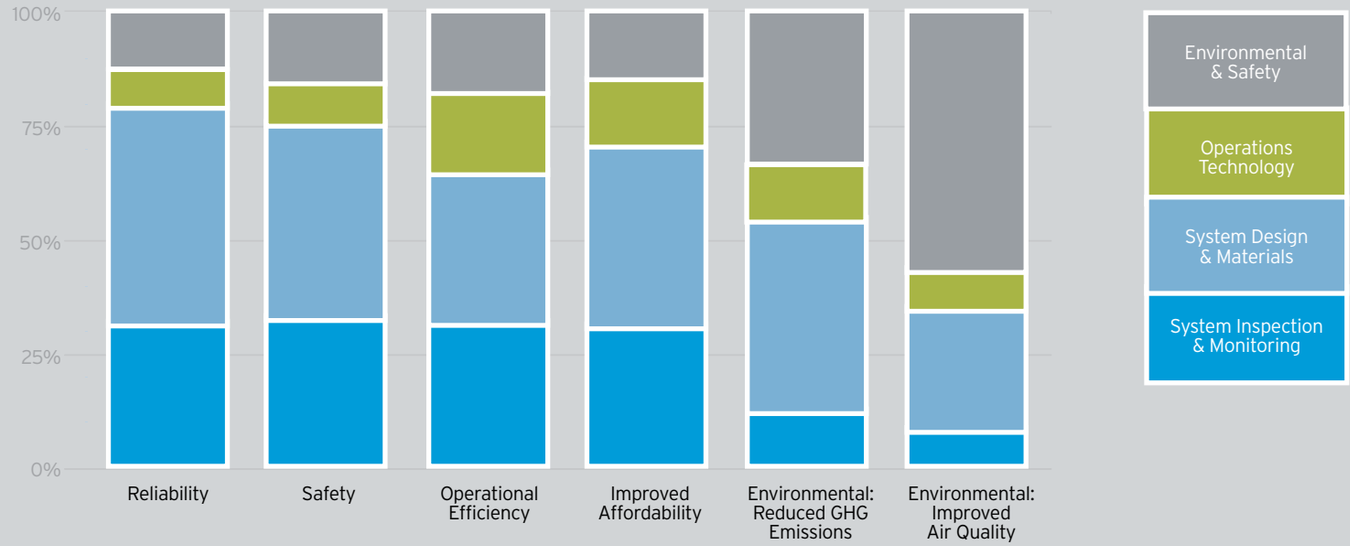
The program invests in technology development projects that are divided into the subprograms below. Detailed summaries of ongoing RD&D projects from 2023 are included within this report in alignment with the revised 2023 RD&D research plan. All projects have associated ratepayer benefits.

For more project details, see the 2023 revised or 2024 Research Plans.

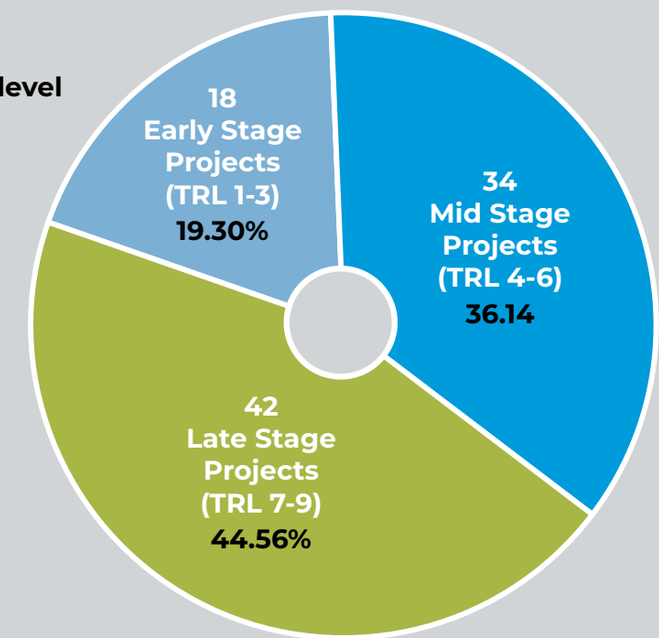
Environmental & Safety

This sub-program seeks to enhance the environmental impact of the integrity of the pipeline network and the safety of those who live and work in proximity to it. Environmental projects focus on developing technologies that also support state goals. Safety projects are concerned with protecting

Benefit breakdown by sub-program percent



Percent of projects by technology readiness level



the pipeline from intentional and unintentional damage and with improving the safety of the public and company employees or contractors working on or around the pipeline. Areas of key project focus include damage prevention, efficiency improvements, criteria pollutant reduction, and exploring how blending hydrogen into the pipeline impacts the operation and maintenance of the pipeline system. Examples of such impacts include modifications to the regulations and standards related to reliability, integrity, environmental impacts, and safety (e.g., odorization). In 2024, projects in this sub-program represented 19% of the Gas Operations project portfolio. RD&D staff initiated one new project in this sub-program in 2024 and completed eight.

Further gas emissions monitoring and reduction research is supported by the SoCalGas Gas Emissions R&D Emission Strategy Program under the SB 1371 compliance plan, pursuant to the Gas Leak Abatement OIR (R.15-01-008).

Operations Technology

This sub-program advances and develops techniques for the construction, operation, maintenance, rehabilitation, and testing of gas pipelines and systems that facilitate continued safe and reliable service. It also supports technologies that improve employee training and explores how to prevent gas leaks of blended clean, renewable hydrogen, and natural gas. Projects in this area refine and advance techniques that optimize current processes and equipment, leading to reliability, safety, operational efficiency, and improved affordability. In 2024, projects in this sub-program represented 10% of the Gas Operations project portfolio. RD&D staff initiated one new project in this sub-program in 2024 and completed three.

System Design & Materials

The objectives of this sub-program are to advance materials and materials science; materials tracking and traceability; and technical tools for designing pipeline systems and infrastructure for safety, reliability, efficiency, affordability, and maintainability throughout the life cycle of pipeline assets. Other considerations include improving air quality and reducing GHG emissions. Projects include research to advance engineering design standards and models, developing risk analytical tools to comply with pipeline integrity regulations, modeling operational efficiencies of gas storage and compressor station assets, and assessing the effects of incorporating gas from nontraditional sources (biogas and hydrogen-blend) on overall natural gas quality and system integrity. Ultimately, lessons learned on these projects help SoCalGas better design, engineer, and develop its pipeline system. In 2024, projects in this sub-program represented 41% of the Gas Operations project portfolio. RD&D staff initiated one new project in this sub-program in 2024 and completed 10.

System Inspection & Monitoring

The objectives of this sub-program include developing technologies and methods for the inspection, monitoring, and testing of pipelines and pipeline components to assess the condition and performance of pipeline facilities. Projects in this subprogram leverage AI, machine learning, and preventive and predictive maintenance technologies, including data analytic models and data lakes. Projects may also focus on improving pipeline reliability, safety, and operational efficiency through data management that enables the identification of precursors to failures or incidents. Projects may also seek to improve performance of the natural gas system through development of new and existing internal inspection, external inspection, and monitoring technologies. In 2024, projects in this sub-program represented 30% of the Gas Operations project portfolio. RD&D staff initiated six new projects in this sub-program in 2024 and completed four.

Innovation drives safety and system integrity

SoCalGas RD&D supported projects to produce a market-ready, obstacle-location technology for use in horizontal directional drilling applications and an evaluation of an downhole well inspection tools.

SPOT LIGHT

on Safety

Program:
Gas Operations

Collaborators:
OTD

Project Benefits:

- SAFETY
- OPERATIONAL EFFICIENCY
- RELIABILITY
- IMPROVED AIR QUALITY
- REDUCED GHG EMISSIONS

Drill head of the ORFEUS horizontal directional drill. Image credit PHMSA.

Gas infrastructure is everywhere—above and below ground, in urban and rural areas, along the coast and in the desert.

Safety is of the utmost importance to natural gas utilities. Safe infrastructure protects lives, minimizes negative environmental impacts, and sustains trust with regulatory agencies and ratepayers. Two of the best ways to maximize safety are preventing third-party damage to gas pipelines and quickly identifying compromised gas infrastructure, whether caused by third parties, corrosion, or natural deterioration over time.

Responding to these situations requires careful management. Compromised infrastructure can result in leaks, reduced operational efficiency, and, in

SPOT LIGHT on Safety

severe cases, safety incidents such as pipeline failures or injuries affecting workers and the public.

“Gas infrastructure needs to deliver gas safely and reliably wherever it is needed,” said Karen McInnis, Project Manager III at SoCalGas RD&D. “Third-party damage, corrosion, and other issues can lead to under-pressurization, fluids in the pipeline, and catastrophic failure—something we want to avoid at all costs.”

To support the continued safe and reliable operation of the company’s gas infrastructure, SoCalGas RD&D supported a variety of projects in 2024, including a project working to produce a field-proven, market-ready, obstacle-location technology for use in horizontal directional drilling (HDD) applications and another to evaluate an array of downhole well inspection tools.

Forward-Thinking—and Looking—Drilling Innovation

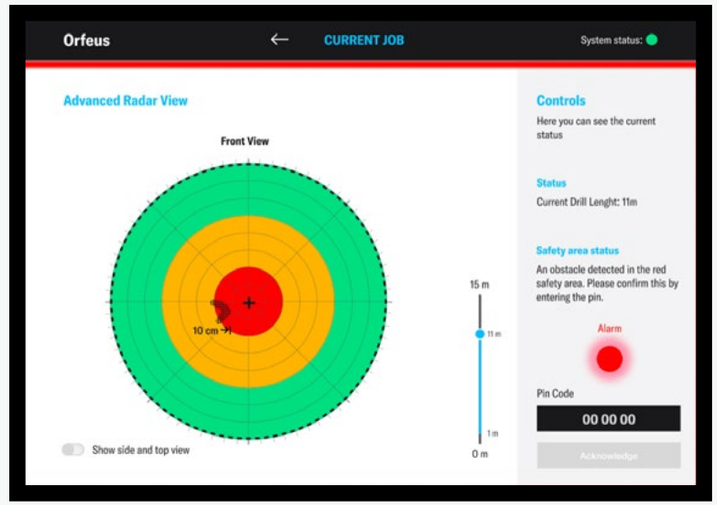
HDD is a safer, more efficient, and trenchless method of installing underground infrastructure. Because it causes minimal surface disruption, it is ideal for use in congested urban areas, enabling precise installation of utilities under obstacles such as existing water or sewer pipes, electrical cables, or gas lines.

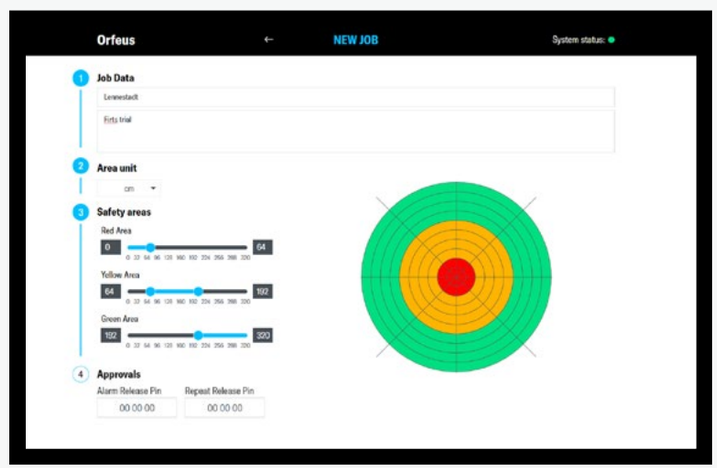
Without careful identification of such obstacles in advance, HDD has the potential to damage existing infrastructure, potentially resulting in service interruptions, soil and water contamination, and the uncontrolled release of gas into the environment. To locate these obstacles, operators use a variety of time-consuming methods, including consulting utility maps and records, soil removal, and acoustic pipe tracing.

“But in some cases, these methods don’t catch everything,” said McInnis. “That’s where ORFEUS comes in.” ORFEUS is the first HDD system that uses ground-penetrating radar (GPR) integrated into the drill head to “look-ahead” and detect any possible obstacles—such as pipes or wires—in time to avoid them. “Before ORFEUS, no commercial technology could do that.”

Originally developed in 2017, ORFEUS underwent successful proof-of-concept field trials and demonstration at sites in Europe and the United States. With new funding provided by the Pipeline and Hazardous Materials Safety Administration (PHMSA), research consortium Operations Technology Development (OTD), and SoCalGas RD&D, the ORFEUS team began a new project that sought to enhance the base technology and demonstrate the performance of a field-proven, commercially viable obstacle-detection technology.

In 2024, the project team continued obstacle configuration tests of ORFEUS begun in 2023, including a new arrangement that had the pipe on the same plane as the drilling path. “This provided a more realistic assessment of the system’s detection capabilities and was more reflective of operational situations,” said McInnis. “The team also demonstrated the integration of the technology into various original equipment manufacturer (OEM) HDD systems.”





The ORFEUS development process resulted in the creation of an extremely user-friendly interface. Image credit PHMSA.

SPOT LIGHT on Safety

The project team completed valuable enhancements to the ORFEUS system. “With the updates, they can drill, identify obstacles up to 18 feet out, and automatically come to a full stop,” said McInnis. “ORFEUS has the potential to increase safety for homeowners, utility companies, and contractors, while also enhancing the installation of distribution gas lines in difficult areas where other utilities may intersect.” In the future, SoCalGas hopes to host a demonstration of the technology.

SoCalGas RD&D in collaboration with other utilities across North America has helped move this technology through the development pipeline into the final stages before full commercialization. “ORFEUS gives us a technology option to bring peace of mind that third-party contractors tasked with working on or near utility lines are much less likely to damage existing lines,” said McInnis. “That increases service reliability and operational efficiency, while minimizing the risk of catastrophic failure, costly repairs, and injury or death.” This technology will be available to all HDD activities including electric utilities in California and the West as they underground their power lines to reduce the risk of sparking wildfires.

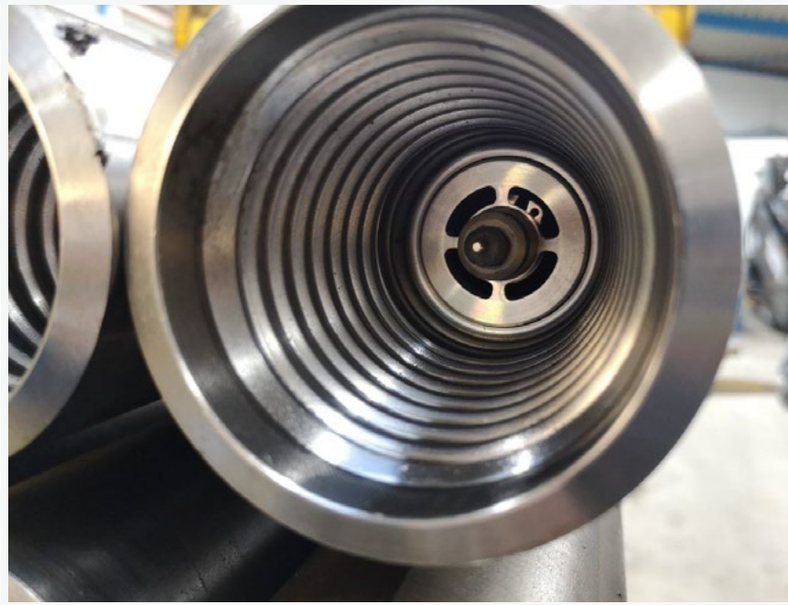


Image credit PHMSA.

Closing the Gap Between Requirements and Current Tool Performance

SoCalGas is required to inspect its gas storage wells by mandate of the California Department of Conservation’s Geologic Energy Management Division (CalGEM) every 24 months, unless previous inspection results support a longer inspection interval. In 2024, for wells with inspection intervals greater than 24 months, CalGEM mandated a thru-tubing (TT) inspection be conducted at the mid-point of the inspection interval.

TT inspections allow the casing to be inspected without removing the smaller tubing inside the casing, generating efficiencies and lowering operational risk. Gas storage operations are regulated by CalGEM and ensuring the integrity of gas storage wells requires downhole well inspections which utilize various technologies.

SoCalGas utilizes magnetic flux leakage (MFL), ultrasonic thickness (UT) and multi-arm caliper (MAC), and electromagnetic TT inspection tools to assess gas storage well integrity.

To evaluate these inspection technologies, SoCalGas RD&D supported a comprehensive evaluation (“pull test”) of standard downhole inspection tools as well as novel, high-resolution UT tools and emerging TT tools. In preparation for pull testing, a test string, consisting of various sized tubing and casing joints was designed. The tubing and casing included natural corrosion features and fabricated features, both of which were measured using a laser scan to precisely determine the feature dimensions and establish a baseline data set.

SPOT LIGHT

on Safety

The pull test was conducted by running the inspection tools through the test string, which was installed in a well to ensure real world conditions. Inspection tool performance was evaluated by calculating the difference between laser scan measurements and inspection tool measurements as well as noting which features the tools were able to detect, or any false calls.

“Benchmarking the capabilities of these tools in a real-world environment is industry-leading research,” said Allen Scoging, Sr. Storage Field Engineer, SIMP Assessment, at SoCalGas. “Tool vendors and other operators have expressed a keen interest in seeing what we learned.”

SoCalGas RD&D conducted testing in two phases. Phase 1 included four UT tools, including two novel, high-resolution tools, five TT tools, and one MFL tool. Many vendors ran MAC alongside their tools. Phase 2 built upon the initial findings from Phase 1, adding different sized features on the tubing and evaluating the tools in a different environment. During Phase 2, SoCalGas evaluated three novel high-resolution UT tools and two TT tools. Final results are expected Q2 2025.

“Well integrity is critical,” said Scoging. “When the integrity of a well is maintained, it keeps ratepayer costs down by minimizing the need for costly infrastructure repairs and inspections and improves system safety, reliability, and efficiency.”

One of the inspection tools evaluated during the project (left) and the project team conducting a "pull test" (right). Image credit PHMSA.

PROGRAM:

CLEAN TRANSPORTATION

In compliance with CPUC Resolution G-3601 (See *Updates on the 2023 Research Plan*), this program has been retired. The Clean Transportation program supported activities that minimize environmental impacts related to the transportation sector. Focusing on utilization of increasingly clean, renewable hydrogen, this program facilitated the development of zero-emission technologies for on-road and off-road applications, as well as fueling infrastructure and on-board storage technologies.

Under the terms of Resolution G-3601, in 2024 SoCalGas RD&D was allowed to track the completion of projects in this sub-program that were fully funded before the resolution but not to initiate any new projects.

Off-Road (Retired)

This sub-program focused on developing zero-emission off-road transportation solutions using clean, renewable hydrogen. Its goal was to achieve emissions reductions from off-road vehicles such as trains, ocean-going vessels, commercial harbor craft, construction equipment, cargo handling equipment, and aircraft.

Onboard Storage (Retired)

This sub-program targeted the development, demonstration, and deployment of cost-effective technologies and systems that improve onboard storage for gaseous transportation fuels. Areas of focus included advanced materials, low-pressure systems, and conformable tanks for hydrogen storage. Onboard storage, which requires compressed storage and/or the use of advanced adsorption technologies, is a critical element needed for increased utilization of clean, renewable hydrogen as a transportation fuel.

On-Road (Retired)

This sub-program targeted the development, demonstration, and deployment of zero-emission, hydrogen-fueled on-road vehicles. This subprogram targeted zero-emission vehicles for transit, package delivery, drayage, and long-haul trucking. Vehicles developed in this subprogram also included a wide range of utility fleet vehicles, such as those used in SoCalGas' daily operations.

Refueling Stations (Retired)

This sub-program targeted the development, demonstration, and deployment of technologies and systems that support refueling for alternative fuels, including gaseous and liquid clean, renewable hydrogen. The sub-program sought to identify and manage concerns and issues arising from refueling of gaseous fuels—from storage to safety and standardization.

PROGRAM:

CLEAN GENERATION

The Clean Generation program targets the development and demonstration of high-efficiency products and technologies associated with the generation of power for the residential, commercial, and industrial market segments. Its goals are to reduce GHG and criteria pollutant emissions, lower customer costs, integrate renewable fuels, and improve energy reliability and resiliency. In 2024, this program included projects in two sub-programs, one of which—Distributed Generation—was retired in CPUC Resolution G-3601. Under the terms of this resolution, in 2024 SoCalGas RD&D was allowed to track the completion of projects in this sub-program that were fully funded before the resolution but not to initiate any new projects.

Distributed Generation (Retired)

This sub-program developed and enhanced distributed generation technologies. Microgrids and the increasing availability of RNG and clean, renewable hydrogen offer new opportunities for the deployment of low-emission and renewably fueled distributed generation technologies.

Integration & Controls

This sub-program develops, enhances, and demonstrates technologies and control systems that integrate diverse distributed generation resources and thermal loads. The focus is on enabling low-emissions, distributed generation, and storage technologies to provide energy resilience and affordability to customers.

PROGRAM:

CUSTOMER END-USE APPLICATIONS

The Customer End-Use Applications program focuses on developing, demonstrating, and commercializing technologies that cost-effectively improve the efficiency and reduce the environmental impacts of gas equipment used in residential, commercial, and industrial settings. In 2024, this program included projects in five sub-programs, two of which—Industrial Process Equipment and Residential Appliances—were retired in CPUC Resolution G-3601. Under the terms of this resolution, in 2024 SoCalGas RD&D was allowed to continue and track the completion of projects in the retired sub-program Industrial Process Equipment because of its goal of decarbonizing a hard-to-electrify sector but not to initiate any new projects.

Advanced Innovation

This sub-program seeks to develop new, nontraditional technologies to improve energy efficiency and decrease GHG and criteria pollutant emissions. Relevant applications include smart thermostats, sensors, advanced construction technologies, and machine learning.

Commercial Applications

This sub-program develops and enhances technologies and advancements related to gas consumption and end uses in the commercial sector. Relevant applications include commercial heating, ventilation, and air conditioning, hot water service, and commercial laundry.

Commercial Food Service

This sub-program develops and enhances technologies and advancements related to commercial food service. This includes restaurants, catering services, and institutional kitchens that rely primarily on fuel supplied by SoCalGas for cooking and water heating.

Industrial Process Heat (Retired)

This sub-program developed advanced heating technologies and systems for use in the industrial sector. In particular, the industrial process heat end-use sector represented some of the largest users of gaseous fuels and the most difficult applications to decarbonize. Examples include food processing, manufacturing, cement production, chemical processing, textile drying, and agriculture.

Residential Appliances (Retired)

This sub-program developed, demonstrated, and enhanced technologies and advancements related to gas-consuming appliances in residences. Relevant appliances include furnaces, hot water heaters, stoves, ovens, and dryers. In compliance with CPUC Resolution G-3601, this subprogram has been retired.

Appendix

2024 Funding Recipients

A-1 Alternative Fuels

Accenture International Limited

Agnew Multilingual

Alliance for Sustainable Energy LLC

American Institute of Chemical Engineers

Anica Inc

ASU Foundation

Baker Hughes Oilfield Operations

Barr Engineering Co

Brillio LLC

Brown & Bigelow Inc

Burns & McDonnell Engineering Co

C-FER Technologies Inc

California Institute of Technology

Captura Corp.

Center for Transportation and the Environment

Clearesult Consulting Inc

Cummins Electrified Power NA Inc

Darcy Partners LLC

DI Drill Survey Services Inc

East Los Angeles College Foundation

Electrochaea GmbH

Emission Free Generators

ESTEM Consulting LLC

Evoloh Inc

Federal Express Corp

FedEx Freight West Inc

Gas Machinery Research Council

Gas Technology Institute

Getty Images Inc

Gladstein Neandross & Associates

GTI Energy

H2U Technologies Inc

Halliburton Energy Services

Horizon Fuel Cell Americas Inc

Innovative Environmental Solutions

Int Translations

Intero Integrity Services US LLC

Isco Industries Inc

Lantec Products Inc

Lawrence Livermore National Laboratory

McMaster Carr Supply Co

Minuteman Press Torrance

Momentum

Noble Thermodynamic Systems Inc

Northeast Gas Association-NYSEARCH

Oak Ridge National Laboratory

Onyx Oil Service Inc

Pacific Petroleum California Inc

Parsons Environment & Infrastructure

PII North America LLC

Pipeline Research Council International

Red Ball Oxygen Company Inc

Regents of the University of California Irvine APEP

RockeTruck Inc

Skipper NDT Corp

South Coast Air Quality Management District

Spec Services Inc

Stafford Multimedia LLC

STARS Technology Corporation

The Select Group

The University of Tulsa

Structural Integrity Assoc Inc

Susteon Inc

Tulare County Economic Development

University of California Berkeley

University of California Irvine

Utility Partners of America LLC

Westland Group Inc

Xendee Corporation

Zero Emission Industries

Zones LLC

Select RD&D Alumni Companies

ANESI

captura

kevala

STARS Technology Corporation

Avnos

CLEAN ENERGY SYSTEMS

LANTEC PRODUCTS INCORPORATED

Susteon

BLUE FRONTIER

Electrochaea

Mainspring

twelve

BRIDGER PHOTONICS

EVOLOH

METRON

Upstart Power®

BRIMSTONE

Graphitic Energy

noble thermodynamics

Calicat California Catalysts

immaterial

SIERRA ENERGY

ZERO EMISSION INDUSTRIES

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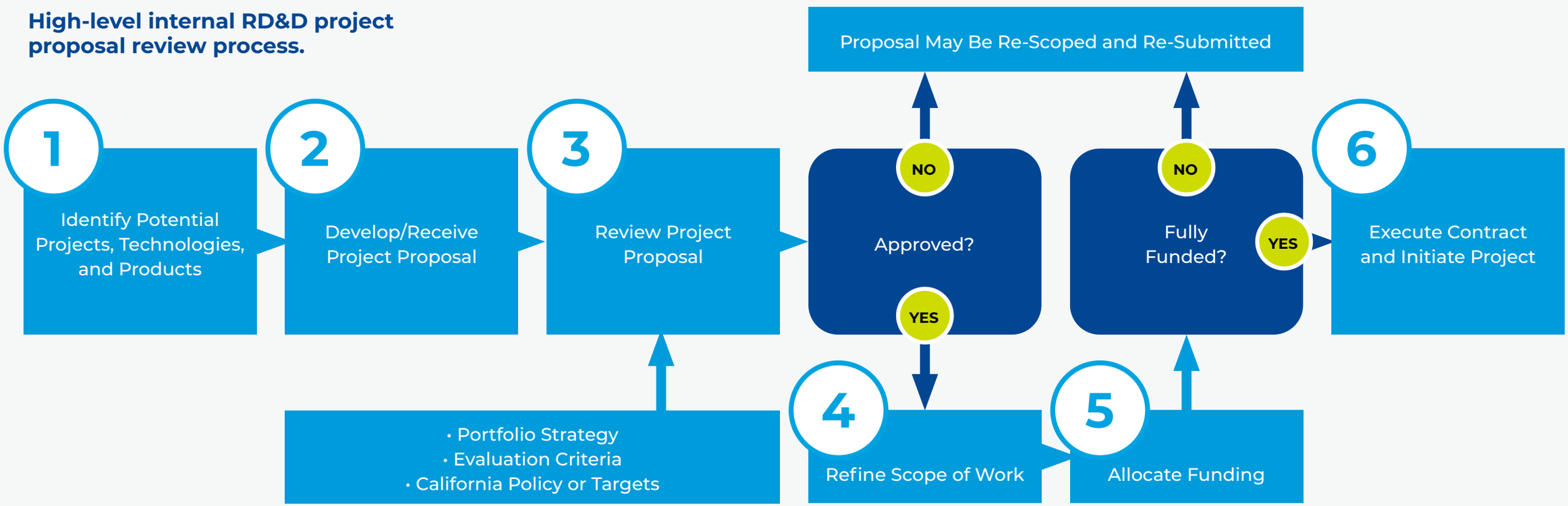
Project Selection Process and Evaluation Criteria

When identifying promising projects and evaluating them for potential funding, RD&D staff take a comprehensive yet flexible approach that enables them to 1) identify potential projects most in alignment with RD&D Department goals, state and federal environmental policy, and industry demand; 2) accurately assess the likelihood of potential projects to succeed; 3) work with proven organizations and technologies over time; and 4) respond nimbly to changing market, technology, and policy drivers. In addition—remembering that some technologies will not result in concrete benefits until implemented at scale—RD&D staff consider the overall development and implementation process and research life cycle of a given technology or product. Although staff from each of the five program areas have distinct research interests, goals, and industry relationships, all follow a similar high-level approach to project identification and selection:

High-level internal RD&D project proposal review process.



Research Consortia

SoCalGas RD&D staff have forged strategic alliances with several research consortia focused on the gas energy industry. The membership of many of these organizations consists of utility companies across North America. Typically, these consortia serve member utilities by facilitating technical collaboration and pooling financial and technical resources to collectively address ongoing or anticipated challenges in the natural gas industry. By working closely with these and other similar organizations, RD&D staff can share knowledge and pool funding with other utilities and researchers to develop and execute impactful projects. Coordination of work among these organizations and access to technical libraries greatly reduce the odds of reproducing previously completed work or work currently underway.

The majority of the SoCalGas RD&D costs associated with consortia, is directly allocated to collaborative research and development projects that are either initiated by or specifically selected for funding by SoCalGas. These projects leverage significant funding from other consortia members, thus reducing the cost burden of research on ratepayers. Participation in the research consortia facilitates collaboration and knowledge sharing among subject matter experts from other natural gas system operators, industry RD&D programs, academia, national laboratories, and other research organizations.

Research consortia generally provide members the opportunity to learn about and discuss emerging operational issues and needs within the industry, both nationally and internationally. One example is sharing knowledge about pipeline incidents, their causes, or insights on interactive threats about which SoCalGas may not otherwise have been aware (as they may have very low probability of occurrence but a high consequence). Consortia memberships also provide access to well-maintained libraries of relevant information to gas system operations. In addition, participation in consortia enhances SoCalGas' awareness of other research efforts, enabling SoCalGas RD&D staff to leverage these findings and identify unique research gaps. This approach maximizes ratepayer dollars by focusing on more pressing and unaddressed issues.

The ratepayer value of such collaboration includes:

- Providing subject matter experts a forum for knowledge sharing and gaining operational insights regarding differences in pipeline system materials and equipment, operating environments, operational experiences, procedures, and practices;
- Operational knowledge that may only apply to a small subset of system assets or operational conditions;

- Knowledge sharing of pipeline incidents, causes, or insights on interactive threats with very low probability of occurrence but high consequence;
- Knowledge sharing between large and small system operators that can provide a positive effect on the performance of the overall natural gas supply chain;
- Knowledge of emerging areas of research or technologies that could be utilized by SoCalGas to support operational efficiency, pipeline safety, system reliability, and environmental improvement.

The following are areas where consortia bring expertise that increases the chance of industry adoption of research that could lead to more tangible ratepayer benefits:

- For a technology or tool to evolve from the early stage and advance to commercialization within Technology Readiness Levels (TRL), it must withstand various operational challenges and impacts that often do not appear until later stages of product development or in early customer adoption trials. With R&D consortia, more companies are involved in piloting the technology or service in pre-commercial demonstrations or testing in a wider range of commercial and operational conditions than individual operators can typically achieve.
- R&D consortia are better positioned to identify and develop potential commercial partners who may need encouragement to take the business risk with innovations developed from consortium projects. Also, consortia provide prospective manufacturers or service providers more market potential because of the larger number of customers that they represent throughout the country, continent, or globe.
- R&D consortia can provide commercial partners with insight into broader industry needs to set market expectations and input on metrics for success.
- R&D consortia can provide more expedient commercialization and implementation of technologies available for the natural gas industry.
- R&D consortia can have experience and visibility with government agencies especially with their research funding opportunities and solicitations.

SoCalGas RD&D is a member of three subscription-based organizations: Northeast Gas Association (NGA)/ NYSEARCH, Operations Technology Development (OTD), and Pipeline Research Council International (PRCI).

NORTHEAST GAS ASSOCIATION (NGA)/NYSEARCH

NYSEARCH manages one of the premier natural gas RD&D programs in North America. NYSEARCH is a collaborative RD&D organization dedicated to serving its 19 gas utility member companies and project funding partners. NYSEARCH members voluntarily participate in projects and programs to target RD&D areas that address their unique challenges and opportunities. For more than 20 years, NYSEARCH has worked as a consortium of natural gas local distribution companies (LDCs) that have common interests and needs, such as continually improving the operation, safety, efficiency, maintenance, and upgrade of gas delivery systems.

Today, as part of NGA, NYSEARCH manages numerous projects in various stages of development. NYSEARCH has grown steadily in recent years because of its success in delivering high-value RD&D projects. The organization is unique in its ability to help member companies and partners leverage RD&D investments while targeting their participation to projects that best meet their individual needs. The core of the NYSEARCH model is joint collaboration and guidance from participating members. These members participate in a variety of RD&D projects, organized under the following categories:

- Improved installation
- Maintenance and repair
- Pipeline integrity/direct and remote assessment
- Pipe location and damage prevention
- Leak detection, real-time sensing, and inspection for distribution
- Environment/reducing greenhouse gas emissions
- Gas quality
- Evaluation of new materials
- Advanced polyethylene piping and joining
- Oracle (emerging technologies from other industries)

Total 2024 Projects

8

Initiated

0

Completed

2

Annual Dues

$76,500

2024 Dues Paid

$76,500

Total RD&D Funding

$476,067

Total Consortium Funding

$4,442,870

Operations Technology Development

OTD is a member-controlled partnership of 30 natural gas distribution companies formed to develop, test, and implement new technologies. The objective of OTD is to address a wide range of technology issues relating to gas operations and its infrastructure. Its projects are designed to:

- Enhance system safety
- Improve operating efficiencies
- Reduce operating costs
- Maintain system reliability and integrity

Since 2003, OTD's collaboration of industry leaders, scientists, technicians, and manufacturers has been charting a course to address integrity issues and other concerns by identifying industry needs and providing focused R&D responses that benefit the natural gas industry and its customers.

By working collaboratively, participating companies leverage funds so that no single company is responsible for carrying the entire financial burden. In addition, participants benefit from input from numerous sources, address common regulatory issues, and demonstrate the broad industry support needed to gain the interest of potential product manufacturers.

Total 2024 Projects

33

Initiated

0

Completed

15

Annual Dues

$750,000

2024 Dues Paid

$0

Total RD&D Funding

$2,444,883

Total Consortium Funding

$38,270,710

Pipeline Research Council International

PRCI is a community of the world's leading pipeline companies and the vendors, service providers, equipment manufacturers, and other organizations supporting the industry. Since 1952, PRCI has been recognized around the world as a unique forum within the energy pipeline industry delivering great value to its members and the industry—both quantitative and qualitative—through the development and deployment of research solutions to improve pipeline safety and performance. PRCI's mission is to collaboratively deliver relevant and innovative applied research to continually improve the global energy pipeline systems.

PRCI is dedicated to ensuring the maximum efficiency of research, development, and deployment through a highly leveraged funding model of member and external funding, information sharing, cooperative research development, and the broad dissemination and application of its results. Along with funding, the strength of the collaborative model stems from the contributions to PRCI of member technical and operations experts and the ongoing support to them from PRCI and its companies. It is this collaboration in the direction, implementation, and adoption of research that defines PRCI's value to its members and the industry.

PRCI's Value Proposition is to use the leverage generated by its members' resource contributions to create a research forum of ideas and results producing solutions that ensure the safe, reliable, environmentally sound, and cost-effective pipeline transportation of energy to consumers worldwide.

Total 2024 Projects

26

Initiated

3

Completed

5

Annual Dues

$162,816

2024 Dues Paid

$162,816

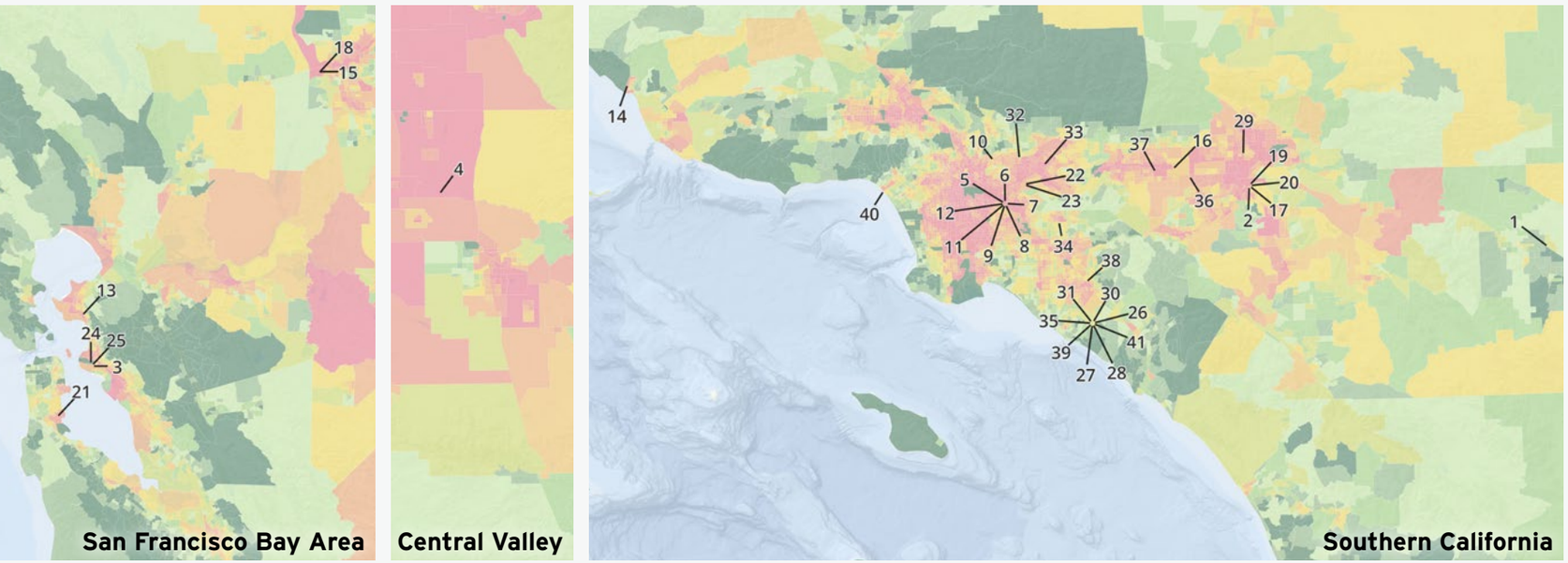
Total RD&D Funding

$1,938,153

Total Consortium Funding

$37,783,014

2024 Projects in ESJ Communities



Low Carbon Resources

1. STARS Corporation Electric Induction Steam Methane Reforming (SMR) Demonstration; Thousand Palms
2. UCR Speeding Anaerobic Digestion Through CO2 Microbubbles; Riverside
3. NTS Iron-Based Catalytic Conversion of Raw Biogas into H2 Demonstration; Alameda
4. AVNOS Combined Water and CO2 Direct Air Capture System Demonstration; Bakersfield

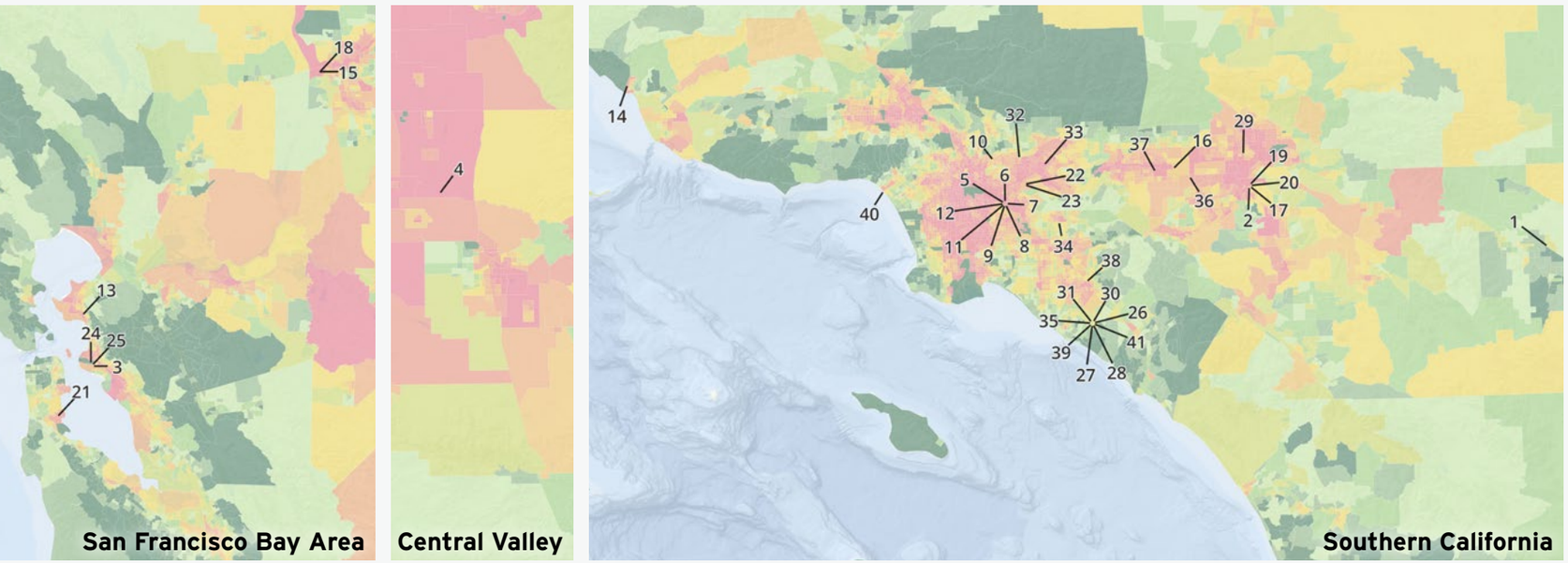
Gas Operations

5. 3D Visualization Software for Mapping Underground Pipelines and Improving Pipeline Asset Management; Pico Rivera
6. Advancing Hydrogen Leak Detection and Quantification Technologies Compatible with Hydrogen Blends; Pico Rivera
7. Data Logger Evaluation Project - Phase II; Pico Rivera
8. Enhanced Locating Technologies for Underground Pipelines with Better Accuracy; Pico Rivera
9. Living Lab for Hydrogen; Pico Rivera
10. Low Flow EMAT ILI Tool Demonstration; Alhambra
11. LUAF Study; Pico Rivera
12. Smart Shutoff Technology for Commercial and Residential; Pico Rivera
13. UCB Monitoring and Risk Assessment for Natural Force Damage to Pipelines; Richmond
14. Skipper NDT Demonstration; Ventura

Clean Transportation

15. Cummins Integrated Fuel Cell Electric Powertrain Demonstration; West Sacramento

2024 Projects in ESJ Communities



16. CTE Fuel Cell Electric Delivery Van Demonstration; Ontario
17. GTI CNG Plug-In Class 8 Hybrid Truck Development and Demonstration; Riverside
18. GTI Energy Hydrogen Fuel Cell Switcher Locomotive Demonstration; West Sacramento
19. SCAQMD Hydrogen Blended Natural Gas in NZE Engine Emissions Study; Riverside
20. UC RIverside Hydrogen Blended Natural Gas Engine Durability Test; Riverside
21. ZEI Harbor Craft Demonstration; South San Francisco

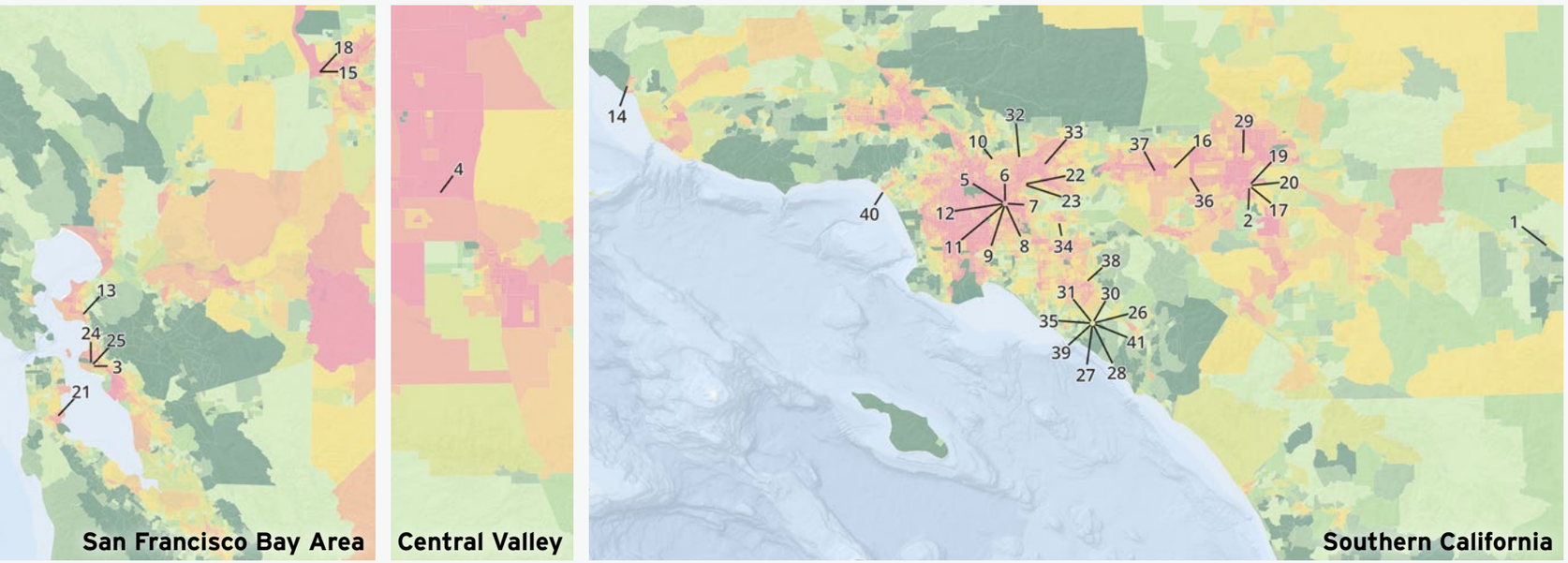
Clean Generation

22. GTI Energy Marathon/EC Power mCHP Testing and Demonstration; City of Industry
23. GTI Marathon /EC Power mCHP Integration and Demonstration; City of Industry
24. Noble Thermodynamic Systems Ultra-Efficient CHP using a Novel Argon Power Cycle Development; Alameda
25. NTS Argon Power Cycle with Blended Hydrogen Integration and Demonstration; Pomona
26. UCI Fuel Cell Supported Nanogrid Controls Evaluation; Irvine
27. UCI Effect of Hydrogen Addition into Natural Gas on SCR of NOx Lab Testing; Irvine
28. UCI Hydrogen Enabled Microgrids for Critical Infrastructure Research; Irvine
29. Mainspring Energy Ultra-Low NOx Linear Power Generator Demonstration; Colton
30. UCI Capstone H2 Blending Research; Irvine
31. UCI Integrated SOFC, Solar, and Storage System in ZNE Residential Nanogrid Design; Irvine

Customer End-Use Applications

32. METRON Energy Virtual Assistant (EVA) Industrial AI

2024 Projects in ESJ Communities



Demonstration; El Monte

33. GTI Model-Based Control Hospital Decarbonization Demonstration; Baldwin Park
34. GTI SCAQMD HE/Low-NOx EcoZone Burner Kroger Demonstration; La Habra
35. UCI Hydrogen Blend Commercial Stove Low NOx Catalytic Burner Development; Irvine
36. GTI Energy Booster Ejector Enhancement of Compressor Refrigeration Demonstration; Mira Loma
37. GTI Energy Burner Exchange to Support Radiative Recuperator Demonstration; Ontario
38. GTI Energy Waste Heat Effective Transfer in Brewery & Distillery Demonstration; Santa Ana
39. UCI Solid Oxide Electrolysis Cells for Green Steel Production Demonstration; Irvine
40. GTI Strategic Pathways and Analytics For Tactical Decommissioning of Natural Gas Infrastructure Research; Santa Monica
41. UCI Catalytic Burner Retrofitted Water Heater Lab Demonstration; Irvine

2024 ATTRIBUTIONS

Page 8 https://pubs.naruc.org/pub/FA85BA08-D94D-E40F-B7E1-98F834372877

Page 9 https://gridworks.org/wp-content/uploads/2019/09/CA_Gas_System_in_Transition.pdf

Page 10 https://calmatters.org/environment/climate-change/2020/10/californias-energy-system-should-be-resilient-flexible-and-affordable/

Page 13 https://energyregulationquarterly.ca/articles/should-ratepayers-fund-innovation

Page 14 Interview with Dr. Robert Flores on October 24, 2024.

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In this report, forward-looking statements can be identified by words such as “believe,” “expect,” “intend,” “anticipate,” “contemplate,” “plan,” “estimate,” “project,” “forecast,” “envision,” “should,” “could,” “would,” “will,” “confident,” “may,” “can,” “potential,” “possible,” “proposed,” “in process,” “construct,” “develop,” “opportunity,” “preliminary,” “initiative,” "target," "outlook," “optimistic,” “poised,” “positioned,” “maintain,” “continue,” “progress,” “advance,” “goal,” “aim,” “commit,” or similar expressions, or when we discuss our guidance, priorities, strategies, goals, vision, mission, projections, intentions or expectations.

Factors, among others, that could cause actual results and events to differ materially from those expressed or implied in any forward-looking statement include: decisions, denials of cost recovery, audits, investigations, inquiries, ordered studies, regulations, denials or revocations of permits, consents, approvals or other authorizations, renewals of franchises, and other actions, including the failure to honor contracts and commitments, by the (i) California Public Utilities Commission (CPUC), U.S. Department of Energy, U.S. Internal Revenue Service and other regulatory bodies and (ii) U.S. and states, counties, cities and other jurisdictions therein where we do business; the success of business development efforts and construction projects, including risks related to (i) completing construction projects or other transactions on schedule and budget, (ii) realizing anticipated benefits from any of these efforts if completed, (iii) obtaining third-party consents and approvals and (iv) third parties honoring their contracts and commitments; changes to our capital expenditure plans and their potential impact on rate base or other growth; litigation, arbitration and other proceedings, and changes (i) to laws and regulations, including those related to tax, (ii) due to the results of elections, and (iii) in trade and other foreign policy, including the imposition of tariffs by the U.S. and foreign countries; cybersecurity threats, including by state and state-sponsored actors, of ransomware or other attacks on our systems or the systems of third parties with which we conduct business, including the energy grid or other energy infrastructure; the availability, uses, sufficiency, and cost of capital resources and our ability to borrow money or otherwise raise capital on favorable terms and meet our obligations, which can be affected by, among other things, (i) actions by credit rating agencies to downgrade our credit ratings or place those ratings on negative outlook, (ii) instability in the capital markets, and (iii) fluctuating interest rates and inflation; the impact on affordability of our customer rates and our cost of capital and on our ability to pass through higher costs to customers due to (i) volatility in inflation, interest rates and commodity prices and (ii) the cost of meeting the demand for lower carbon and reliable energy in California; the impact of climate policies, laws, rules, regulations, trends and required disclosures, including actions to reduce or eliminate reliance on natural gas, increased uncertainty in the political or regulatory environment for California natural gas distribution companies, the risk of nonrecovery for stranded assets, and uncertainty related to emerging technologies; weather, natural disasters, pandemics, accidents, equipment failures, explosions, terrorism, information system outages or other events, such as work stoppages, that disrupt our operations, damage our facilities or systems, cause the release of harmful materials or fires or subject us to liability for damages, fines and penalties, some of which may not be recoverable through regulatory mechanisms or insurance or may impact our ability to obtain satisfactory levels of affordable insurance; the availability of natural gas and natural gas storage capacity, including disruptions caused by failures in the pipeline and storage systems or limitations on the injection and withdrawal of natural gas from storage facilities; and other uncertainties, some of which are difficult to predict and beyond our control.

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