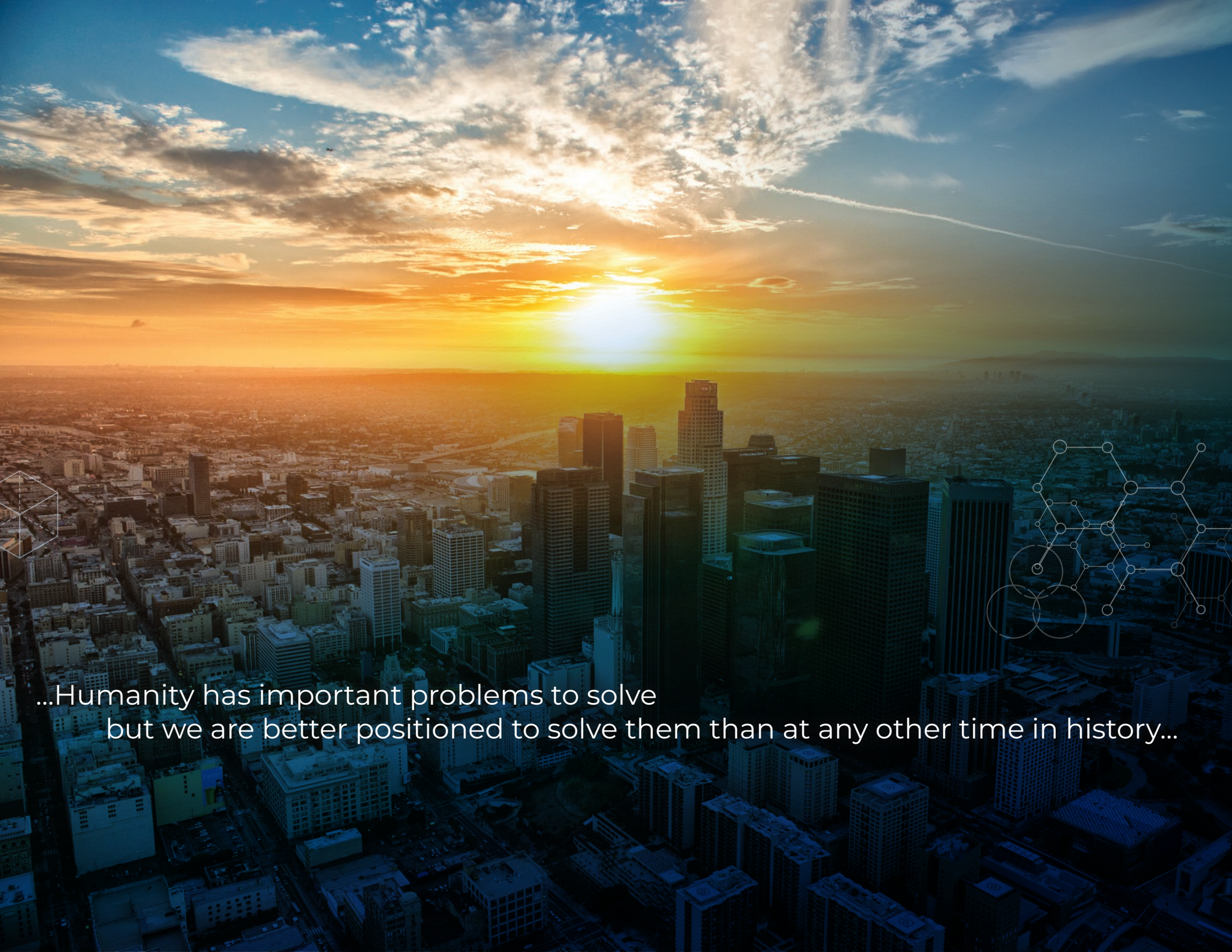
SoCalGas

RESEARCH, DEVELOPMENT, AND DEMONSTRATION PROGRAM

2021 ANNUAL REPORT


“The future
IS VERY BRIGHT...


...Humanity has important problems to solve
but we are better positioned to solve them than at any other time in history...

...To help build a decarbonized energy system for California, SoCalGas is overcoming challenges, implementing solutions, and collaborating with innovative partners so every Californian can have access to clean, reliable, and affordable energy."

—MARYAM BROWN
PRESIDENT
SOCALGAS

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Introduction

2021 was a year of challenges. The pandemic continued to wreak havoc on our healthcare system and on the many individuals and families who suffered illness and loss. Supply chain disruptions plagued the global economy. And an ever-warming planet saw more frequent and intense fires, drought, and heat waves.

But it wasn't all bad news.

2021 was also a time of renewal, with scientific research and exploration leading to incredible discoveries and advancements. Widespread vaccination and the development of promising new antiviral medications began to mitigate the worst impacts of the pandemic. Humanity landed rovers on the Moon and Mars and launched a deep space telescope capable of peering back billions of years to a time when our universe was young.

The energy industry reached significant milestones in its efforts to decarbonize how we produce, store, distribute, and consume energy. Today, more than 90% of newly installed electric capacity comes from onshore wind and solar installations[1]. Over the last decade, the average price of solar installations has dropped by 89%, while onshore wind costs have declined by 70%[2]. And, according to the International Energy Agency's (IEA) Global Hydrogen Review 2021, there are signs that low-carbon hydrogen is on the "cusp of significant cost declines and widespread global growth."[3]

In California and across the nation, investment in clean energy is booming. In 2021, California committed more than $1 billion to clean transportation, long-duration energy storage, green hydrogen production, and other programs and technologies focused on reducing carbon emissions. Nationally, 2021 marked the passage of the Infrastructure Investment and Jobs Act, which allocates more than $20 billion to pilot and demonstration projects that advance carbon capture and removal, hydrogen, and green industrial technologies.

In 2021, California committed more than $1 billion to clean transportation, long-duration energy storage, green hydrogen production, and other programs and technologies focused on reducing carbon emissions.

SoCalGas™ Leads Decarbonization Efforts

With more than 21 million customers and one of the nation's largest networks of gas transmission, storage, and distribution infrastructure, SoCalGas is well-positioned to play a central role in the ongoing decarbonization of the energy industry.

In the short term, the existing gas distribution network can be used to carry drop-in clean fuels, such as renewable natural gas (RNG). California also has access to abundant geological resources that can be repurposed for carbon sequestration.

Sustainable progress, however, will require a diversified portfolio of clean energy sources, technologies, and tools, as well as energy efficiency, to provide resilience and reduce the risks of over-dependence on any one technology.

The SoCalGas Research, Development, & Demonstration (RD&D) Program is tasked with identifying and supporting 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. In 2021 alone, RD&D Program staff invested almost $17 million in hundreds of energy technology and clean fuels projects—from those that remove carbon dioxide from ocean water to projects that use hydrogen-fuel-cell-powered drones to inspect gas infrastructure or affordably extract green hydrogen blended into the gas pipeline for use in industry or transportation.

Driven by scientific research and collaboration with subject matter experts from universities, national labs, public agencies, private industry, and research consortia, RD&D Program staff are deeply committed to accelerating the energy transition to clean fuels and educating policy makers, industry, and the general public about the many ways it is seeking to achieve that goal.

"Governments need to take rapid actions to lower the barriers that are holding low-carbon hydrogen back from faster growth, which will be important if the world is to have a chance of reaching net zero emissions by 2050."

—Fatih Birol
Executive Director
International
Energy Agency

Vision, Mission, and Values

The vision, mission, and values of the SoCalGas Research, Development, and Demonstration Program align with SoCalGas' mission to build the cleanest, safest, and most innovative energy company in America.

OUR VISION

Advancing innovative technologies for safer, cleaner, and more reliable energy.

OUR MISSION

Identify transformational energy solutions. Build them. Share them with the world.

OUR VALUES

Science

Our experts in science, engineering, energy systems, and environmental policy seek answers to some of today's most pressing energy questions.

Synergy

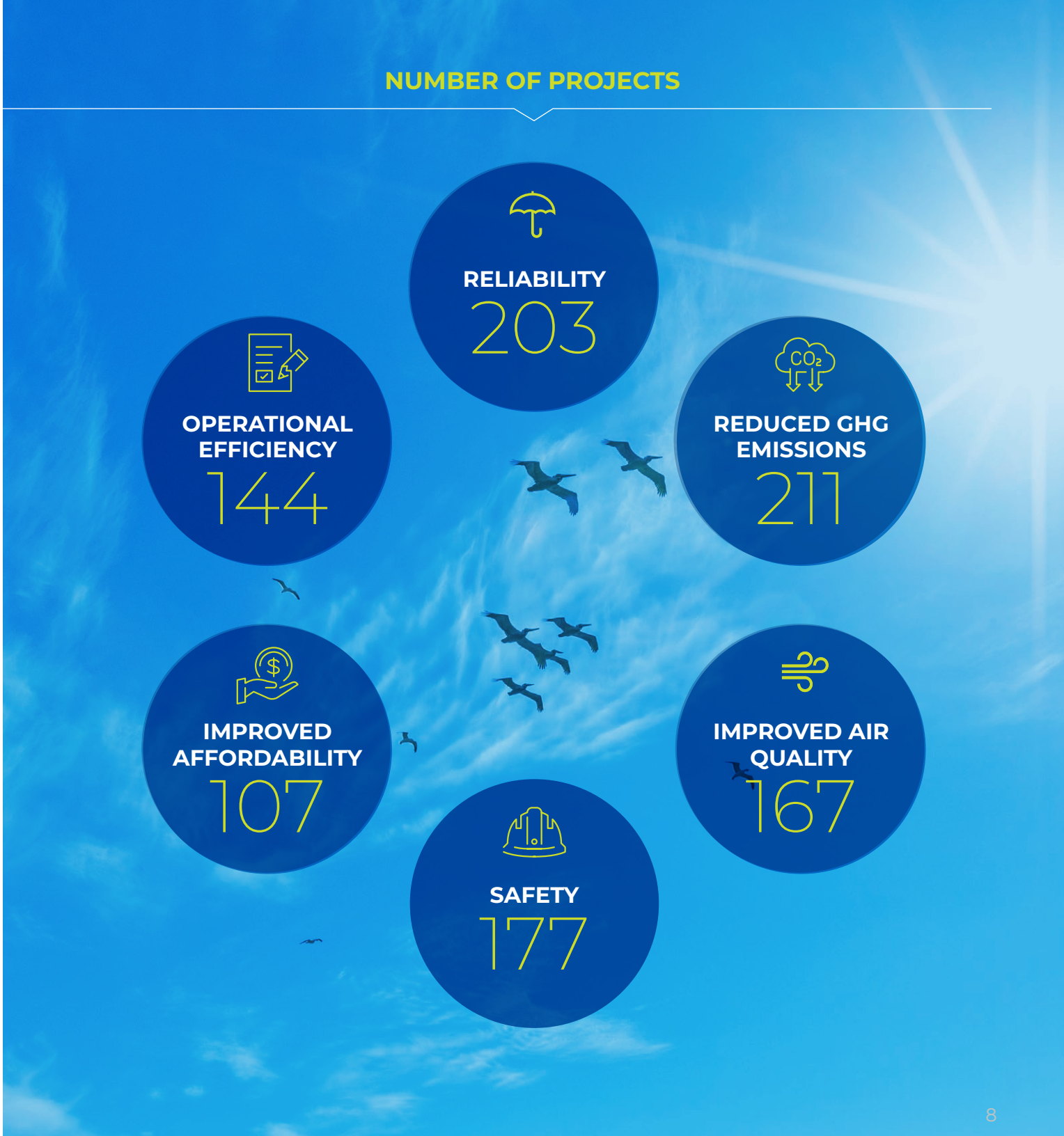
We work with the world's finest researchers in universities, national labs, and industry to develop transformational technologies that support decarbonization, energy security, and economic development.

Equity

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

Program Benefits

Each year, the RD&D Program supports hundreds of projects along the commercialization pathway, with the ultimate goals of saving energy, reducing GHG emissions, improving air quality, and increasing energy safety, reliability, and affordability.



2021 IN REVIEW

"We've got the whole delegation here as a united front on this challenge, which is, how do we make sure that people understand that this clean energy transition is about opportunity and creating jobs instead of fearing it."

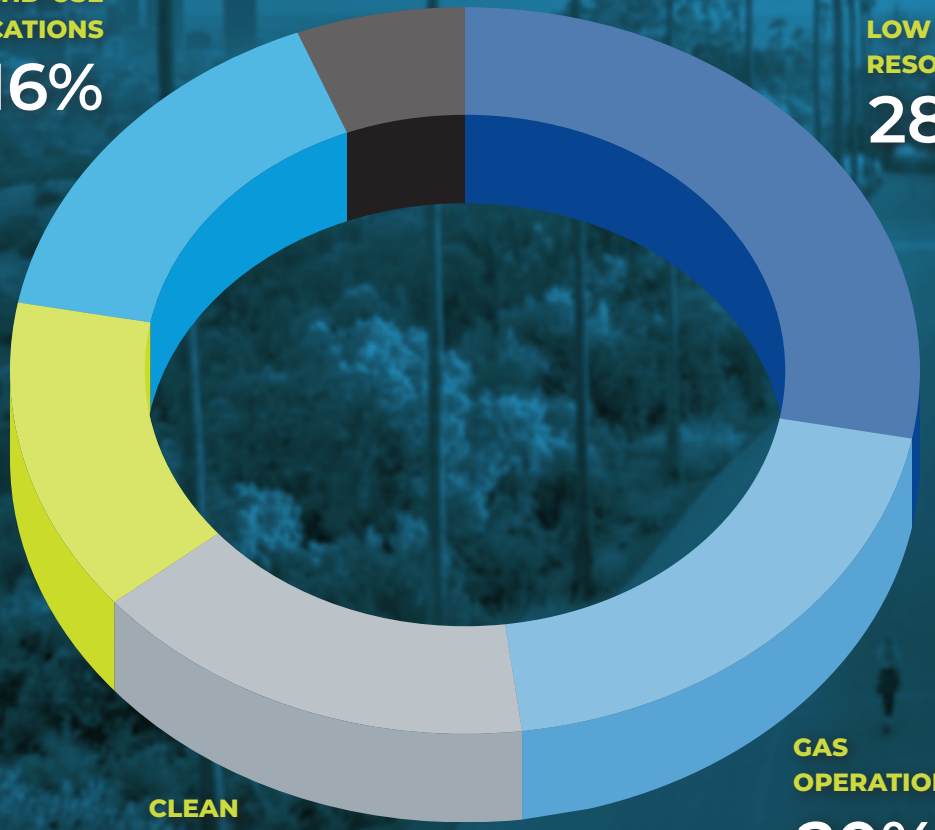
—Jennifer Granholm
U.S. Energy Secretary

Financial Highlights

In 2021, the RD&D Program supported 379 RD&D projects and distributed $16,977,474 to projects across the entire gas value chain. In executing these projects, SoCalGas collaborated with many of the most forward-thinking research consortia, universities, national labs, public agencies, and entrepreneurs across the nation and around the world. Collectively, these organizations provided significant funding, as well as invaluable guidance, review, technical expertise, and access to resources and infrastructure.

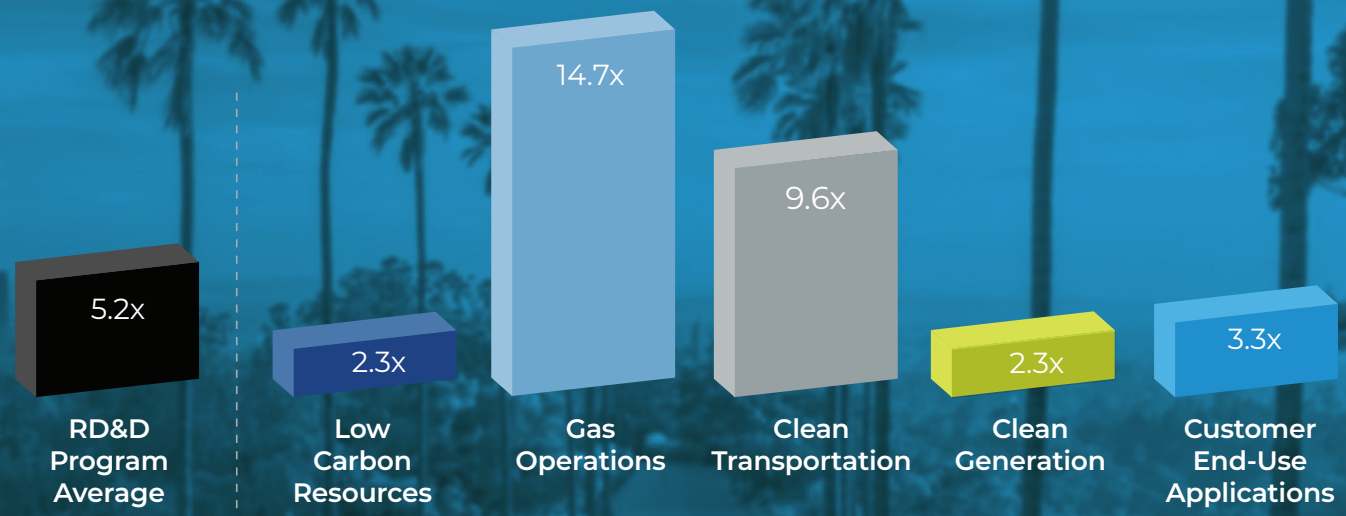
Split across five program areas—Low Carbon Resources, Gas Operations, Clean Transportation, Clean Generation, and Customer End-Use Applications—these projects encompassed everything from fundamental

2021 ACTUAL FUNDING BY PROGRAM AREA AND ADMINISTRATIVE COSTS



research and laboratory testing to real-world demonstrations and pilots. Importantly, they achieved substantial progress toward commercializing new, safe, reliable, and affordable clean energy products and technologies.

RATIO OF OUTSIDE FUNDING TO SOCALGAS FUNDING



2021 Funds Expended

In 2021, the SoCalGas RD&D Program invested $16,977,474 in numerous projects across the entire gas value chain, with an additional $1,057,195 going toward program management and administration. Collectively, these projects leveraged significant co-funding from businesses, research consortia, and other participating organizations. On average, every dollar of SoCalGas RD&D funds expended was matched by $5.20 in funding from other sources in 2021.

PROGRAM	2021 ACTUALS
Low Carbon Resources	$5,018,729
Gas Operations	$3,561,049
Clean Transportation	$2,844,666
Clean Generation	$2,608,167
Customer End-Use Applications	$2,944,863
SUBTOTAL	**$16,977,474**
Management & Administration	$1,057,195
TOTAL	**$18,034,669**

Significant 2021 Milestones

TOTAL **ACTIVE PROJECTS** IN 2021
379

TOTAL **PROJECTS COMPLETED** IN 2021
114

TOTAL **PROJECTS INITIATED** IN 2021
72

2021 ANNUAL STAKEHOLDER WORKSHOP

On April 14, 2021, RD&D Program staff hosted an online workshop attended by 165 individuals from a wide variety of organizations, including GTI, Lawrence Berkeley National Laboratory, Los Angeles Department of Water and Power, National Renewable Energy Laboratory (NREL), Society of Professional Hispanic Engineers, Stanford University, and the University of California. Program staff incorporated input received at the workshop into the 2021 RD&D Program Research Plan.

RESEARCH WEBINARS

In 2021, SoCalGas presented quarterly research webinars discussing three projects supported by the RD&D program.

- **Materials-Based Hydrogen Storage for Heavy Duty Vehicles**
  October 14, 2021: Representatives from Sandia National Laboratories and the DOE Hydrogen Materials–Advanced Research Consortium discussed the development of light-weight materials based on metal hydrides that could enable the use of light-weight alloys to construct storage tanks that operate at relatively low pressure (maximum 100 bar).

- **Biomethanation: Using Natural Organisms to Convert Waste CO2 and Renewable H2 to RNG for Long-Duration Energy Storage and Decarbonization**
  August 24, 2021: In this webinar, Dr. Kevin Harrison, Senior Engineer at NREL, discussed a new technology that uses naturally-occurring micro-organisms to transform renewable hydrogen and carbon dioxide into RNG. This process, known as biomethanation, could aid in decarbonizing the natural gas grid.

- **SoCalGas and C-Zero present: Co-producing Hydrogen and Valuable Solid Carbon from Natural Gas**
  June 23, 2021: Zach Jones and Dr. Fadl Saadi introduced a new process for transforming natural gas into hydrogen and a solid carbon co-product via methane pyrolysis and the role that this process can play in decarbonizing existing natural gas infrastructure.

Significant 2021 Milestones

FOLLOW-ON FUNDING

» **Electrochaea**
With support from the RD&D Program, Electrochaea demonstrated its biomethanation technology at NREL. In 2021, Baker Hughes—a $20-billion industrial services company—purchased a 15% stake in Electrochaea, backing a technology intended to address concerns about GHG emissions.

» **Twelve (formerly Opus 12)**
After early support from the RD&D Program, this electrochemical carbon dioxide reduction startup raised $57 million in Series A funding from lead investors Capricorn Technology Impact Fund and Carbon Direct Capital Management.

» **Stone Mountain Technologies, Inc. (SMTI)**
The RD&D Program provided early support to SMTI, a company focused on providing cost-effective, low-carbon heating and cooling solutions, including gas heat pump technology. In 2021, Enbridge, Inc. invested CAN$4,000,000 in SMTI.

» **High yield Energy Technologies (HyET) Group**
SoCalGas supported a closed-loop field demonstration of HyET's technology by providing access to a demonstration site, funding, and detailed specifications needed to blend hydrogen into the natural gas pipeline. Fortesque Future Industries acquired a 60% stake in HyET in late 2021.

FORTNIGHTLY TOP INNOVATOR 2021

Public Utilities Fortnightly, a forum for stakeholders in utility regulation and policy, recognized the RD&D Program as a Fortnightly Top Innovator in 2021. Fortnightly Magazine interviewed RD&D Program staff members Eric Coene, Ron Kent, and Matt Gregori on October 25, 2021.

EXPANDED OUTREACH

In 2021, the RD&D Program began sharing content about program activities and projects on its new LinkedIn page:

https://www.linkedin.com/showcase/socalgas-research-development-&-demonstration-rd&d-/about/

Leveraged Public Funding

In 2021, program staff supported 11 winning proposals applying for public funding. These projects were awarded $48,429,528 in research funding from the California Energy Commission (CEC), the U.S Department of Energy (DOE), and the DOE's National Energy Technology Laboratory (NETL).

5 PROJECTS WON A TOTAL OF **$12,999,620** FROM THE CEC

Publications

In 2021, projects co-funded or otherwise supported by the RD&D Program were featured in 40 reports, technology briefs, or articles in prestigious academic journals, such as Nature Communications and ACS Energy Letters.

See Appendix page 43 for more information.

Deployed Technologies

A major goal of the RD&D Program is to bring technology from the lab to market. In 2021, organizations across California and throughout the nation deployed numerous products and technologies for real-world use as a direct result of the support they received from the RD&D Program. Examples from 2021 include:

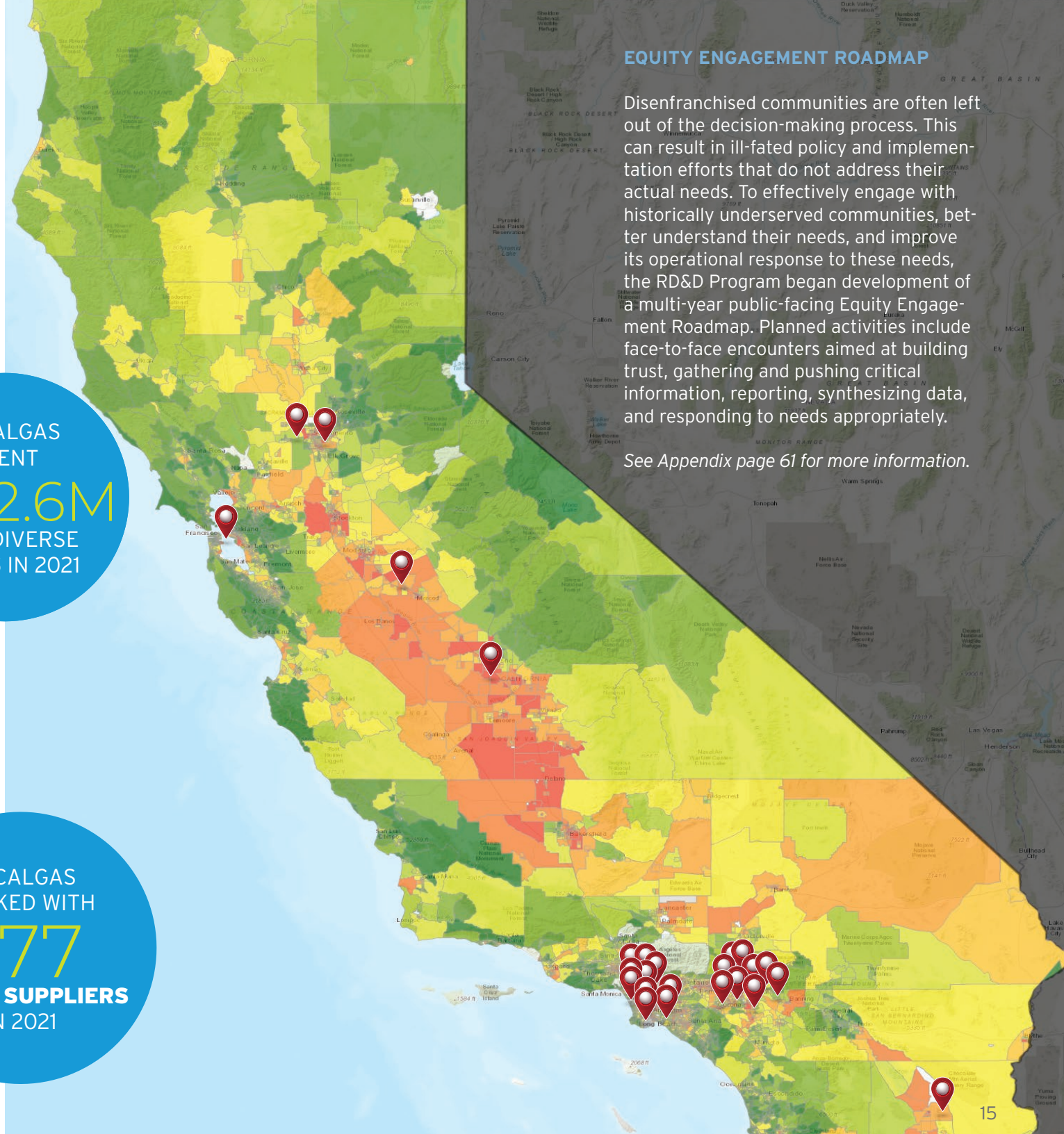
- AC Earth Faults (9.16.d)
- Biomethane Justification Study for Improved/Accepted Gas Quality Standards (7.18.b)
- Fault Displacement Hazard Initiative (UCLA)
- Flow Testing of FS500 Meters (MEAS-6-11A)
- Kiefner Interactive Threats Project (T-768)
- Material - Suppliers Quality Assurance Program (5.17.g)
- Rough Walled Pipe Gas Metering Applications (MEAS-6-5D)
- SMTI Heat Pump Commercialization (Stone Mountain Technologies)
- ThermoLift Combined Heating/Cooling System Technical Support – Phase 2 (1.17.F.2)
- Trace Constituent Database (7.18.h)
- Tracking and Traceability for Transmission, Pipe Materials, Phase 4 (Additional Demos) (5.14.d.4)
- Uniform Frequency Code (5.18.m)
- Unmanned Aerial System RD&D
- Update ASTM Standard on Soil Compaction Control Using the DCP (5.20.o)

2021 Equity Activities

SOCALGAS SPENT
$972.6M
WITH DIVERSE **FIRMS** IN 2021

THE RD&D PROGRAM SUPPORTED
27
PROJECTS LOCATED IN SB 535 DISADVANTAGED **COMMUNITIES** IN 2021

SOCALGAS WORKED WITH
577
DIVERSE **SUPPLIERS** IN 2021



EQUITY ENGAGEMENT ROADMAP

Disenfranchised communities are often left out of the decision-making process. This can result in ill-fated policy and implementation efforts that do not address their actual needs. To effectively engage with historically underserved communities, better understand their needs, and improve its operational response to these needs, the RD&D Program began development of a multi-year public-facing Equity Engagement Roadmap. Planned activities include face-to-face encounters aimed at building trust, gathering and pushing critical information, reporting, synthesizing data, and responding to needs appropriately.

See Appendix page 61 for more information.

2021 Equity Activities

COMMUNITY OUTREACH CALLS

- **February 24, 2021:** SoCalGas met with representatives from Home Aid Orange County, Proteus Inc., Pomona Chamber of Commerce, Unity Shoppe Santa Barbara, Santa Barbara Zoo, Southeast Community Development Corporation, Family Assistance Ministries, El Concilio Family Services, and Family Service Association. RD&D Program staff presented material about new technologies with the potential to benefit disadvantaged communities and priority populations. Attendees raised concerns about energy reliability and its relation to storing medications or preparing meals. Affordability of both energy and the new technologies was a key concern.

- **March 10, 2021:** Representatives from CSET Community Services Employment Training, Proteus Inc., Orange County Asian and Pacific Islander Community Alliance, Inc., Community Action Partnership of Kern, Asian Youth Center, Endowment for Youth Committee, and the Greater Lakewood Chamber of Commerce. RD&D Program staff presented material about new technologies with the potential to benefit disadvantaged communities and priority populations. Attendees posed numerous questions and raised several concerns, including affordability, which is "the number one concern for our low-income constituents."

- **May 19, 2021:** SoCalGas met with representatives from the University of California Riverside's Center for Renewable Natural Gas, Cal Poly Pomona, California State University (CSU) Long Beach, CSU Fullerton, the University of California-Irvine, and Cal State Los Angeles met with SoCalGas. RD&D Program staff asked the participants how the program could help them meet their goals and solicited input on their key concerns, including energy affordability, safety, air quality, and emissions.

- **August 25, 2021:** SoCalGas hosted representatives from Cypress College, Pasadena City College, Santa Barbara City College, Kern Community College District, East Los Angeles College Engineering & Technologies, Bakersfield College, Cerritos Community College, and Saddleback College. RD&D staff sought to understand how the program could help the participants meet their goals and solicited input on their key concerns, including energy affordability, safety, air quality, and emissions.

- **September 8, 2021:** SoCalGas met with representatives from the University of Southern California, California Greenworks, Delhi Center, and the Municipal Water District of Orange County. RD&D Program staff asked the participants how the program could help them meet their goals and solicited input on their key concerns, including energy affordability, safety, air quality, and emissions.

SPOTLIGHT

2021 Equity Activities

Cal State LA drives upward mobility through senior-year engineering program

The Capstone Senior Design Program helps students learn to solve real-world engineering challenges and gain valuable professional skills.

Located in the heart of Los Angeles, Cal State LA is a public university known for serving numerous Hispanic, Asian American, Pacific Islander, and minority students. Many are from low-income families and are the first in their families to attend college.

The university is ranked number one in the nation for upward mobility, in part due to programs such as its Engineering, Computer Science, & Technology Capstone Senior Design Program. Each year, funded by corporate and university sponsorships, the program gives students open-ended, real-world problems to solve. Working in small groups, the students meet with faculty advisors and project sponsors, work collaboratively, learn new skills, and present their results to faculty and sponsors.

In 2021, Arezoo Khodayari, an Associate Professor in the Department of Civil Engineering, served as faculty advisor on a project sponsored by SoCalGas. Two groups of students sought to optimize the hydrogen production schedule at Cal State LA's Hydrogen Research and Fueling Facility (H2 Station).

With an onsite storage capacity of 60 kilograms (kg), H2 Station is the

Students in Cal State LA's Capstone Senior Design Program sought to optimize the hydrogen production schedule at the university's Hydrogen Research and Fueling Facility.

largest university-located hydrogen fueling facility in the U.S. The station uses grid-sourced electricity to run an electrolyzer to produce hydrogen throughout the day, including during peak demand periods when the cost of electricity—and, therefore, hydrogen—is high. The students sought to minimize the cost of producing hydrogen by developing a smarter production schedule.

The two teams approached the challenge in different ways, with each developing different optimization models. Additionally, each team modeled multiple optimization scenarios, factoring in seasonality, time of day, utility seasonal rates, minimum hydrogen storage levels, and sales demand. One team also explored the impact of incorporating onsite solar into the power supply mix.

The students created an algorithm that used 2019-2020 fuel sales data to estimate fuel production costs for the same period if H2 Station had used the optimized production schedules developed by the students. The students determined that the station could reduce its electricity costs by between 10 and 30%, depending on various factors, such as minimum storage tank capacity and time of hydrogen production.

The students presented their results to SoCalGas, Professor Khodayari, and Professor David Blekhman, the director of H2 Station. "The students showed that the university could significantly reduce electricity costs for H2 Station while continuing to meet demand," said Khodayari. "It was eye-opening."

Sponsorship by SoCalGas has been valuable on many fronts. "The Capstone Program is costly," said Khodayari. "We need funding to reimburse faculty time and purchase supplies and equipment. Our sponsors—including SoCalGas—provide funding and other resources that we use to keep the program running." SoCalGas also helped develop the project concept, advised the students throughout the year, and provided feedback on the end-of-year presentation.

"SoCalGas is a leader in the energy industry, an area that increasingly interests our students," added Khodayari. "Many of them are excited to work for and learn from SoCalGas. In fact, SoCalGas has hired more than one graduate of the program. It has been a great collaboration."

"Without the Capstone experience, many of our students would have no other opportunity to prepare themselves for the job market and gain valuable experience," said Khodayari. "Through the program, they develop valuable skills, grow professionally, and learn how to work on a team and with clients. They become problem solvers—something that is needed on a real job."

"The Capstone Program is costly. We need funding to reimburse faculty time and purchase supplies and equipment. Our sponsors—including SoCalGas—provide funding and other resources that we use to keep the program running."

—Arezoo Khodayari
Associate Professor
Department of Civil Engineering
Cal State LA

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Program Goals and Structure

The goals of the RD&D program 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 seeks to decarbonize its pipeline by replacing conventionally sourced, fossil-based natural gas with increasingly higher amounts of RNG and hydrogen to benefit its customers and support California in the achievement of its ambitious climate change 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 regulatory and policy drivers, input from knowledgeable industry stakeholders, equity, and corporate policy and goals.

In 2021, the RD&D Program allocated funding across five research program areas: Low Carbon Resources, Gas Operations, Clean Transportation, Clean Generation, and Customer End-Use Applications.

FIVE RESEARCH PROGRAM AREAS

Low Carbon Resources

- Low Carbon Hydrogen Production
- Low GHG Chemical Processes
- Renewable Gas Production

Gas Operations

- Environmental & Safety
- Operations Technology
- System Design & Materials
- System Inspection & Monitoring

Clean Transportation

- Off-Road
- Onboard Storage
- On-Road
- Refueling Stations

Clean Generation

- Distributed Generation
- Integration & Controls

Customer End-Use Applications

- Advanced Innovation
- Commercial Applications
- Commercial Food Service
- Industrial Process Heat
- Residential Appliances

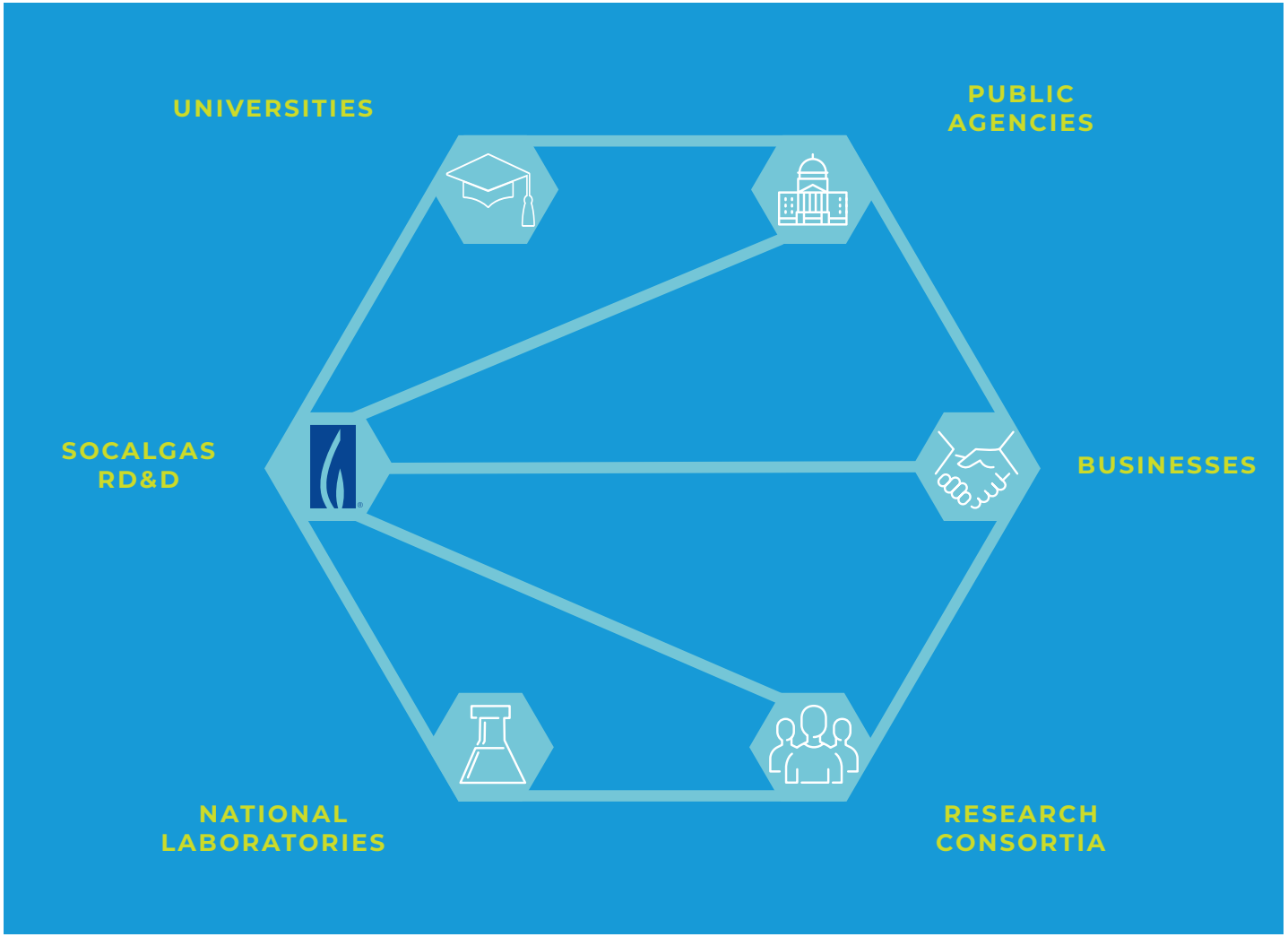
Research Collaborators

The SoCalGas RD&D Program is a vital element of a much larger technology funding ecosystem that includes gas industry research consortia and numerous federal, state, and regional public agencies. Program staff work with professionals and subject matter experts from these organizations, as well as from universities, national labs, and businesses, to maximize the impact of their investments in promising technologies and products with clear commercialization pathways.

These relationships enable SoCalGas to engage in open dialogues to more effectively identify and close knowledge and research gaps, avoid duplication of previous and ongoing research, and mitigate technical, economic, and commercialization risks. This helps program staff in their quest to develop products and technologies that reduce customer costs, save energy, increase safety and reliability, improve air quality, and reduce GHG emissions.

Together, RD&D staff and research collaborators exchange information and research concepts, collaborate on project development, establish partnerships, and actively seek public and private funding opportunities, with the goals of securing additional co-funding and assembling capable and impactful project teams.

See Appendix for more information.



"Our planet's health, economic well-being, and national security are all at risk. It is imperative that we address the climate challenges we face with a fierce sense of urgency — human lives and livelihoods are at stake."

— Colorado Senator John Hickenlooper

PROGRAM: LOW CARBON RESOURCES

The primary goal of the Low Carbon Resources program area is to decarbonize the gas supply while maintaining its affordability and reliability. To accomplish this goal, program staff members develop, promote, and advance new technologies aimed at increasing the production of renewable gas to displace conventionally sourced pipeline gas, while also limiting or recycling GHG emissions.

In 2021, this program included three subprograms:

Low-Carbon Hydrogen Production

This subprogram focuses on the production of low-carbon and GHG-emissions-free hydrogen from various methane feedstocks, including biomethane. Areas of focus include, but are not limited to, advanced steam methane reforming (SMR) and methane pyrolysis technologies.

Low-GHG Chemical Processes

This subprogram focuses on the design, development, and deployment of technologies that can minimize reliance on natural gas combustion, and on carbon capture utilization and sequestration (CCUS) technologies for the capture of GHG emissions and their conversion into valuable chemicals or sequestration.

Renewable Gas Production

This subprogram focuses on the safe, reliable, and cost-effective production of renewable gaseous fuels—specifically, RNG and hydrogen—from various feedstocks and multiple technological pathways. Areas of focus include, but are not limited to, biomass processing and conversion, renewable hydrogen production from direct water splitting, and methanation pathways to produce RNG from captured carbon dioxide.

SPOTLIGHT

Low Carbon Resources

Novel technology extracts hydrogen blended into existing gas pipelines on demand

HyET Hydrogen develops distributed technology with no moving parts that can cost-effectively extract hydrogen from existing gas pipelines.

HyET Hydrogen recently demonstrated a closed-loop pilot system capable of extracting pure streams of hydrogen from blends of methane and hydrogen at the SoCalGas Engineering Analysis Center in Pico Rivera, California.

TOTAL PROJECT COST: $609,500

SOCALGAS:	$609,500
COFUNDING:	$0

Hydrogen is poised to play a key role in the decarbonization of transportation. One of the greatest barriers to its widespread adoption, however, is the cost and difficulty associated with its distribution from the point of generation to its ultimate end users.

Using conventional technologies, this process requires energy-intensive compression and transportation via tanker truck, both of which increase cost and emissions.

To overcome these challenges, gas utilities and technology companies have begun to explore blending hydrogen into existing natural gas infrastructure. One company, HyET Hydrogen, recently demonstrated a closed-loop pilot system capable of extracting pure streams of hydrogen from blends of methane and hydrogen, with hydrogen concentrations ranging from 2.5% to 15% at a variety of flow rates and operating pressures. HyET demonstrated the system at the SoCalGas Engineering Analysis Center in Pico Rivera, California.

"Transporting hydrogen via existing gas pipelines would be a major step forward," said Jonne Konink, Co-CTO of HyET Hydrogen. "You avoid the emissions associated with transporting hydrogen via tanker truck as well as the need to construct a costly, parallel distribution system—something that's virtually impossible in many congested urban areas."

Constructed within a 20-foot shipping container, the pilot system included multiple sample points, storage tanks for methane and hydrogen, a circulation fan, and HyET's innovative compressor and extractor.

At the heart of the extractor is a membrane electrode assembly (MEA), which consists of a proton-conducting membrane coated on both sides with catalysts that can dissociate hydrogen into protons when current is applied. "The membrane allows protons to pass through it and acts as a barrier to other gases in the pipeline," says Konink. On the other side, they recombine with the electrons to form hydrogen gas in a compression stack that gradually builds in pressure as the number of protons increases. "The only moving parts are the molecules."

Initially, the project faced numerous challenges. "We started out trying to build a system in the United States from the Netherlands because we were unable to travel for much of 2020 due to COVID-19," said Konink. When HyET staff finally reached the United States, they faced difficulties sourcing materials and labor. "Hydrogen molecules are quite small and tend to migrate through materials. We had to source specially rated steel for piping as well as welders experienced in working with it."

The team's hard work and perseverance paid off. "The first time we filled up the system and turned on the extractors, we pulled out hydrogen immediately," said Konink. "No tinkering needed. It just worked." HyET experienced similar results with the compressor. "It compressed to 400 bar—as designed—with no issues. We made minor adjustments to sensors and other components, but the actual science worked in one go."

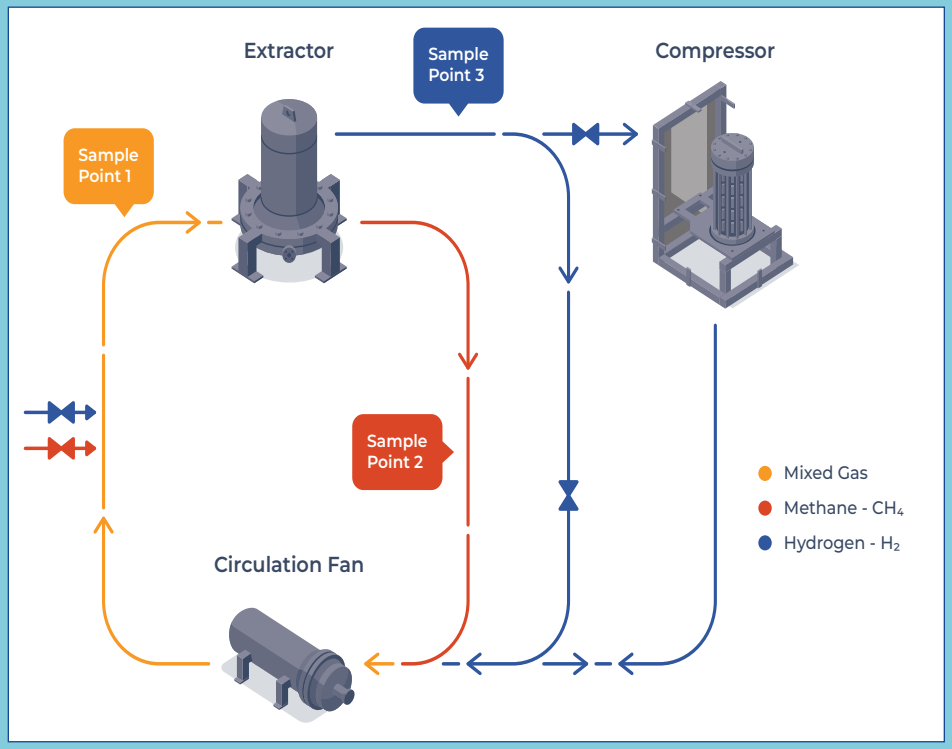
"Our technology does not really have any competitors," said Maria Fennis, CEO of HyET Hydrogen. "You can install it anywhere you have a natural gas line that contains a blend of hydrogen." The system is quiet, turns on and off in seconds, and requires little maintenance. "It literally provides on-demand hydrogen production." Designed to extract 10 kg per day, the pilot can easily scale to 2,000 kg per day simply by increasing vessel size.

"With this technology, hydrogen distribution is close to being solved," said Konink. Unfortunately, formidable regulatory barriers still remain. "Utilities are not allowed to blend hydrogen into existing pipelines," said Konink. "For the moment, we are confined to testing it on infrastructure isolated from the main gas network."

In the near term, however, HyET's technology shows promise in other applications, such as replacing the costly purification and compression components of conventional SMR systems, today's most common method of hydrogen production. "That would be a tremendous success and would enable us to continue to develop the technology until regulatory conditions are more favorable," said Fennis.

"Ultimately, we are trying to convert consumers to a gas—hydrogen—that doesn't harm the planet, while continuing to earn money with our operations," said Rombout Swanborn, Co-CTO and founder of HyET Hydrogen. "This technology enables us to leverage existing infrastructure while transitioning gradually from natural gas to hydrogen."

"In all of these efforts, SoCalGas staff were absolutely critical," Swanborn continued. "They have been the driving force behind this project, providing access to the demonstration site, funding, and detailed specifications for pressure output, temperature, and blend percentages. They are also helping us plan larger-scale, future applications."



The pilot system included multiple sample points, storage tanks for methane and hydrogen, a circulation fan, and HyET's innovative compressor and extractor.

SPOTLIGHT

Low Carbon Resources

Innovative technology captures carbon dioxide from ocean water

Caltech achieves highest current density ever achieved at lab scale in an electrodialyzer and sets stage for lower-cost carbon capture.

TOTAL PROJECT COST: $1,050,000

SOCALGAS:	$200,000
COFUNDING:	$850,000

In 2021, the average concentration of carbon dioxide (CO2) in the Earth's atmosphere reached 419 parts per million—the highest level in recorded history—with the total mass of atmospheric carbon surpassing 750 quadrillion kilograms. That number is dwarfed, however, by the vast quantities of carbon found in the oceans, which contain 93% of the carbon stored in the atmosphere, oceans, and land biosphere.[4]

The oceans absorb 30% of the CO2 released into the atmosphere. As anthropogenic carbon emissions have increased, however, the oceans have been negatively impacted. "When CO2 diffuses into oceanwater, it combines with water molecules to form carbonic acid, a weak acid that dissociates into hydrogen ions—protons essentially—and bicarbonate ions," says Chengxiang Xiang, Research Professor of Applied Physics and Materials Science at the California Institute of Technology (Caltech). "More CO2 in the air means more protons in the water, which decreases the pH of the ocean and contributes to acidification."

Many companies have begun capturing carbon from industrial processes or removing it from the atmosphere via Direct Air Capture (DAC). "Unfortunately, DAC alone is not enough," says Xiang. Removing CO2 from the air changes the gas pressure balance between air and water. When the gas pressure of CO2 in the air drops below that of CO2 in the ocean, CO2 diffuses across the air-ocean boundary into the atmosphere—undoing a significant part of the progress made by DAC.

With support from SoCalGas and the U.S. Department of Energy, Caltech is seeking to reverse that process by developing an innovative and affordable Direct Ocean Capture (DOC) technology. "By capturing CO2 from oceanwater—and changing the CO2/bicarbonate equilibrium at the ocean water/air interface—the oceans will actually suck CO2 from the air," says Xiang. When scaled, the technology could potentially remove carbon from the oceans at the gigaton scale.

The project had an unlikely beginning. "In 2020, SoCalGas helped us develop a techno-economic analysis (TEA) of potential ways to produce renewable methane," says Xiang. That study led the team to consider using CO2 in the air and oceans as a possible feedstock for processes such as methanation, which converts hydrogen and CO2 into methane. This TEA helped Caltech determine the key technical goals

required to affordably capture carbon from oceanwater.

The Caltech team envisioned an offshore system that would capture CO2 from oceanwater, remove it for industrial use or sequestration, and increase the pH of the water it returns to the ocean to pre-industrial levels, helping to mitigate ocean acidification.

The system inputs oceanwater at a pH of 8.1 and passes it through a micro-screen filter that removes grit, debris, and suspended solids. A very small fraction of the oceanwater is diverted to an electrodialyzer. Here, the ocean-water is dissociated into a concentrated acid, a concentrated base, and dilute streams through use of an electrodi-alysis system supported by a bipolar membrane (BPM). The concentrated acid is used to acidify a large volume of the oceanwater for the subsequent CO2 stripping step. Before its return to the ocean, the process water is combined with the concentrated base and dilute stream to adjust the water's pH to pre-industrial levels.

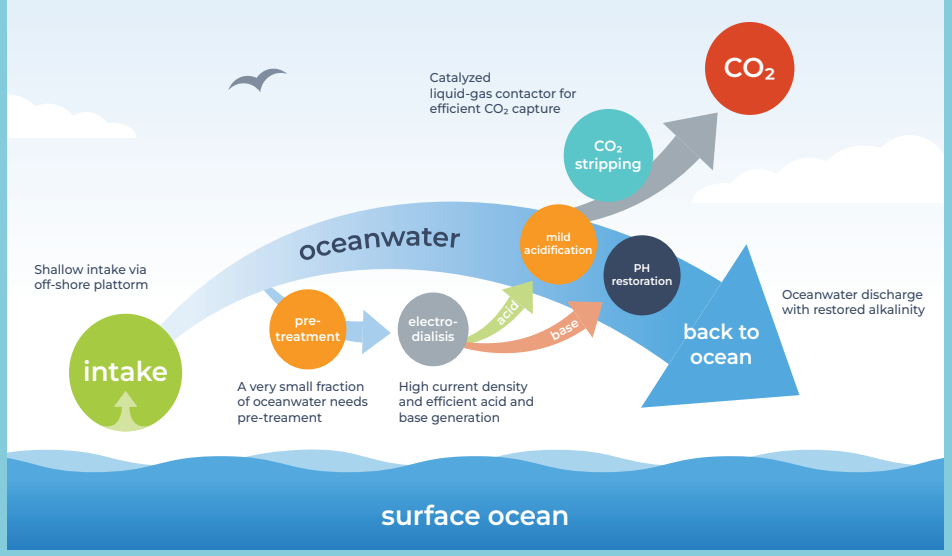
"Early seed funding for the TEA from SoCalGas gave us the time to explore possibilities and attract additional funding," said Xiang. This included an $850,000 award from the DOE's Advanced Research Projects Agency–Energy program for development of an off-shore, electrochemical-driven CO2 capture process. SoCalGas invested an additional $200,000 specifically to advance development of the electrodialyzer.

"The electrodialyzer is the critical cost lever of the entire system," says Xiang. "It is responsible for roughly 80% of overall system energy consumption." To drive down capital costs, Caltech ultimately hopes to achieve a current density of >500 mA/cm2, an order of magnitude higher than traditional sys-tems. "If we can do that, the overall system will be cost-competitive with other carbon capture technologies."

During the lab-scale work on the electrodialyzer, Caltech made signif-icant progress toward that ultimate goal. Caltech staff experimented with a range of materials and configura-tions until identifying a configuration that achieved a current density of 1 A/cm^2. "That's the highest current density ever achieved at lab scale in an electrodialyzer," says Xiang.

Caltech also sought to re-engineer the BPM. "In existing electrodialyzers, the water dissociation reaction is too slow," says Xiang. Additionally, at high current densities, water cannot flow into the BPM interface at a fast enough rate, which limits the maximum allowable cur-rent density. Thus, as voltage increases, there is no corresponding increase in current. "The BPM interface also dries out, which can cause irreversible damage to the membrane. We overcame these limitations by fabricating a custom, asymmetric BPM and using a graphene oxide catalyst at the BPM interface to increase the rate of reaction."

By the end of 2021, Caltech had demon-strated a lab-scale electrodialyzer



The system inputs ocean water and diverts a very small fraction to an elec-trodialyzer, where it is dissociated into a concentrated acid, a concentrated base, and dilute streams. The concentrated acid is used to acidify a large volume of the oceanwater for the subsequent CO2 stripping step. Before its return to the ocean, the process water is combined with the concentrated base and dilute stream to adjust the water's pH to pre-industrial levels.

capable of CO2 extraction from oceanwater at 93% purity with an electrochemical energy of 1 kWh/kg-CO2 at an applied current density of 3.3 mA/cm^2. "We have achieved close to 100% capture efficiency," says Xiang. "Electrodialyzers are not new, but we really pushed the envelope in terms of how they are used in carbon capture."

In 2022, Xiang seeks to scale up the technology to demonstrate the com-mercial viability of a pilot plant capable of capturing CO2 from oceanwater at a rate of 100 metric tons per year. "At that scale, the system will intake 700 to 1,000 gallons a minute," says Xiang.

"SoCalGas has been really support-ive in helping us move from the lab to a much larger scale," says Xiang.

"They not only provided seed and follow-on funding but also specifica-tions for industrial-quality CO2 that could be sequestered to offset the utility's carbon emissions or used to produce renewable methane. SoCal-Gas is also assisting Caltech with an early-stage spinoff, Captura, that is developing a one-ton-per-year pilot system for demonstration in 2022.

"If scaled, this technology could be critical to the fight against climate change," says Xiang. "It would enable industries that are difficult to decarbonize—such as steel, cement, and chemicals—to offset their current carbon emissions. It would also enable them and many other industries to capture histori-cal emissions."

PROGRAM:

GAS OPERATIONS

The Gas Operations RD&D program supports pipeline transportation and storage operations through innovations that enhance pipeline and employee safety, maintain system reliability, increase operational efficiency, and minimize GHG impacts to the environment. The program also supports 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 through improvements in public and pipeline safety, system reliability, operational efficiency, and environmental benefits.

The program invests in technology development projects that are divided into the following subprograms:

Environmental & Safety

This subprogram seeks to advance the environmental 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 the pipeline from intentional and unintentional damage and with improving the safety of the general public and company employees or contractors working on or around the pipeline. Projects include exploring how blending hydrogen into the pipeline impacts the operation and maintenance of the pipeline system regarding safety, reliability, integrity, and environmental impacts.

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

Operations Technology

This subprogram supports technologies that improve employee training, efficiency of construction, and the operation/maintenance/rehabilitation of gas pipelines, as well as systems that facilitate continued safe and reliable service. This subprogram also explores how best to prevent gas leaks that result from blending hydrogen into the pipeline.

System Design & Materials

The objectives of this subprogram are to advance materials and materials science, materials tracking and traceability, and technical tools for designing pipeline systems and infrastructure for safety, reliability, efficiency, and maintainability throughout the lifecycle of pipeline assets. 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 non-traditional sources (biogas and hydrogen-blend) on overall natural gas quality and system integrity.

System Inspection & Monitoring

The objectives of this subprogram include developing technologies and methods for inspection, monitoring, and testing of pipelines and pipeline components to assess the condition and performance of pipeline facilities. The goal is to improve system performance, reliability, safety, and operational efficiencies through data management to identify precursors to failures or incidents. Projects in this subprogram leverage artificial intelligence, machine learning, and preventive and predictive maintenance technologies, including data analytic models and data lakes, and innovative data sources such as Crowd Source and the Internet of Things. This subprogram also seeks to explore tools for managing the potential impacts of blending hydrogen into the gas pipeline.

SPOTLIGHT

Gas Operations

Utility consortium drives policy change through R&D

OTD develops new pipeline integrity methodologies that reduce cost, increase reliability, and improve safety.

The U.S. Pipeline and Hazardous Materials Safety Administration (PHMSA) is responsible for developing and enforcing regulations for the safe, reliable, and environmentally sound operation of the nation's 2.6 million miles of pipelines.

In 2020, Congress enacted a law that strengthened PHMSA's authority to advance the safe transportation of energy and other hazardous materials. One consequence of the new law was the sunsetting of a "grandfather" clause that exempted pipeline operators from obtaining critical safety information about pipelines installed prior to 1970. Operators must now provide this information, often at great cost.

"The current gold standard for determining pipeline material properties involves cutting a ring sample from the pipe and subjecting it to destructive testing," says Michael Adamo, Vice President of Operations at Operations Technology Development (OTD), a gas research consortium. This process is costly and can require the temporary shutdown of a pipeline or installation of a bypass.

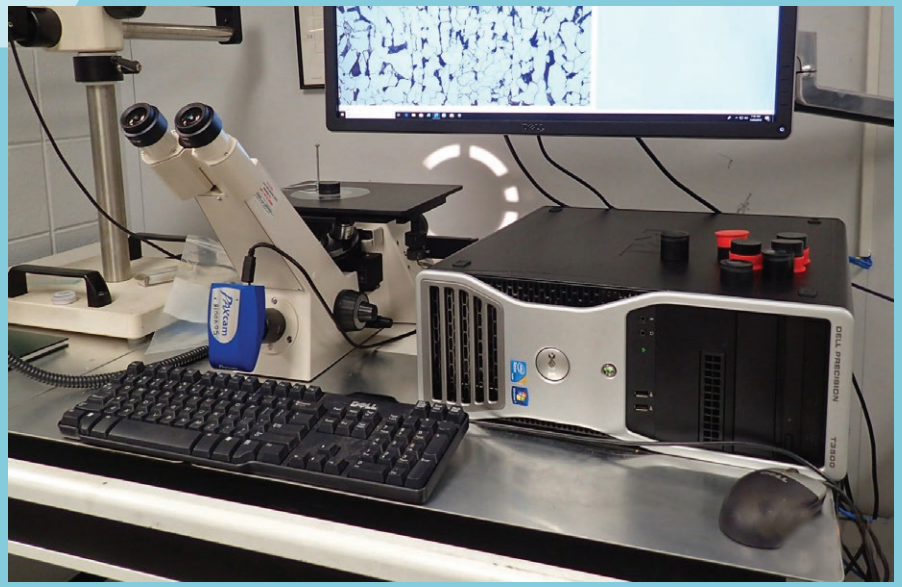
In 2018, PHMSA awarded OTD a $489,515 Safety Research & Development (R&D) grant to develop testing procedures that would enable operators to use nondestructive evaluation (NDE) technologies on a pipe and, through correlation, accurately determine a variety of characteristics about the pipeline properties, including yield and tensile strength, as well as steel chemistry. OTD subcontracted the work of integrating state-of-the-art causal and data modeling to GTI, a non-profit R&D organization focused on new energy technologies.

"Pipeline steel, depending on the manufacturing method and material type, can have varying characteristics on its outside wall compared to its bulk properties throughout the pipe wall," said Adamo. "But

The project sought to develop testing procedures that would enable operators to use nondestructive evaluation technologies on a pipe and, through correlation, accurately determine a variety of pipeline characteristics, including yield and tensile strength, and steel chemistry.

TOTAL PROJECT COST: $1,054,516

SOCALGAS:	$57,874
COFUNDING:	$996,642



Project team members first lab-tested the samples for yield strength, ultimate tensile strength, steel chemistry, grain size, hardness, and in a subset of 30 samples, material fracture and Charpy toughness.

when determining yield strength and setting operating pressure, it's very important to have a consistent and accurate way of modeling these variations. Inaccurate information can lead to unsafe operations."

Daniel Ersoy of Element Resources served as principal investigator. Arizona State University assisted Ersoy with in-depth statistical modeling. Several utilities—including Intermountain Gas Company, Dominion Energy, and Southwest Gas Corporation—provided 70 pipeline samples for use in characterizing pipeline properties, correlating the surface-to-bulk properties, and developing predictive models of bulk properties based solely on surface-obtained pipeline data. More than 60% of the samples were installed prior to 1970.

Project team members first lab-tested the samples for yield strength, ultimate tensile strength, steel chemistry, grain size, hardness, and, in a subset of 30 samples, material fracture and Charpy toughness. Technology providers Frontics, SciAps, and Massachusetts Materials Technology (MMT) then performed NDE testing of the surface of the pipelines using their respective nondestructive testing equipment. The project team compared these data to full wall testing data and used causal and statistical modeling with surface-obtained pipe data to establish yield and tensile strength surface-to-bulk property predictions and chemical variance distributions.

SoCalGas supported this project through its membership in OTD, which includes 28 member utilities from around the country that pool funds to develop advanced technologies for the natural gas industry. "SoCalGas has been a great asset to OTD in helping provide an end user's perspective," said Adamo. "This project is a great example of collaboration between the research community, a regulatory body, and industry to achieve solutions to problems that the entire industry faces. In the end, ratepayers are the real beneficiaries of this research because it reduces operational costs, increases system reliability, and improves safety."

Following successful completion of the project, GTI is working closely with PHMSA to incorporate knowledge gained into its regulation on pipeline safety and testing. Once this happens, utilities across the nation—including SoCalGas—will be able to formally adopt the new methodologies and practices.

SPOTLIGHT

Gas Operations

Design safer, more reliable pipelines

UCLA-led team creates comprehensive database and models to more accurately predict fault displacement hazards that could damage underground pipelines.

California is home to thousands of miles of underground natural gas infrastructure, much of which crosses earthquake fault zones. Moderate to severe earthquakes can rupture the earth's surface along these zones, producing permanent ground displacements. For example, in 2016 an earthquake along the Kekerengu Fault in New Zealand resulted in a displacement of 12 meters.[5] Such displacements can cause significant damage to underground pipeline infrastructure.

Engineers can develop site-specific engineering solutions to quantify the seismic performance of pipelines and other extended infrastructure against fault displacements. To do so effectively, however, they need access to accurate fault displacement data and models.

To address this challenge, the University of California, Los Angeles (UCLA) initiated the Fault Displacement Hazard Initiative (FDHI) Project in 2018. UCLA collaborated with multiple national and international universities, gas and water utilities, and public agencies such as the California Geological Survey.

California is home to thousands of miles of underground natural gas infrastructure, much of which crosses earthquake fault zones. Moderate to severe earthquakes can rupture the earth's surface along these zones, producing permanent ground displacements and damaging pipelines.

TOTAL PROJECT COST: $2,415,000

SOCALGAS:	$150,000
COFUNDING:	$2,265,000

The project seeks to develop a structured relational fault displacement database that will support creation of new, probabilistic models and, ultimately, a probabilistic fault displacement hazard map of the state of California. "Utilities will be able to overlay their pipeline maps on the hazard map and obtain a color-coded risk assessment of their infrastructure that will identify where the risk of catastrophic fault displacement is highest," said Dr. Yousef Bozorgnia, a professor in UCLA's Department of Civil & Environmental Engineering.

For help funding the multiyear project, UCLA first turned to California's largest utilities, SoCalGas and Pacific Gas & Electric Company. "They provided seed funding that enabled us to seek and obtain additional funding from other sponsors," said Bozorgnia. "Their early support was very valuable." The project leveraged this early funding to obtain a grant from the California Energy Commission to further support this fault displacement work as well as research on landslides, liquefaction, and ground shaking.

In 2021, the project team completed the database. "Earthquakes happen around the world but before now there were only databases with limited fault displacement data for various styles of faulting," said Bozorgnia. "Through a literature review and international collaboration, especially with colleagues in Europe, we systematically collected data from 66 global earthquakes of magnitudes 5.0 to 8.0 and then assessed the data for completeness, accuracy, and consistency."

While developing the database, the researchers collaborated extensively with the model developers to ensure that database content addressed the needs of model development. "Several fault displacement models are in use today," said Bozorgnia. "These models differ widely, however, in their input datasets, estimated displacement metrics, modeling techniques, and treatment of uncertainty."

To mitigate these issues, the FDHI modelers are relying on the comprehensive FDHI database and creating four probabilistic fault displacement models, each using different sets of assumptions. It is important to develop multiple models as each model has its own strengths and weaknesses. Model development is on track for completion in summer of 2022. In the final phase of the project—scheduled for completion by early 2023—the team will create the probabilistic hazard map of the state of California for fault displacement.

Once complete, the database, models, and hazard map will be published on the UCLA website and available to everyone. Following publication, the project team will continue to collect data, especially for larger-magnitude earthquakes. "Ultimately, we will update the model every few years to further improve its accuracy," said Bozorgnia.

"Earthquakes happen sooner or later," said Bozorgnia. "With this project, our goal is to reduce the risk that potential hazards will become disasters. What we are doing is not abstract. It is based on real-world numbers and input and will help utilities design safer pipelines and prioritize replacement schedules based on realistic estimates of risk."

PROGRAM:

CLEAN TRANSPORTATION

The Clean Transportation program supports activities that reduce environmental impacts related to the transportation sector. Focusing on utilization of RNG and renewable hydrogen, this program facilitates the development of zero-emissions technology for on-road and off-road applications, fueling infrastructure, and on-board storage technologies.

This program includes four subprograms:

Off-Road

This subprogram focuses on developing zero emission off-road transportation solutions using RNG and renewable hydrogen. Its goal is to achieve emissions reductions from off-road vehicles such as trains, ocean-going vessels, commercial harbor craft, construction equipment, and cargo handling equipment. Subprogram staff have also begun to explore aviation applications, including hydrogen fuel cell aircraft and drones.

Onboard Storage

This subprogram targets the development, demonstration, and deployment of cost-effective technologies and systems that improve onboard storage for gaseous transportation fuels. Areas of focus include advanced materials, low-pressure systems, and conformable tanks for both RNG and hydrogen. Onboard storage, which requires compressed storage and/or the use of advanced adsorption technologies, is a critical element needed for increased utilization of low-carbon, low-emission gaseous fuels.

On-Road

This subprogram targets emissions reductions from medium- and heavy-duty on-road vehicles. The focus is zero-emission, on-road transportation technologies using RNG and renewable hydrogen.

Refueling Stations

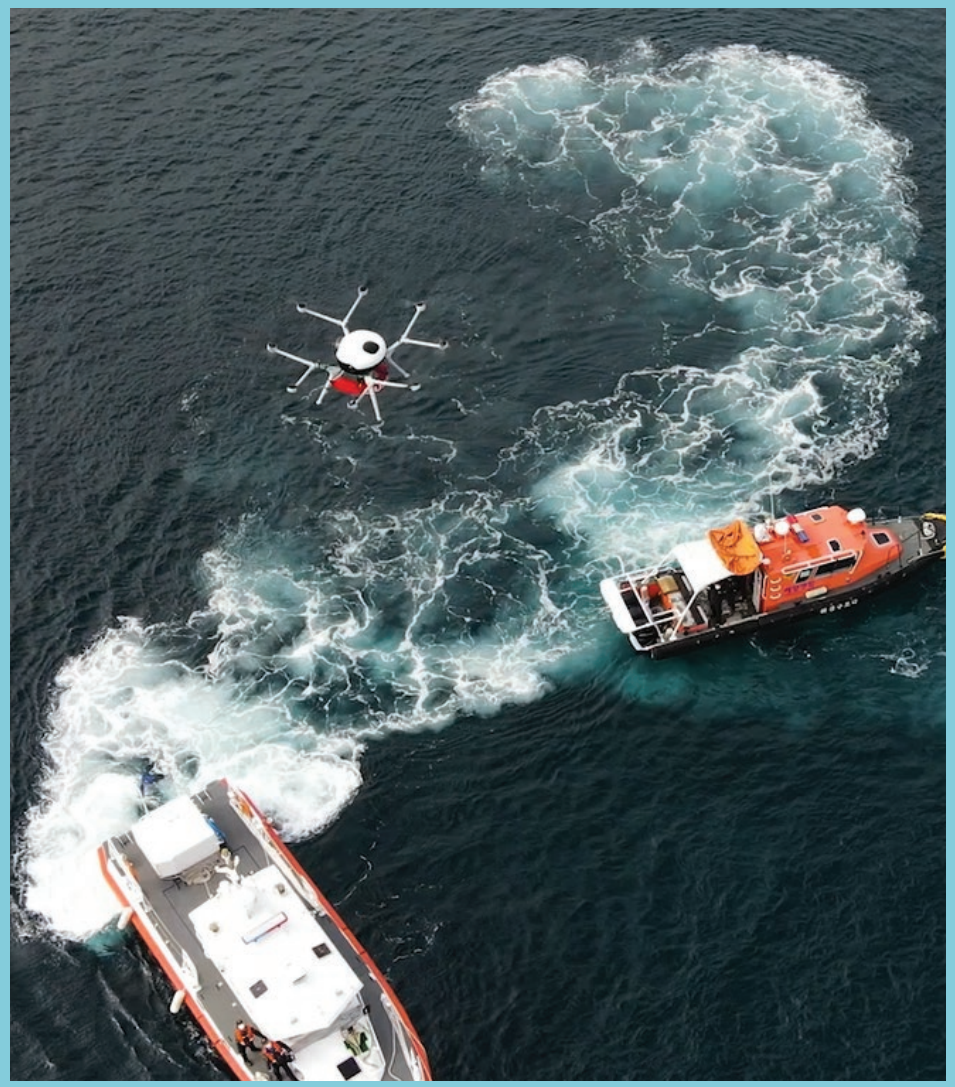
This subprogram targets the development, demonstration, and deployment of technologies and systems that support refueling for alternative fuels, including gaseous and liquid hydrogen and RNG. Subprogram staff also seek to identify and manage concerns and issues related to refueling, from storage to safety and standardization.

SPOTLIGHT

Clean Transportation

Hydrogen-fuel-cell drones enable long-range pipeline inspection

Zero-emission drones lay the groundwork for a companywide transition to hydrogen-fuel-cell-powered aircraft.



SoCalGas operates a fleet of fixed-wing airplanes, rotary aircraft, and battery-electric drones. "We use the drones to inspect difficult-to-access sections of our pipeline network," says Miguel Cara, Aviation and Flight Operations Management Team Leader for the company's Aviation Services Group.

To improve the efficiency of its inspections, SoCalGas has begun exploring the use of zero-emission, hydrogen-fuel-cell-powered drones with Korean firm Doosan Mobility Innovation (DMI) and GTI, an R&D organization that develops and demonstrates new energy technologies.

DMI has developed a suite of drones and fuel cell powerpacks with a wide range of potential applications, including surveillance, search and rescue, product delivery, and aerial inspection. On this project, DMI integrated its DP30 fuel cell powerpack with its DS30 commercial drone. Designed for operation in harsh environments, the integrated drone weighs 21 kg, is equipped with an LTE modem, and can carry a payload of 5 kg. Critically, the DP30 powerpack carries 300 grams of hydrogen and

TOTAL PROJECT COST: $250,000

SOCALGAS:	$250,000
COFUNDING:	$0

DMI's integrated drone weighs 21 kg, is equipped with an LTE modem, and can carry a payload of 5 kg for up to 120 minutes—roughly four times the range of battery-electric drones. Potential applications include surveillance, search and rescue, product delivery, and aerial inspection.

can travel up to 120 minutes—roughly four times the range of battery-electric drones.

"Through a series of demonstrations, our goal is to show SoCalGas that it can replace its battery-electric drones with hydrogen-fuel-cell-powered drones," says Soonsuk Roh, a manager in DMI's Business Execution Team. Although the project experienced significant delays due to COVID-19, it achieved its first significant milestone in September 2021 with a demonstration at SoCalGas' facilities in Downey, California.

Buoyed by this success, DMI began planning extensive field tests for 2022. "Because SoCalGas' battery-electric drones have ranges of only 20 to 30 minutes, the missions they fly are necessarily short," says Roh. DMI carefully evaluated the existing missions and developed new missions that took advantage of its drone's much longer range.

To close out 2021, DMI conducted one additional demonstration at the University of Texas, Austin under a GTI-led project funded by the US Department of Energy's H2@Scale program. "We are building a hydrogen ecosystem that includes generation, storage, and end use on one campus," says Ted Barnes, Director of R&D at GTI. "Integrating hydrogen fuel cell drones enabled us to prove their value and reliability to potential commercial end users."

In 2022, DMI plans to run the real-world missions it developed in the previous year. DMI will also seek to optimize the sensors carried by the drones, including thermal cameras, gas sensors, multi-spectral cameras, and air quality sensors. GTI will provide valuable assistance on hydrogen infrastructure and refueling planning—both for the immediate project and for future mass deployments of hydrogen fuel cell drones. "Our role is to support the integration of hydrogen into a new technology space," says Barnes. "For example, although many standards and codes exist for fueling hydrogen vehicles, there are none for hydrogen drones. That's an area where we can add value."

"SoCalGas has shown great leadership in using hydrogen fuel cell drones for field inspections of its pipeline network," says Roh. By the end of 2022, DMI hopes to see its drones in full commercial deployment at SoCalGas. Ultimately, DMI hopes to replicate the success of this project at other gas utilities around the nation.

Miguel Cara sees even more possibilities. "SoCalGas is evolving into a provider of innovative solutions for alternative fuels. This project—and others funded by the RD&D Program—are laying the groundwork for that transition. If it is successful, it could spur the adoption of hydrogen in all of the company's aircraft and position SoCalGas to be the largest supplier of hydrogen for air transportation in the United States."

PROGRAM: CLEAN GENERATION

This 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 emissions, lower customer costs, integrate renewable fuels, and improve energy reliability and resiliency.

Clean Generation is composed of two subprograms:

Distributed Generation

This subprogram develops and enhances distributed generation technologies. Microgrids and the increasing availability of RNG and hydrogen offer new opportunities for the deployment of low-emission and renewably fueled distributed generation technologies.

Integration & Controls

This subprogram 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.

SPOTLIGHT

Clean Generation

Residential nanogrids promise a more distributed and equitable energy future

University of California, Irvine team optimizes residential nanogrid configurations for climate, cost, equity, and emissions.

TOTAL PROJECT COST: $881,153

SOCALGAS:	$761,653
COFUNDING:	$120,000

PHASE 1 TOTAL COST: $325,000

SOCALGAS:	$325,000
COFUNDING:	$0

PHASE 2 TOTAL COST: $556,000

SOCALGAS:	$436,653
COFUNDING:	$120,000

California has some of the world's most ambitious climate goals, including decarbonizing its thermal and electricity energy loads. One approach to this challenge that has seen success at larger scales—such as industrial or university campuses—is the microgrid. Microgrids combine power generation and energy storage technologies to reduce consumption of costly grid-sourced electricity or sustain operations during power outages.

To date, however, little progress has occurred in the development of much smaller, residential nanogrids. To address this gap, researchers at the University of California, Irvine (UCI) are working with SoCalGas and two industrial partners—Heila Technologies and InstantOn—to explore ways to achieve zero net energy in providing heat and power to residences.

The ultimate goal of the multi-phase project is to design and analyze a residential nanogrid that integrates a solid oxide fuel cell (SOFC) combined heat and power system, photovoltaic (PV) solar electricity, and battery storage to achieve zero net energy. Work began on phase one in late 2019.

As a first step, UCI conceived four potential residential nanogrid configurations and assessed their effectiveness across California's 16 climate zones. "Homes in different regions have different energy requirements," said Jack Brouwer, PhD, Professor of Mechanical and Aerospace Engineering at UCI. "A nanogrid solution that works well in a hot, dry climate might not be optimal for a house located in a much colder, damp environment."

UCI determined that an entirely electric solution was impractical due to the surface-area requirements of a PV system large enough to meet a residence's typical electrical demand. Instead, the research indicated that a more practical approach to achieving zero net energy could be found in

two mixed-fuel scenarios modeled by the team, where natural gas is used for heating. Mixed-Fuel #2 scenario resulted in the least reliance on the electrical grid while still achieving zero net energy. This scenario was particularly effective because the SOFC produced electricity and co-generated heat.

Configurations	PV	Heat	SOFC Fuel	Battery
All-Electric #1	Yes	Electric	N/A	Yes
All-Electric #2	Yes	Electric	Natural Gas	Yes
Mixed-Fuel #2	Yes	Natural Gas	N/A	Yes
Mixed-Fuel #2	Yes	Natural Gas	Natural Gas	Yes

In early 2021, UCI began assembling hardware for a lab-scale system that it would use to model how a nanogrid would respond to a variety of environmental conditions, energy costs, and electrical loads. The system—which UCI energized in December 2021—includes solar panels, an inverter, battery energy storage, an SOFC, and a residential simulator to simulate residential power demand dynamics. "Using the simulator, we will be able to replicate the power demand dynamics of any residence and connect it to the residential nanogrid hardware in the lab," said Brouwer.

During phase two of the project, UCI plans to use residential dynamic load profiles from earlier research and relevant literature to demonstrate the system at lab scale. "We will work with Heila and InstantOn to modify their control software based upon the results we obtain working with the physical hardware," said Pegah Mottaghizadeh, a PhD candidate in UCI's Advanced Power and Energy Program (APEP). The system will be capable of responding to static price signals from the grid. "But we will also develop new software and algorithms that enable it to accept more dynamic, real-time rates—something that could help homeowners pay significantly less for heat or electricity in the future."

That ties in with another key driver of the project: equity. "To date, most adoption of renewable and energy storage technologies has occurred in relatively affluent neighborhoods," said Brouwer. "We believe that this technology opens up new possibilities for bringing affordable renewable energy to all residents in California."

One of the key goals of the research is to understand the role of renewable gas in a sustainable energy future. "Many think total electrification of residential neighborhoods is the answer, with full reliance on wind and solar," said Robert Flores, PhD, a Senior Scientist at APEP. "Fundamentally, we agree with that approach but think that delivering some of that sun and wind energy as renewable gas might make the most sense."

For example, groups of houses with solar power could share energy storage or fuel cells. "If they are trying to achieve net zero energy, then they would all have to export electricity to the grid in the middle of the day—when the grid needs it least," said Flores. "With a network of residential nanogrids and shared resources, the houses could store that electricity for use when demand for electricity—and its cost—rises." The residences could also use the surplus renewable electricity to produce renewable gases, such as green hydrogen.

UCI will evaluate the cost, equity, and GHG and criteria pollutant emissions implications of the different strategies. "Depending on whether cost, environmental, or utility infrastructure impacts are prioritized, we anticipate quantifying very different cost savings and emissions reductions that can be achieved with residential nanogrids," said Brouwer.

At project's end, UCI anticipates being able to determine with a high level of certainty which nanogrid technologies should be considered in any given climate zone. UCI also hopes to provide valuable feedback to Heila and InstantOn so that they can adapt their control systems and improve their products. "That will not only help improve the efficiency of the nanogrids but also make the products more consumer friendly," said Brouwer.

Finally, Brouwer hopes the project will contribute to the understanding of how to optimally decarbonize both the gas and the electric systems. "We want everyone to have access to clean energy and clean air," said Brouwer. "That's not necessarily possible today because many cannot afford solar PV and battery systems or they don't own their residences. But in the future, clean renewable energy is going to cost less and be much more distributed, reliable, and equitable, particularly if both the gas and electric systems are decarbonized."

PROGRAM:

CUSTOMER END-USE APPLICATIONS

This 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.

This program includes five subprograms:

Advanced Innovation

This subprogram seeks to develop new, non-traditional technologies to improve energy efficiency and decrease emissions. Relevant applications include smart thermostats, sensors, advanced construction technologies, and machine learning.

Commercial Applications

This subprogram develops and enhances technologies and advancements related to gas consumption and end uses in the commercial sector. Relevant applications include commercial HVAC, hot water service, and commercial laundry.

Commercial Food Service

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

Industrial Process Heat

This subprogram develops advanced heating technologies and systems for use in the industrial sector. Relevant applications include food processing, textile drying, chemical processing, and other process heat needs.

Residential Appliances

This subprogram develops, demonstrates, and enhances technologies and advancements related to gas-consuming appliances in residences. Relevant appliances include furnaces, hot water heaters, stoves, ovens, and dryers.

SPOTLIGHT

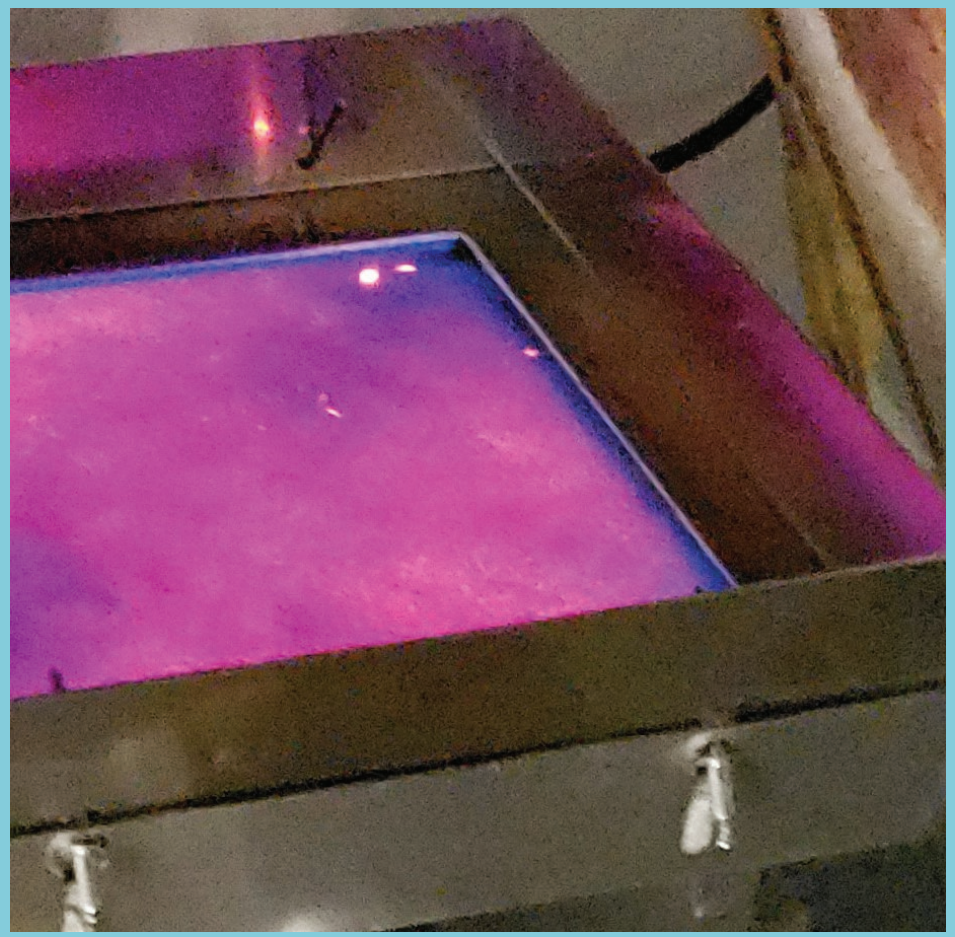
Customer End-Use Applications

Fuel-flexible, flameless appliance consumes blends of natural gas and hydrogen

Oak Ridge National Laboratory develops cooking appliance that delivers immediate emissions and efficiency benefits while enabling future blends of hydrogen.

TOTAL PROJECT COST: $1,000,000

SOCALGAS:	$470,000
U.S. DOE:	$500,000
CO-FUNDING:	$30,000

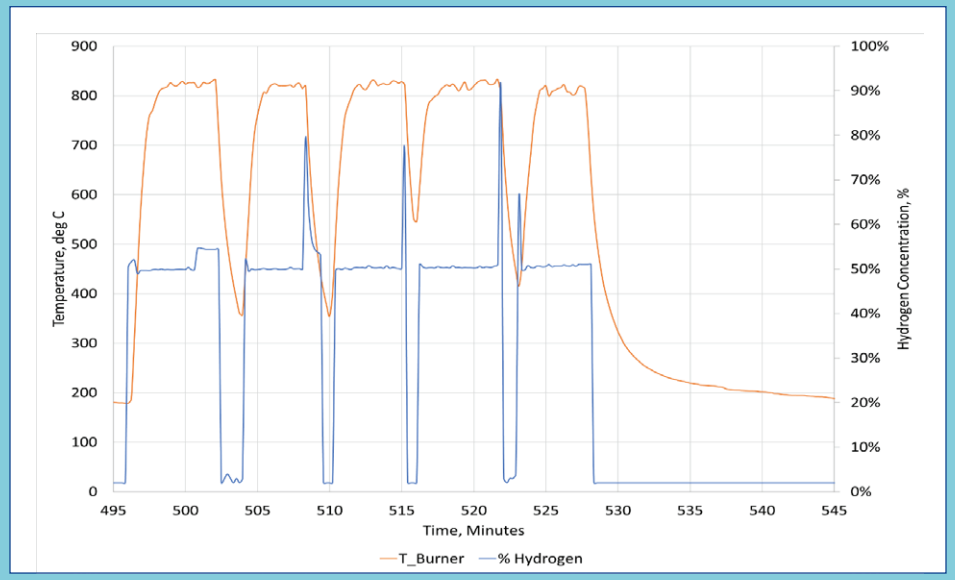


To support the transition to zero-carbon hydrogen, ORNL began developing a clean, safe, fuel-flexible cooking appliance that can combust any blend percentage of hydrogen in natural gas—from zero to 100%—while delivering immediate efficiency and emissions reduction benefits.

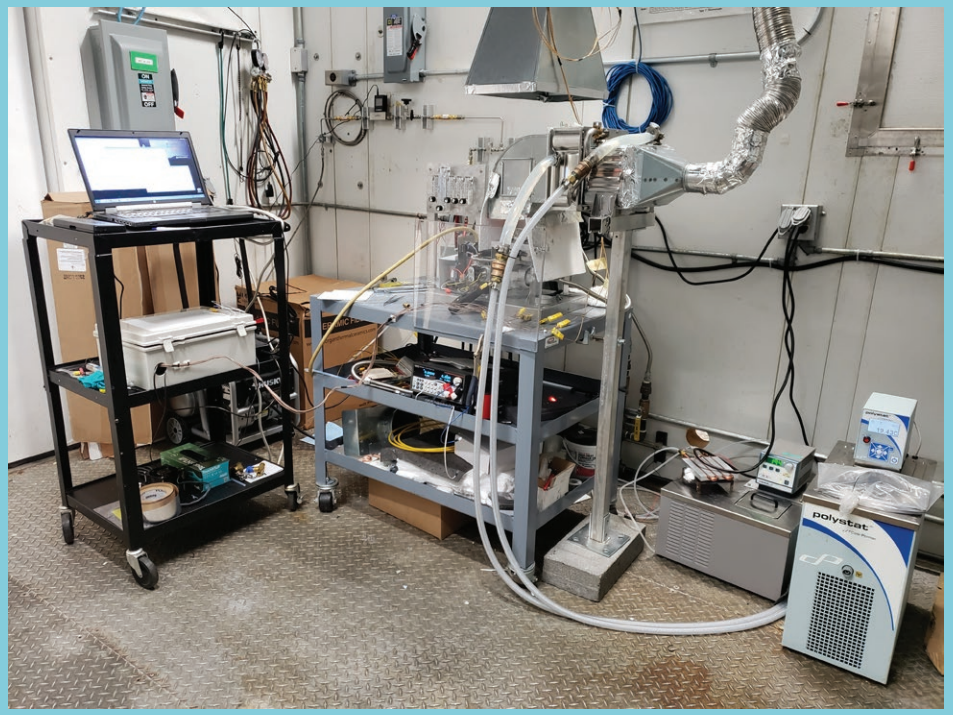
Across the United States, more than 33% of residential and commercial buildings use natural gas for cooking[6], representing 97 million metric tons (MT) of annual direct and indirect carbon emissions[7].

By blending zero-carbon hydrogen into the natural gas pipeline, it is possible to reduce those emissions. "Many of today's gas cooking appliances can accept blends of up to 20% hydrogen before they pose operational challenges," says Praveen Cheekatamarla, Senior Researcher at Oak Ridge National Laboratory (ORNL). "Blending at that percentage could eliminate more than 19 million MT of carbon emissions without any new equipment."

Ultimately, however, decarbonizing commercial and residential cooking will require higher blends of zero-carbon hydrogen. To support this transition, ORNL began developing a clean, safe, fuel-flexible cooking appliance that can combust any blend percentage of hydrogen in natural gas—from zero to 100%—while delivering immediate efficiency benefits and eliminating emissions of nitrogen oxides (NOx).



Thermal cycling test of the heterogeneous burner in the presence of 50% hydrogen. Also shown is the cold and hot restart of the burner.



"Safety and emissions are the key challenges associated with adding hydrogen to the fuel mix in a cooking range," says Cheekatamarla. Hydrogen causes flame temperature to rise, which increases the risk of thermally induced NOx creation. "It also increases flame velocity, which can cause flame propagation to the fuel source and auto-ignition of the feed mixture. That will destroy the burner and create a safety hazard."

To overcome these challenges, ORNL designed a flameless burner that relies on heterogeneous catalytic oxidation. A hybrid combustion module integrating a novel heterogeneous combustion surface with tailored thermal and fluid transfer characteristics enables operation of the burner at moderate temperatures in a safe and clean manner.

Using this approach, the energy of combustion is distributed via infrared radiation (IR) over a much larger surface—and, therefore, at a lower temperature—than in conventional burners, which rely on convection. "Cooking applications require an operating range between 400°C and 800°C," says Cheekatamarla. Flame-based technologies, however, operate at roughly 1,500°C—a temperature that favors NOx formation. "With our technology, NOx cannot form because the burner never reaches the threshold temperature."

In 2021, ORNL drew up multiple design options, fabricated prototypes, and evaluated them with blends of up to 50% hydrogen with natural gas. "By year's end, we demonstrated that the prototype can safely produce IR heat without risk of flashback," says Cheekatamarla. Preliminary testing also confirmed complete elimination of NOx emissions and compliance with carbon monoxide regulations.

In 2022, ORNL will integrate the prototype into commercial appliances supplied by a major appliance manufacturer. "We will evaluate a variety of blend compositions in a realistic cooking environment, with multiple burners operating simultaneously at different energy intensities," says Cheekatamarla. "Our goal is to demonstrate that IR-based heat transfer is 20% more efficient than convection." The OEM will provide engineering resources, product knowledge, and assistance ensuring compliance with industry standards.

"Because the prototype can run on natural gas, you can install it today and it will provide immediate efficiency and emissions benefits," says Cheekatamarla. When hydrogen becomes available, the burner will be able to run on a mixture of the two gases. "Our goal in 2022 is to demonstrate an appliance that can run at both extremes—100% hydrogen or natural gas—as well as anywhere in between."

Appendix

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2021 Funding Recipients

2020vet Inc.
3vGeomatics
A-1 Alternative Fuels
A-Best Industrial
Acoustic LP
Airgas USA LLC
Aisin Seiki Co Ltd
Alliance For Sustainable Energy LLC
ALS Environmental
American Institute Of Chemical Engineers
ARB Inc.
Arthur D Little LLC
Battelle Memorial Institute
Bloom Energy Corporation
Blue Frontier LLC
Brillio LLC
Burns & McDonnell Engineering
C H Robinson Company
C4-MCP LLC
C-FER Technologies 1999 Inc.
California Institute Of Technology
CALSTART
Campos EPC LLC
Captura Corp.
Colorado State University
Connection
C-ZERO LLC
DNV GL USA Inc
Douglas G Honegger
Dragonfly Vision
Eclipse Mapping And GIS LLC
EDM Services Inc.
Electricore Inc.
Fedex Freight West Inc.
Frontier Energy Inc.
Gas Machinery Research Council
Gas Technology Institute
Gas Transmission Systems Inc.
Getty Images Inc.
GIS Surveyors Inc.
Golden Gate Zero Emission Marine Inc.
H2U Technologies Inc.
HiLine Engineering & Fabrication Inc.
Independent Electric Supply Inc.
Ingevity Corporation
Innovative Environmental
INT Translation Services
IWVC LLC
Jacobs Engineering Group Inc.
Lantec Products Inc.
Linde Engineering North America LLC
Mainspring Energy Inc.
Metron
Minuteman Press Torrance
Momentum
NegaWatt Consulting Inc.
Netcentric Technologies Inc.
Noble Thermodynamic Systems Inc.
Northeast Gas Association
Oak Ridge National Laboratory
Operations Technology Development
Opus 12 Inc.
Parsons Environment & Infrastructure
Pipeline Research Council International Inc.
Primary Gas Solutions
Ramboll US Corporation
ReactWell LLC
Resource Innovations LLC
Rinnai America Corporation
Royal Industrial Solutions
Sandia National Laboratories
Sigma-Aldrich Marketing Inc.
Smokey Point Distributing Inc.
South Coast Air Quality Management District
Stafford Multimedia LLC
Stanford University
Staples Contract & Commercial LLC
Stars Technology Corporation
Structural Integrity Assoc Inc.
Summit Fluid Technologies LLC
Supco Engineering
Susteon Inc.
Synergis Consulting
The Regents Of The University Of California
The Sourcium Group
Transient Plasma Systems Inc.
Trench Shoring Company
Trimeric Corporation
Uline
United Rentals North America Inc.
Utilization Technology Development
WHA International Inc.
Xebec Adsorption Inc.
Yankee Scientific Inc.

2021 Publications

PUBLICATIONS, REPORTS, AND TECHNOLOGY BRIEFS

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2021 Public Funding Awards

Lead Investigator	Research Program	RD&D Funding Committed	Funding Awarded	Agency
TravelCenters of America	Clean Transportation	$100,000	$4,000,000	CEC
Susteon, Inc.	Low Carbon Resources	$25,000	$1,500,000	DOE
Solar Turbines	Clean Generation	$0	$4,500,000	DOE
Pipeline Research Council International	Gas Operations	$273,473	$788,594	PHMSA
Electric Power Research Institute	Clean Generation	$300,000	$1,999,953	CEC
CTE	Clean Transportation	$400,000	$3,000,000	CEC
Ford Motor Company	Clean Transportation	$0	$29,952,314	DOE
National Renewable Energy Laboratory	Clean Generation	$450,000	$1,189,000	DOE
Cummins, Inc.	Clean Transportation	$500,000	$2,000,000	CEC
GTI	Clean Transportation	$500,000	$1,999,667	CEC
GTI	Clean Transportation	$250,000	$2,500,000	DOE
TOTAL		**$2,798,473**	**$48,429,528**	

Policy Drivers

Category	Regulations & Policy Drivers
GHG Emissions	**AB 32:** Reduce CO2 emissions 40% below 1990 levels by 2030 **SB 100:** Zero-carbon electricity by 2045 **EO B-55-18:** Carbon-neutral California economy by 2045 **AB 3232:** Building decarbonization
Pipeline Safety	**CPUC General Order 112F:** Rules governing design, testing, operation, and maintenance of gas transmission and distribution systems **DOT 49 CFR Part 192:** Federal pipeline safety regulations **AB 1900:** Biomethane quality standards **OIR R.13-02-008, Phase 4:** Addresses injection of renewable hydrogen into gas pipelines
Local Air Quality	**Clean Air Act:** Air quality standards for NOx and PM **AB 617:** Pilot communities for air quality improvements
Methane Emissions	**SB 1383:** Reduce methane emissions from decomposition of organic wastes **CARB Oil and Gas Rules:** Requires new monitoring and repairs to reduce methane emissions **Natural Gas STAR Program:** Encourages adoption of methane-reducing technologies and practices **EPA Methane Challenge Program:** Recognizes oil and gas companies that take comprehensive action to reduce methane emissions **SB 1440:** Authorizes a state procurement program for biomethane
Clean Transportation	**ARB Implementation Plan:** Low-NOx standard for trucks **AB 8:** Development of 100 hydrogen fueling stations in California **EO-B32-15:** Sustainable freight action plan **EO-B48-18:** 200 hydrogen refueling stations by 2025 **EO N-79-20:** 100% of medium- and heavy-duty vehicle be zero emission by 2045 for all operations where feasible **LCFS:** Reduce carbon intensity of fuels by 10% by 2020 **SB 1275:** One million zero-emission and near-zero-emission vehicles by 2023
Equity	**CPUC General Order 156:** Encourages IOUs to procure or contract goods and services from women, minority, disabled veteran and/or LGBT owned business enterprises **CPUC ESJ Action Plan:** Increases investment in clean energy resources to benefit environmental and social justice communities (ESJ), especially to improve local air quality and public health

Project Selection Process and Evaluation Criteria

When identifying promising projects and evaluating them for potential funding, RD&D Program staff take a comprehensive yet flexible approach that enables them to 1) identify potential projects most in alignment with RD&D Program 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 Program staff consider the overall development and implementation process and research life cycle of a given technology or product.

RD&D Program area staff explore a variety of avenues to identify and conceive potential projects, including:

Table 1: RD&D Program area staff explore many avenues to identify and conceive potential projects.

Addressing Internal Operations Needs	RD&D Program staff address the needs of SoCalGas operations through regular engagement with a large number of SMEs within the organization. These SMEs provide input into technology development strategies, review research proposals, and participate in RD&D Program projects by providing technical input and guidance. They also serve as the internal technical leaders in regulatory proceedings, provide awareness of industry activities, and help manage internal policies and procedures.
Addressing Customer Needs	SoCalGas Account Executives work closely with commercial and industrial customers. The Customer Strategy & Engagement group interacts with residential customers through programs such as the Customer Insight Panel. These teams often bring customer challenges to RD&D Program staff, seeking to identify available products or technologies to address a need, or, if none exists, to spur research aimed at advancing or developing appropriate new technologies or products.
Literature Surveys, Conferences, and Workshops	RD&D Program staff engage in ongoing education in their areas of expertise to remain abreast of the latest technologies and research and also scout potential opportunities. They regularly read technical journals, visit national laboratories, and attend clean technology forums/webinars held by various DOE divisions, such as the Advanced Research Projects Agency-Energy (ARPA-E), Energy Efficiency and Renewable Energy (EERE), and the Office of Fossil Energy's National Energy Technology Laboratory (NETL). These activities enable them to identify the latest technology developments in their respective fields as soon as they are made available and perform detailed gap analyses to better understand which research areas merit further study and evaluation.

Research Consortia	RD&D Program staff leverage the national and international experience of other utilities through participation in industry research consortia, such as Utilization Technology Development (UTD) and Pipeline Research Council International (PRCI). Close relationships with these organizations facilitate the generation of project ideas, enable SoCalGas to vet potential projects with real-world end users, and provide access to significant amounts of co-funding.
External Funding Opportunities	When public agencies, such as the CEC or the DOE, release a funding opportunity, RD&D Program staff often receive proposals from third-party researchers or entrepreneurs applying to the opportunity with a request for a letter of support and/or cost share from SoCalGas. Additionally, RD&D Program staff continually track various governmental funding opportunities and leverage their existing relationships with researchers and entrepreneurs to assemble teams, develop proposals, and submit applications when funding opportunities are identified.
Proposals from Researchers	RD&D Program staff have developed a strong network of researchers throughout North America. These researchers serve as a rich source of project concepts for RD&D Program staff, who often work with the researchers to refine and improve concepts of interest and identify relevant co-funding opportunities, project demonstration sites, or strategic partners that can enhance the quality of the project and maximize potential customer benefit.
Technology Roadmap Development	RD&D Program staff often engage groups of SMEs to identify scientific and technological gaps as well as promising technology pathways in each program area. After identifying the gaps and pathways, the team recommends promising technologies that are close to demonstration or commercialization and others that are earlier in the development cycle but are likely to result in significant long-term benefits. Staff then develop a detailed long-term plan to address the gaps and demonstrate the feasibility of a selected technological pathway.
Public Workshops and Outreach	The annual RD&D Stakeholder Workshop provides a forum for many stakeholders—including private, governmental, and academic researchers, regulatory and policy staff, entrepreneurs, businesses, equity and environmental justice advocates, community-based organizations (CBOs), and the general public—to offer guidance, discuss research needs, and describe project ideas to RD&D Program staff. SoCalGas also conducts pre- and post-workshop outreach to interested stakeholders to enable longer, more thoughtful discussion about RD&D topics. RD&D Program staff also participate in panel discussions and conferences where stakeholders present project proposals or where education and engagement opportunities exist.
Policy Drivers	SoCalGas strives to align the RD&D Program with California's policy goals, including building and transportation decarbonization. RD&D Program staff leverage a network of relationships with experts at local, state, and federal agencies to track current and potential future policies and regulations in order to identify and develop project concepts to achieve these goals.

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. In summary, program staff 1) identify potential areas for research, development, and demonstration and collaborate with researchers to develop project proposals; 2) prepare or receive project proposals; 3) review project proposals with the RD&D Program team and SMEs, considering a wide range of evaluation criteria and the overall portfolio strategy; 4) refine scopes of work for approved

projects, if necessary; 5) allocate funding following SoCalGas accounting policies; and 6) execute the project contract and initiate project research (Figure 1).

During the internal project review process, RD&D Program staff evaluate potential projects using numerous selection criteria. Project selection criteria are based primarily on California Public Utility Code 740.1, which provides guidelines in evaluating the research, development, and demonstration programs proposed by electrical and gas corporations (Table 2). The criteria were also influenced by stakeholder input, industry best practices, and the RD&D staff's extensive experience evaluating research proposals. Program staff do not numerically score potential projects or necessarily weight the selection criteria for several reasons, including the need to retain flexibility to respond to changing market, policy, and technical conditions while supporting promising projects, the diversity of types and scope of individual projects, and the variety of business needs and policy drivers.

Figure 1: High-level internal RD&D project proposal review process.

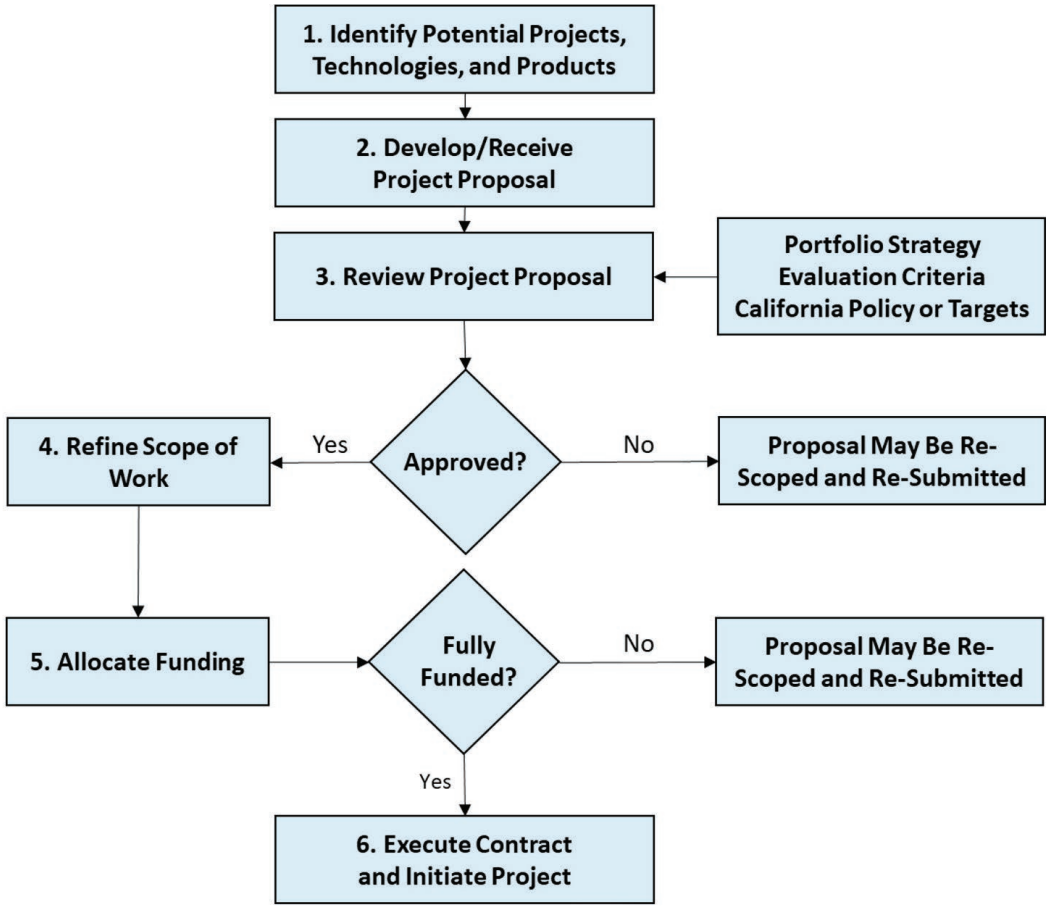

Table 2: RD&D Program staff relied primarily on CPU Code 740.1 in developing project selection criteria.

Benefit	Relevant Section of CPU Code 740.1	Relevant Language
Customer Benefit	740.1a 740.1e	"Projects should offer a reasonable probability of providing benefits to ratepayers." "Each project should also support one or more of the following objectives: (1) Environmental improvement. (2) Public and employee safety. (3) Conservation by efficient resource use or by reducing or shifting system load. (4) Development of new resources and processes, particularly renewable resources and processes which further supply technologies. (5) Improve operating efficiency and reliability or otherwise reduce operating costs."
Lead Investigator/Team **Technical Feasibility** **Commercialization Potential**	740.1b	"Expenditures on projects which have a low probability for success should be minimized."
Alignment with California Policy	740.1c	"Projects should be consistent with the corporation's resource plan." SoCalGas also considers guidance from stakeholders and regulators to ensure that projects support California's environmental goals.
Co-funding Collaborators	740.1d	"Projects should not unnecessarily duplicate research currently, previously, or imminently undertaken by other electrical or gas corporations or research organizations."
Equity	N/A	SoCalGas included equity in response to feedback from multiple stakeholders and regulators and was guided in part by the CPUC's ESJ Action Plan.

The 2023 project selection criteria are as follows:

Criteria	Description/Justification
Customer Benefit	RD&D Program staff seek to advance a significant portion of the products, technologies, and solutions they help develop to the point where they can be implemented by SoCalGas and other utilities for the benefit of ratepayers. To assess this criterion, RD&D Program staff ask questions such as: Will advancing the proposed technology benefit gas utility ratepayers? If the technology becomes commercially available, how will it help SoCalGas customers, as well as internal (i.e., RD&D Program operations teams) and external stakeholders in a meaningful way? Does the technology address a key policy driver relevant to the SoCalGas service territory? Is the research new and not duplicative of previous or ongoing work by other research and development organizations?
Alignment with California Policy	The RD&D team also seeks to align its program with key company, state, and federal objectives. To assess this criterion, RD&D staff ask questions such as: Does the project address a key California state policy driver? Does the project advance the state of the technology along a development roadmap? Does the research address an internal operational need?
Lead Investigator/ Team	Successful R&D Program teams need industry knowledge and technical skills to succeed, but they must balance these characteristics with soft skills, such as curiosity, perseverance, people management, and critical and strategic thinking. To assess this criterion, RD&D Program staff ask questions such as: Are the researchers, labs, or technology developers skilled and experienced in the space? Do they have a track record of success in executing research projects of a similar scope and leading research teams? Do they have unique capabilities or facilities for conducting the required research? Do they have the skills and resources necessary to commercialize the proposed new technology?
Technical Feasibility	Although the RD&D Program team funds early-stage RD&D Program projects, it has a responsibility to ratepayers to fund projects with a high likelihood of success. To assess this criterion, RD&D Program staff ask questions such as: Has the technology been vetted internally or externally for feasibility? Is the basic science sound? Does the technology display favorable thermodynamic modeling or technoeconomic fundamentals? Does documentation of proof-of-concept work exist?
Co-funding Collaborators	One of the key objectives of the RD&D Program is to leverage the funds it uses to support promising projects with significant additional funding from other organizations, such as public agencies, universities, and private businesses. In fact, in 2021, every dollar of RD&D Program funds expended was matched by an average of $5.20 in funding from other sources. To assess this criterion, RD&D Program staff ask questions such as: Are other R&D programs, government agencies, or industrial entities collaborating on the project, either via co-funding or time and expertise? Can co-funding collaborators help validate and substantiate the feasibility of the technical claims? Is co-funding available to leverage the RD&D Program funding? Are other stakeholders supportive of the research? Is there consortium involvement to minimize the risk of duplicating work?

Criteria	Description/Justification
Commercialization Potential	Ultimately, RD&D Program staff seek to advance a significant portion of the products, technologies, and solutions they help develop to the point where they can be advanced to market in support of energy decarbonization, safety, and reliability. To assess this criterion, RD&D Program staff ask questions such as: Does the proposed level of funding match the technology readiness level (TRL)? Does a clear path to commercialization exist for the technology that this research advances? Is there immediate and anticipated future demand for the proposed technology based on defined market trends and competitive advantages in comparison to the status quo or alternative technologies? Does the project team bring sufficient financial support to the project to fund multiple years of development runway? Is the project team working with established commercialization experts who have proven track records with similar products or technologies?
Equity Considerations	The RD&D Program seeks to advance and champion products and technologies that support widespread access to clean, affordable, and renewable energy for all Californians, including those living and working in Environmental and Social Justice (ESJ) communities. To assess this criterion, RD&D Program staff ask questions such as: Does the proposed technology directly address the specific needs of a Disadvantaged Community or Low-Income Community? Is the project sited near such a community? Does the project include engagement by a Community Based Organization (CBO) or Diverse Business Enterprise (DBE)? Is the Principal Investigator (PI) a member of an underrepresented population? Does the project include a workforce development or job training component?

Research Collaborators

Universities

SoCalGas regularly collaborates with scientists, engineers, and other academics at some of our nation's most prominent universities, including Stanford University, Caltech, and the University of California at Davis, Riverside, and Irvine. These professionals perform fundamental science work through lab- and bench-scale applied research on a variety of critical energy topics, including fuel cell development, carbon-free hydrogen production and energy storage, and carbon capture and utilization. University collaborators also possess expertise in modeling, technoeconomic analysis, and lifecycle analysis—areas of immense importance to the evaluation, development, and demonstration of cleaner, safer, affordable, and more reliable energy solutions.

National Laboratories

The U.S. National Laboratories and Technology Centers form a system of facilities and laboratories overseen by the DOE to advance science and technology. Researchers and scientists at the 17 national labs tackle the critical scientific challenges of our time—from combating climate change to discovering the origins of our universe—and possess unique instruments, equipment, and testing facilities. The labs are unequaled in their ability to address large-scale, multifaceted, and complex research and development challenges with a multidisciplinary approach that emphasizes translating basic science to innovation. SoCalGas regularly engages national lab personnel for subject matter expertise, guidance, and collaboration in developing and executing research projects. Through such collaborations, SoCalGas often co-funds projects supported by the DOE, amplifying the impact of RD&D funds for maximum leverage. In many cases, SoCalGas also obtains licensing or intellectual property (IP) rights, which can generate revenue and offset RD&D Program costs.

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 Program staff regularly work with numerous agencies, including the DOE, CEC, the California Air Resources Board, and the PHMSA. For projects focused on early-stage technologies, public funding programs can significantly reduce many of the risks associated with deploying staff and resources on untested products. This, in turn, can attract high-caliber team members and other leveraged funding to compound the impact of invested dollars. Importantly, if successful, publicly funded projects can serve as springboards to additional public and private funding, larger demonstration projects, and, ultimately, product and technology commercialization.

Businesses

At its core, the RD&D Program is about developing and promoting practical applications to overcome challenges facing the energy sector, in alignment with California's decarbonization goals. To help ensure that the new technologies and products supported by SoCalGas advance to real-world applications and markets, RD&D Program staff leverage their

connections, knowledge, and expertise by working closely with leading equipment manufacturers and global technology developers to demonstrate new technologies in large-scale and/or long-term pilot demonstration projects under real-world conditions. These demonstrations constitute the final stages of validation before commercial launch.

Research Consortia

RD&D Program staff have developed strong ties with several research consortia focused on the gas 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 gas industry. By working closely with these and other similar organizations, RD&D Program staff can share both knowledge and funding with other utilities and researchers to develop and execute impactful projects. Coordination of work between these organizations and access to technical libraries also greatly reduce the odds of reproducing previously completed work or work currently underway.

To facilitate collaboration with research consortia, the RD&D Program is a member of five subscription-based organizations: Northeast Gas Association (NGA)/NYSEARCH, Operations Technology Development (OTD), Pipeline Research Council International (PRCI), Sustaining Membership Program (SMP), and Utilization Technology Development (UTD).

Total 2021 Projects
24

Initiated
11

Completed
2

2021 Dues
$72,250

Total RD&D Project Funding
$560,962

Northeast Gas Association (NGA)/NYSEARCH[8]

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 20 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 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 the NGA, NYSEARCH manages more than 30 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 & 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 wide variety of RD&D projects, organized under the following categories:

- Improved Installation
- Maintenance & Repair
- Pipeline Integrity/Direct & Remote Assessment
- Pipe Location & Damage Prevention
- Leak Detection, Real-time Sensing & 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 2021 Projects
56

Initiated
12

Completed
9

2021 Dues
$425,174

Total RD&D Project Funding
$782,398

Operations Technology Development[9]

OTD is a member-controlled partnership of 27 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 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 serve to demonstrate the broad industry support needed to gain the interest of potential product manufacturers.

Total 2021 Projects
53

Initiated
11

Completed
11

2021 Dues
$147,564

Total RD&D Project Funding
$900,382

Pipeline Research Council International[10]

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 2021 Projects
35

Initiated
11

Completed
5

2021 Dues
$100,000

Total RD&D Project Funding
$95,400

Sustaining Membership Program

The SMP is a collaborative R&D program with two segments, Utilization and Operations. SMP's mission is to build a strong technology base in natural gas operations, energy utilization, environmental science and renewable energy; to create new, innovative solutions through "proof of concept" work that addresses the most important industry needs; and to conduct early-stage R&D that serves as the building blocks of subsequent commercial research efforts. Members collectively leverage experience, expertise, and funds to reduce the risk and uncertainty of R&D to help push clean, safe energy solutions on a path toward future gains. In 2020, the RD&D Program worked on 30 active/continuing SMP projects.

2020 Completed SMP Projects

- Development of Electromagnetic (EM) sensing system for rapid and high accuracy cross bores detection
- Technology to Detect Unmapped Couplings (Cancelled)
- Drone Applications in the Natural Gas Industry
- Evaluating the Potential of Algae Capture of CO2
- Uncertainty Quantification of Machine Learning and Mechanistic Simulation Models

New 2020 SMP Projects

- Acoustic Service Line Tracing Device
- Computer Vision/Machine Learning to Identify Safety Hazards for Augmented Reality (AR)
- De-blending Technology Solutions (Downstream Hydrogen Separation)
- Development of a Pipe Load Measurement Device
- Urban canyon study and testing - IMU sensor development
- UV Exposure Detection for PE Pipe and Fittings
- Artificial Intelligence for Field Operations QA/QC
- Biochar and Microbe for Siloxane Removal
- Hydrogen handheld sensor/detector
- Renewable Fuels and Natural Gas Interconnect Map
- Investigate the Nature and Impacts of Hydrogen Segregation and Stratification in Large Customer Networks

Total 2021 Projects
107

Initiated
26

Completed
30

2021 Dues
$650,000

Total RD&D Project Funding
$586,433

Utilization Technology Development[11]

UTD is at the forefront of research, development, and deployment for end-use equipment and appliances. As a not-for-profit corporation led by our 20 utility member companies, UTD represents over 37 million natural gas customer accounts in the Americas. UTD directs and sponsors a wide-ranging program to enhance the use, reliability, and efficiency of appliances and technologies that use natural gas or renewable natural gas to benefit ratepayers, utilities, and the environment.

UTD's mission is to "Identify, select, fund, and oversee research projects resulting in innovative customer solutions which maximize the environmental performance, affordability, efficiency, and safety of equipment and processes that use natural gas and renewable energy resources."

UTD's RD&D technology portfolio impacts residential, commercial, industrial, and transportation market segments, and includes gas equipment and appliances, industrial process and combustion systems, distributed generation, CHP systems, and natural gas vehicles. UTD's member companies work together in a collaborative manner to control and direct program content, initiatives, individual research projects, and other activities. These solutions more effectively:

- Save consumers money
- Save energy
- Enable safe, reliable, and resilient operation of end user equipment and energy delivery systems
- Achieve superior environmental performance
- Integrate with renewable energy sources

UTD partners closely with federal, state, and local government research funding agencies, as well as manufacturers, universities, research organizations, and other industry stakeholders to ensure effective program results and leverage member investments with significant additional research funding. With its members and partners, UTD has been shaping the energy future with new efficient end-use technologies since 2004.

Citations and Attributions

Citations

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2. https://www.fastcompany.com/90583426/the-price-of-solar-electricity-has-dropped-89-in-10-years#

3. https://www.iea.org/news/decisive-action-by-governments-is-critical-to-unlock-growth-for-low-carbon-hydrogen

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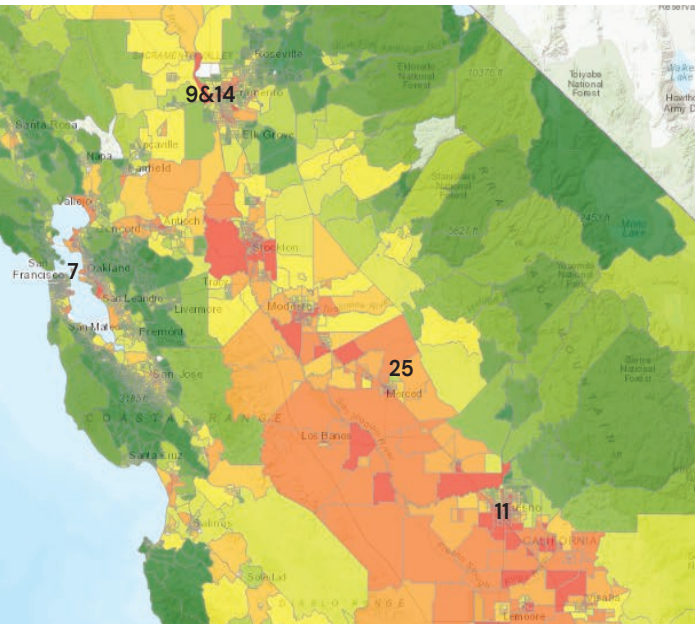
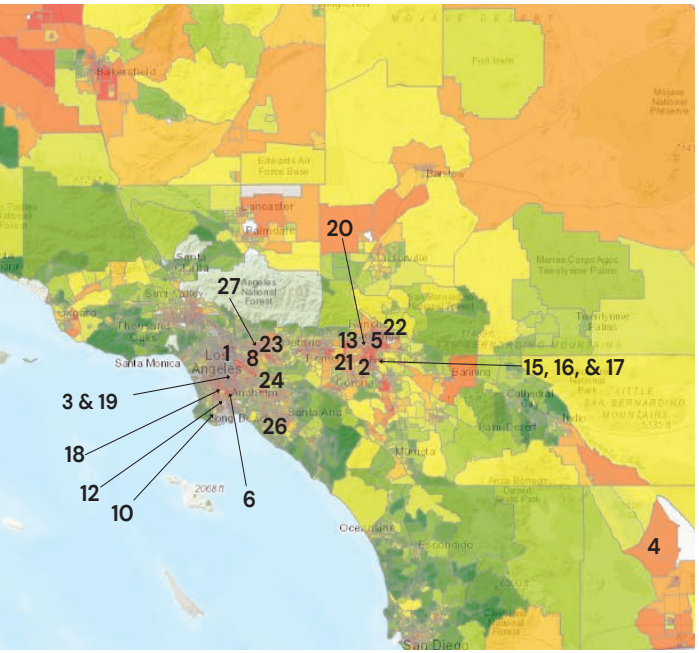
Projects in Disadvantaged Communities





The RD&D program supported 27 projects located in SB 535 disadvantaged communites in 2021. 23 of the projects are located in Southern California. The remaining four are located in Northern California.

Low Carbon Resources

1. Kore Biosolids Pyrolyzer Field Test: Los Angeles, CA
2. Speeding Anaerobic Digestion Through CO2 Microbubbles: Riverside, CA
3. HyET Hydrogen -- Electrochemical Hydrogen Compression and Purification Skid Procurement: Pico Rivera, CA
4. STARS Solar Microchannel Steam Methane Reformer Commercialization (PNNL CRADA 380): Brawley, CA

Clean Generation

5. Mainspring Linear Generator Demonstration: Colton, CA
6. EPRI ORC Demonstration: Compton, CA
7. Scaled Power Turbo Generator Development: San Francisco, CA
8. GTI Lochinvar mCHP Demonstration: Whittier, CA

Clean Transportation

9. GTI Hydrogen Fuel Cell Switcher Locomotive Demonstration: West Sacramento, CA
10. GTI Hydrogen Fuel Cell Yard Truck Port of Los Angeles Demonstration: Wilmington, CA
11. A1 Alt Fuels Fuel Cell Electric Paratransit Shuttle Demonstration: Fresno, CA
12. CALSTART CNG Hybrid Class 8 Truck Demonstration: Compton, CA
13. CTE Fuel Cell Electric Delivery Van Demonstration: Ontario, CA
14. Frontier Energy MC Formula Protocol for H35HF Fueling Demonstration: West Sacramento, CA
15. SCAQMD Hydrogen Blended Natural Gas in NZE Engine Emissions Study: Riverside, CA
16. UC Riverside Hydrogen Blended Natural Gas Engine Durability Test: Riverside, CA
17. UCR RNG and HD Truck Pathways to Achieve Climate Goals Study: Riverside, CA
18. US Hybrid CNG Plug-In Hybrid Electric Truck Demonstration: Downey, CA

Customer End-Use Applications

19. EAC Hydrogen Blended Residential Tankless Water Heater Validation Research: Pico Rivera, CA
20. GTI Booster Ejector Enhancement of Compressor Refrigeration Demonstration: Mira Loma, CA
21. GTI Burner Exchange to Support Radiative Recuperator Demonstration: Ontario, CA
22. GTI Ceramic Radiant Tube Inserts for Waste Heat Recovery Demonstration: San Bernardino, CA
23. GTI Model-Based Control Hospital Decarbonization Demonstration: Baldwin Park, CA
24. GTI SCAQMD HE/Low-NOx EcoZone Burner Kroger Demonstration: La Habra, CA
25. GTI Solar Thermal and Particle Fluid Demonstration: Merced, CA 95343
26. GTI Waste Heat Effective Transfer in Brewery & Distillery Demonstration: Santa Ana, CA and Huntington Beach, CA
27. METRON Energy Virtual Assistant (EVA) Industrial AI Demonstration: CA 91731

Acronyms

Acronym	Definition
°C	Degree Celsius
A/cm^2	Ampere Per Square Centimeter
AB	Assembly Bill
ABTEG	Advanced Burner Thermoelectric Generator
AC	Alternating Current
AFRC	Air Fuel Ratio Control
AERMOD	EPA's required tool for estimating impacts from air pollutant emission sources, including natural gas compressor drivers.
AFUE	Annual Fuel Utilization Efficiency
AGA	American Gas Association
AHU	Air Handler Unit
AI	Artificial Intelligence
AMI	Advanced Metering Infrastructure
ANG	Adsorbed Natural Gas
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
APC	Argon Power Cycle
APEP	Advanced Power and Energy Program
API	American Petroleum Institute - API is a standards-setting organization for America's oil and natural gas industry.
ARPA-E	Advanced Research Projects Agency-Energy
ASHP	Air Source Heat Pump
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BF	Butt Fusion
BioMAT	Bioenergy Market Adjusting Tariff
BP	Best Practice
BPM	Bipolar Membrane
BPMN	Business Process Modeling and Notation
BTO	U.S. DOE's Building Technology Office
Btu or BTU	British Thermal Unit
C&I	Commerical and Industrial
CA	California
CalSEED	California Sustainable Energy Entrepreneur Development Initiative
Caltech	California Institute of Technology
CARB	California Air Resources Board
CBO	Community Based Organization
CCTWH	Central Condensing Tankless Water Heating System
CCS	Carbon Capture and Sequestration
CCUS	Carbon Capture, Utilization, and Storage
CEC	California Energy Commission
CEPA	Canadian Energy Pipeline Association
CFD	Computational Fluid Dynamics
CFR	Code of Federal Regulations
CFS	Commercial Food Service
CGA	Common Ground Alliance
CH^4	Methane
CHG	Catalytic Hydrothermal Gasification
CHP	Combined Heat and Power
CHS	Center for Hydrogen Safety
CLSM	Controlled Low-Strength Material
cm^2	Square Centimeter
CMIC	Carbon Management Information Center
CMR	Center for Methane Research

CNG	Compressed Natural Gas
CNT	Carbon Nanotube
CNTP	Catalytic Non-Thermal Plasma
CO	Carbon Monoxide
CO_2 or CO2	Carbon Dioxide
COP	Coefficient of Performance
COVID-19	Coronavirus Disease 2019
CPUC	California Public Utilities Commission
CRADA	Cooperative Research and Development Agreement
CSU	California State University
CSULA	California State University Los Angeles
CT	Computed Tomography
CWI	Cummins Westport, Inc.
DAC	Direct Air Capture
DB	Database
DBE	Diverse Business Enterprise
DC	Direct Current
DCP	Dynamic Cone Penetrometer
DG	Distributed Generation
DHW	Domestic Hot Water
DMI	Doosan Mobility Innovation
DOAS	Dedicated Outdoor Air System
DOC	Direct Ocean Capture
DOE	U.S. Department of Energy
DOE BETO	U.S. Department of Energy's Bioenergy Technology Office
DOT	U.S. Department of Transportation
DRGM	Diaphragm Residential Gas Meter
DSM	Demand-Side Management
EAC	The SoCalGas Engineering Analysis Center in Pico Rivera, CA
ECA	Engineering Critical Assessments
ECDA	External Corrosion Direct Assessment

EEDs	Electricity Emitting Diodes
EERE	Office of Energy Efficiency and Renewable Energy
EFI	Emerging Fuels Institute
EH	Energy Harvesting
EHP	Electric Heat Pump
EHPC	Electrochemical Hydrogen Purification & Compression
EM	Electromagnetic
EMAT	Electromagnetic Acoustic Transducer
EM-TDR	Electromagnetic Time Domain Reflectometry
EO	Executive Order
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ERW	Electric Resistance Welding
ESJ	Environmental and Social Justice
FCAW-S	Self-Shielded Flux-Cored Arc Welding
FCEV	Fuel Cell Electric Vehicle
FCGR	Fatigue Crack Growth Rate
FDHI	Fault Displacement Hazard Initiative
FEF	FirstElement Fuel
GAHP	Gas Absorption Heat Pump
GEHP	Gas Engine-driven Heat Pump
GFEHP	Gas-Fired Ejector Heat Pump
GGE	Gasoline Gallon Equivalent
GGZEM	Golden Gate Zero Emission Marine
GHA	Geohazard Area
GHG	Greenhouse Gas
GHP	Gas Heat Pumps
GHPWH	Gas Heat Pump Water Heater
GIS	Geographic Information System
GMRC	Gas Machinery Research Council
GPS	Global Positioning System

GQDB	Gas Quality Database
GQS	Gas Quality Sensor
GTI	Gas Technology Institute
GVHP	Gas Vuilleumier Heat Pump
H_2 or H2	Hydrogen
H2-CH4	Hydrogen-Methane
H2-NG	Hydrogen-Natural Gas
H_2SO_4	Sulfuric Acid
HAZ	Heat-Affected Zone
HCA	High Consequence Area
HDAC	Hybrid Direct Air Capture
HDD	Horizontal Directional Drilling
HDPE	High-Density Polyethylene
HES	Hydrogen Energy Storage
HSD	Hardness, Strength, and Ductility
HTL	Hydrothermal Liquefaction
HVAC	Heating, Ventilation, and Air Conditioning
IAQ	Indoor Air Quality
IC	Interconnection
IES	Integrated Energy System
ILI	In-Line Inspection
ILS	Interlaboratory Study Program
IP	Intellectual Property
IR	Infrared
IRV	Internal Relief Valve
ISO	International Organization for Standardization
ITS-Davis	University of California, Davis Institute of Transportation Studies
JCAP	Joint Center for Artificial Photosynthesis
JIP	Joint Industry Program
kg	Kilogram
KPI	Key Performance Indicator

L	Liter
LA	Los Angeles
LADWP	Los Angeles Department of Water and Power
LBNL	Lawrence Berkeley National Lab
LCFS	Low Carbon Fuel Standard
LDC	Local Distribution Company
LDDOAS	Liquid Desiccant Dedicated Outdoor Air System
LEL	Lower Explosive Limit
LLNL	Lawrence Livermore National Laboratory
LoRaWan	Low-Power Wide-Area Network
LPWAN	Low Power Wide Area Network
LSM	Large Standoff Magnetometry
LSU	Lab-Scale Unit
LT	Lookup Table
LTHS	Long-term Hydrostatic Strength
LTP	Locate Technology Platform
MAOP	Maximum Allowable Operating Pressure
MCA	Medium Consequence Area
mCHP	Micro Combined Heat and Power
MCS	Measurement Collection System
MD/HD	Medium-Duty/Heavy-Duty
MEA	Membrane Electrode Assembly
MEC	Magnetic Eddy Current
MEMS	Micro-electromechanical Systems
METRON-EVA	METRON's "Energy Virtual Assistant Factory Solution"
MFL	Magnetic Flux Leakage
MMBTU	Million International British Thermal Units
MMT	Massachusetts Materials Technology
MS-SOFC	Metal-Supported Solid Oxide Fuel Cell
MT	Metric Tonne
MW	Megawatt

N/A	Not Applicable
NBR	Nitrile Butadiene Rubber
NDE	Nondestructive Evaluation/Examination
NDST	Non-destructive Surface Testing
NDT	Nondestructive Testing
NETL	National Energy Technology Laboratory
NFPA	National Fire Protection Association
NG	Natural Gas
NGA	Northeast Gas Association
NGI	Stanford's Natural Gas Initiative
NGV	Natural Gas Vehicle - An NGV is an alternative fuel vehicle that uses compressed natural gas or liquefied natural gas.
NGVA	NGVAmerica
NIST	National Institute of Standards and Technology
NK-ITM	NYSEARCH/Kiefner Interacting Threats Model
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxides
NPT	National Pipe Thread
NREL	National Renewable Energy Laboratory
NTSB	National Transportation Safety Board
NYSEARCH	A part of The Northeast Gas Association.
NZE	Near-Zero Emission
NZEV	Near-zero-emission Vehicle
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
OGI	Optical Gas Imaging
OPC	Ordinary Portland Cement
ORC	Organic Rankine Cycle
ORFEUS	Operational Radar For Every drilling string Under the Street
ORNL	Oak Ridge National Laboratory
OTD	Operations Technology Development
P2G2P	Power-to-Gas-to-Power
P2S	Pipe-to-Soil
PCC	Pre-Combustion Chamber
PE	Polyethylene
PEC	Photoelectrochemical
PEM	Proton Exchange Membrane
PEMS	Portable Emissions Monitoring System
PERC	The Property and Environment Research Center
PFM	Probabilistic Fracture Mechanics
PG&E	Pacific Gas and Electric Company
PHET	Plug-In Hybrid Electric Truck
PI	Principal Investigator
PHMSA	Pipeline and Hazardous Materials Safety Administration
PNNL	Pacific Northwest National Laboratory
POC	Proof-of-Concept
POF	Probability-of-Failure
PPE	Personal Protection Equipment
PPQP	Pipeline Personnel Qualification Program
PRCI	Pipeline Research Council International
PSMS	Pipeline Safety Management Systems
PV	Photovoltaic
QA/QC	Quality Assurance/Quality Control
R&D	Research & Development
RD&D	Research, Development and Demonstration
RAMMS	Rapid Mass Movement Simulation
RANGE	Range of Acceptability for Natural Gas Equipment
REPAIR	Rapid Encapsulation of Pipeline Avoiding Intensive Replacement
RFID	Radio-Frequency Identification
RH	Relative Humidity
RNG	Renewable Natural Gas
ROWs	Rights-of-Way
RRSE	Radiative Recuperator with Secondary Emitters

RTI	Radiant Tube Inserts
RTK	Real-Time Kinematic
SAC	Synthetic Air Combustion
SB	Senate Bill
SBR	Styrene Butadiene Rubber
SCAQMD	South Coast Air Quality Management District
SCR	Selective Catalytic Reduction
SHW	Service Hot Water
SI	Surface Loading
SME	Subject Matter Expert
SMP	Sustaining Membership Program
SMR	Steam Methane Reforming
SMS	Structured Material System
SMTI	Stone Mountain Technologies, Inc.
SMYS	Specified Minimum Yield Strength
SoCalGas	The Southern California Gas Company
SOEC	Solid Oxide Electrolyzer Cell
SOFC	Solid Oxide Fuel Cell
SRP	Strategic Research Priority
SSWC	Selective Seam Weld Corrosion
STARS	Solar Thermal Advanced Reactor System
STEPS	Sustainable Transportation Energy Pathways
sUAS	Small, Unmanned Aircraft System
T2M	Technology-to-Market
TAP	Technical Advisory Panel
TC	Trace Constituent
TCD	Thermal Catalytic Decomposition
TDC	Technology Development Center
TEA	Techno-economic Analysis
TER	Trapped Equivalency Ratio
THP	Thermal Heat Pump
THz	Terahertz
TOU	Time Of Use
TPTS	Two Phase Thermosyphoning
TPV	Thermal Photovoltaic
TRL	Technology Readiness Level
TSA	Temperature Swing Adsorption
UC	University of California
UCD	University of California at Davis
UCI	University of California at Irvine
UCLA	University of California at Los Angeles
UCR	University of California at Riverside
U.S.	United States of America
USGS	United States Geological Survey
USM	Ultrasonic Meter
USR	Utonomy Smart Regulator
UT	Ultrasonic Technology
UTD	Utilization Technology Development
VCV	Vibratory Compaction Vehicle
VIV	Vortex-Induced Vibration
VLE	Vapor Liquid Equilibrium
VOCs	Volatile Organic Compounds
VPN	Virtual Private Network
VR	Virtual Reality
VTH	Virtual Test Home
WCEC	Western Cooling Efficiency Center
WHET	Waste Heat Effective Transfer
WVU	West Virginia University
WWTP	Wastewater Treatment Plant
WZIA	Work Zone Intrusion Alarm
ZEV	Zero-emission Vehicle
ZNE	Zero Net Energy

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

2021 SUMMARY OF ONGOING AND COMPLETED PROJECTS

LOW CARBON RESOURCES

SUB-PROGRAM: LOW CARBON HYDROGEN PRODUCTION

De-Risking Molten Salt-Based Methane Pyrolysis Reactors – Phase 1

C-Zero is working to commercialize a new process for transforming methane into hydrogen and a solid carbon co-product. The method uses high-temperature liquids in a multi-phase pyrolysis reactor with limited carbon dioxide generation. Several engineering challenges must be tackled before C-Zero can build a large-scale prototype unit based on its molten salt reactor design. Two of these engineering challenges are optimizing the gas flow in the reactor and post-processing the carbon to add value to construction materials like cement. The goals of this project were to design and build a scaled-up reactor with optimized gas inlet and bubble hold up and explore carbon post-processing techniques and applications such as cement additives. Testing phases of the project concluded in Q4 2020 by demonstrating a hydrogen production rate of 700 g/day and ~2,100 g of solid carbon per day. For reference, the hydrogen production rate at the beginning of the project and the target production rates were 2 and 17 g of hydrogen per day, respectively. In addition, C-Zero tested carbon in concrete with up to 7.5% wt. On June 23, 2021, SoCalGas hosted a webinar with C-Zero to explain and share its technology with the public.

Co-Funders: PG&E, DOE ARPA-E

Start Date: 08/01/2019
End Date: 04/30/2021
Status: Completed
2021 Funds Expended: **$15,000**
Total Project Cost: **$2,230,000**
Total SCG Cost: **$115,000**
Total Co-Funding: **$2,115,000**
Benefits:

JPL Catalytic Nonthermal Plasma (CNTP) – Advanced Methane Reforming Technology Development and Commercialization – Phase 1

Susteon is developing a compact distributed hydrogen generator to produce high-purity pressurized hydrogen at $3 to $4 per kg while capturing carbon dioxide. The catalytic non-thermal plasma (CNTP) technology converts methane into hydrogen-rich syngas using a commercial nickel-based steam methane reforming (SMR) catalyst assisted by dielectric barrier discharge non-thermal plasma. The non-thermal plasma activates methane molecules more efficiently than a current thermal-based SMR. The electrification of the reaction in combination with the higher efficiency from the plasma drastically lowers the carbon intensity of hydrogen production to less than 3 kg of carbon dioxide per kg of hydrogen, assuming the current California electricity grid carbon intensity. In 2020, a single-tube reactor system design went through several iterations of plasma formation testing to determine construction materials, plasma stability, operating conditions, and potential points of failure. The results show that uniform plasma can be sustained for methane steam reforming reaction. In 2021, a bench-scale multi-tube system was tested to obtain process data to further advance the development at pilot-scale. The bench-scale system produced up to 0.86 kg of hydrogen per day.

Co-Funders: DOE

Start Date: 06/01/2019
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$35,232.19**
Total Project Cost: **$462,024**
Total SCG Cost: **$392,024**
Total Co-Funding: **$70,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Linde HydroPrime HC300 (Distributed Steam Methane Reformer – SMR) Purchase for Integration with STARS and Other Low Carbon Hydrogen Technologies

The project's objectives are to 1) deploy the Linde HydroPrime MIN HC300 hydrogen plant capable of producing up to 300 Nm3/hr of hydrogen and 2) support the integration of the Solar Thermal Reactor System (STARS) steam methane reformer (SMR) with the Linde plant. This integration will enable researchers to interchange the Linde-supplied reformer component of the HydroPrime MIN HC300 hydrogen plant with the STARS unit and other SMR technologies. The integrated system will utilize the balance of plant components—water shift reactor, pressure swing adsorption, heat exchangers, gas processing, instrumentation and controls, and electrical—of the HydroPrime MIN HC300 hydrogen plant to handle and process both the feed stream and syngas output stream of the STARS unit and other SMR technologies. Successful integration will demonstrate and validate the production of a pure hydrogen output stream using several distributed SMR technologies. The SMR skid equipment was delivered to SoCalGas in Q2 2021. In Q4 2021, an agreement with FirstElement Fuel (FEF) was reached. FEF will host the Linde HydroPrime plant on-site in Livermore, California to support its hydrogen refueling operations for fuel cell electric vehicles. This deployment will mark the first time that a Linde HydroPrime unit has been deployed in the Americas.

Co-Funders: N/A

Start Date: 11/15/2019
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$844,844**
Total Project Cost: **$2,540,000**
Total SCG Cost: **$2,540,000**
Total Co-Funding: **$0**
Benefits:

Microwave Catalysis for Process Intensified Modular Production of Carbon Nanomaterials from Natural Gas

C4-MCP is developing a low-cost intensified modular process to directly convert methane into carbon-dioxide-free hydrogen and solid carbon with high conversion, selectivity, and stability. One of the goals is to design and develop a pilot demonstration microwave reactor system. The intensified modular approach is considered a key element and will enable the deployment of the unit at flared gas sites. The approach used in this project relies on the use of a microwave reactor to enable the conversion of methane into hydrogen and carbon nanotubes (CNTs) and/or carbon nanofibers. Compared to other methane pyrolysis technologies, this technique demonstrates competitive energy efficiencies, regeneration of microwave catalysts, and high-quality CNT products that have the potential to offset the system's capital and operating expenses. In 2021, C4-MCP performed market and techno-economic analysis to identify commercial opportunities for the carbon nanomaterials produced in this process. Work is currently underway to analyze carbon nanomaterials for their quality and potential commercial applications.

Co-Funders: DOE, West Virginia University, North Carolina State University, H-Quest Vanguard

Start Date: 05/05/2020
End Date: 05/04/2023
Status: Active
2021 Funds Expended: **$112,500**
Total Project Cost: **$3,791,221**
Total SCG Cost: **$112,500**
Total Co-Funding: **$3,678,721**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

PNNL Methane Pyrolysis for Base-Grown Carbon Nanotubes and CO2-Free H2

Pacific Northwest National Laboratory (PNNL) and West Virginia University (WVU) are developing a new patent-pending process to produce carbon dioxide-free hydrogen and valuable solid carbon from natural gas and demonstrate its commercial viability. Based on thermal catalytic decomposition (TCD), the process reduces the net cost of hydrogen by selling valuable crystalline solid carbon co-product. TCD is promising as it enables lower operating temperatures and reduces energy requirements in comparison to other approaches. Rapid catalyst deactivation and separation of catalyst and carbon product are long-standing challenges to this approach. A highly efficient bimetallic catalyst—active, stable, and selective toward desirable carbon and hydrogen co-products—was developed to address these challenges. Second, the project team developed a process for the separation of catalyst and carbon product and the resynthesis of the catalyst. Five cycles of TCD, separation, and catalyst resynthesis were demonstrated at the bench scale. In 2021, the team conducted a final techno-economic analysis and found that the $1.0 per kg of hydrogen production cost goal can be met, assuming the sale of the solid carbon co-product is in the range of $1.3-$1.7 per kilogram of carbon (100,000 kg hydrogen per day scale). The strategy moving forward with this technology is to partner with appropriate commercialization partners for further de-risking the process through piloting/scale-up. PNNL and WVU will focus on further understanding produced carbon characteristics and developing carbon markets.

Co-Funders: C4-MCP, DOE

Start Date: 02/02/2018
End Date: 08/15/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$4,048,000**
Total SCG Cost: **$1,548,000**
Total Co-Funding: **$2,500,000**
Benefits:

STARS Corporation Electric Induction Steam Methane Reforming (SMR) Equipment Purchase for Demonstration Project

STARS Corporation is developing an advanced and highly efficient steam methane reforming reactor that utilizes induction-based heating. STARS' reactor design uses micro- and mesoscale catalytic channels and efficient heat recycling to demonstrate record efficiencies in the conversion of electrical energy and natural gas to produce hydrogen. STARS' reactor technology features modularized construction capability and a small construction footprint. This technology will be deployed to support on-site storage and fueling operations for SunLine Transit's fleet of hydrogen-powered buses in Thousand Palms, California. Renewable hydrogen production is scheduled to begin in Q4 2022. The first demonstration of syngas produced by a STARS unit was achieved during testing in Q4 2021. Additionally, air permitting for the demonstration has been granted. Site construction is planned for 2022.

Co-Funders: N/A

Start Date: 04/01/2020
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$69,149.31**
Total Project Cost: **$2,175,000**
Total SCG Cost: **$2,175,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

STARS Manufacturing Supply Chain Development for a Modular Solar-Thermochemical Conversion Platform (PNNL CRADA 387)

In collaboration with the Pacific Northwest National Laboratory (PNNL) and Oregon State University, SoCalGas and STARS Technology Corporation are working to develop low-cost manufacturing approaches and technologies for the mass production of chemical process modules containing microchannel reactors and heat exchangers. Co-sponsored by the RAPID Institute, a U.S. Department of Energy Advanced Manufacturing Institute, the effort is assisting with the near-term commercialization of STARS systems for distributed hydrogen production. Goals include lowering equipment costs by improving manufacturing processes, developing innovative equipment designs, and stimulating equipment supply chains. Project accomplishments include: 1) a U.S. Patent, awarded in 2020, based on additive manufacturing of steam methane reforming (SMR) reactors; 2) the submittal, in 2021, of a patent application describing improvements to the design that minimize thermal expansion stresses; 3) testing of an advanced, inductively-heated SMR that achieved a world-record; 4) electrical-to-chemical energy efficiency exceeding 80%; and 5) preliminary efforts on microchannel water-gas shift and methanol synthesis reactors that, integrated with the SMR concept, provide greater opportunities for improved efficiencies and reduced carbon emissions.

Co-Funders: N/A

Start Date: 11/02/2018
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$100,000**
Total Project Cost: **$650,000**
Total SCG Cost: **$650,000**
Total Co-Funding: **$0**
Benefits:

STARS Solar Microchannel Steam Methane Reformer Commercialization (PNNL CRADA 380)

SoCalGas is working with Pacific Northwest National Laboratory (PNNL) and STARS Technology Corporation to advance—to a high degree of commercial readiness—a highly efficient, hydrogen production system that features process-intensive, microchannel reactors and heat exchangers plus other chemical process components. Co-funded by the U.S. Department of Energy's Office of Hydrogen and Fuel Cell Technologies and the Solar Energy Technology Office, the effort includes a solar dish-concentrator as the source of energy for the endothermic steam methane reforming (SMR) reaction. Onsite testing at the San Diego State University Brawley Campus achieved world-record, solar-to-chemical energy conversion efficiency (~71%). In 2021, the effort focused on preliminary development of a catalytic oxidizer/steam generator that, once advanced to commercial readiness, is intended to provide an inexpensive method of steam production for the SMR while minimizing production of nitrogen oxides.

Co-Funders: DOE

Start Date: 11/01/2017
End Date: 06/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$2,990,000**
Total SCG Cost: **$750,000**
Total Co-Funding: **$2,240,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Susteon Catalytic Non-Thermal Plasma (CNTP) Reactor Scale-Up Demonstration

The project team seeks to build a catalytic non-thermal plasma (CNTP) reactor capable of producing 10kg of hydrogen per day. This project follows up on CNTP technology developed in a previous project with the Jet Propulsion Laboratory, in which the technology was successfully demonstrated at lab scale. The CNTP reactor uses plasma to improve the conversion of methane and water into a hydrogen-rich syngas at much lower temperatures relative to other steam methane reforming technologies. Susteon also aims to use the CNTP reactor to demonstrate its ability to produce sustainable aviation fuel from carbon dioxide and methane, creating an opportunity for utilization of captured carbon dioxide to provide a new pathway to reduce greenhouse gas emissions in an otherwise difficult-to-decarbonize sector. The project kicked off in Q3 2021. Design and equipment procurement activities for a bench-scale unit have been completed. Commissioning of this equipment will continue in 2022.

Co-Funders: N/A

Start Date: 08/01/2021
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$300,000**
Total Project Cost: **$500,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$0**
Benefits:

Susteon Stanford Iron-Oxide Based Catalytic Methane Pyrolysis Development

Pacific Northwest National Laboratory (PNNL) and West Virginia University (WVU) are developing a new patent-pending process to produce carbon dioxide-free hydrogen and valuable solid carbon from natural gas and demonstrate its commercial viability. Based on thermal catalytic decomposition (TCD), the process reduces the net cost of hydrogen by selling valuable crystalline solid carbon co-product. TCD is promising as it enables lower operating temperatures and reduces energy requirements in comparison to other approaches. Rapid catalyst deactivation and separation of catalyst and carbon product are long-standing challenges to this approach. A highly efficient bimetallic catalyst—active, stable, and selective toward desirable carbon and hydrogen co-products—was developed to address these challenges. Second, the project team developed a process for the separation of catalyst and carbon product and the resynthesis of the catalyst. Five cycles of TCD, separation, and catalyst resynthesis were demonstrated at the bench scale. In 2021, the team conducted a final techno-economic analysis and found that the $1.0 per kg of hydrogen production cost goal can be met, assuming the sale of the solid carbon co-product is in the range of $1.3-$1.7 per kilogram of carbon (100,000 kg hydrogen per day scale). The strategy moving forward with this technology is to partner with appropriate commercialization partners for further de-risking the process through piloting/scale-up. PNNL and WVU will focus on further understanding produced carbon characteristics and developing carbon markets.

Co-Funders: N/A

Start Date: 11/01/2021
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$500,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

SUB-PROGRAM: LOW-GHG CHEMICAL PROCESSES

A Combined Water and CO2 Direct Air Capture System

Avnos Inc. is developing a hybrid direct air capture (HDAC) system that is capable of capturing both water and carbon dioxide from ambient air in one system. The HDAC system will test the new carbon capture technology called "Isothermal Water Vapor and CO2 Capture," which was originally developed at the Pacific Northwest National Laboratory. The HDAC is expected to produce 10 tons of potable water for every ton of CO_2 captured. The HDAC system also eliminates external heat and water consumption for competitive direct air capture. This project will further demonstrate the outstanding technical and economic performance of the transformational HDAC technology. The goal of this project is to design, build, and operate a system that captures 30 tons per year of carbon dioxide and 300 tons per year of water located at the SoCalGas site in Brawley, California. This project kicked off in 2020. The project team completed the design of a detailed HDAC system unit in 2021. The next task involving HDAC unit fabrication and shakedown testing began in late 2021 and is ongoing.

Co-Funders: DOE

Start Date: 10/01/2020
End Date: 09/30/2023
Status: Active
2021 Funds Expended: **$325,000**
Total Project Cost: **$3,170,000**
Total SCG Cost: **$672,000**
Total Co-Funding: **$2,500,000**
Benefits:

Battelle – PNNL Production of CO2-Negative Building Composites Development – CRADA 553

Pacific Northwest National Laboratory will build off its "Integrated Capture and Conversion of Carbon dioxide (CO_2) to Methanol" (IC^3M) process to develop a platform to produce carbon-dioxide-negative composite building materials. This project seeks to develop a deep decarbonization approach that can sequester millions of tons of carbon dioxide annually by using water-lean solvents as an organic base catalyst to produce building materials derived from waste lignin and lignite. This approach will produce durable composite materials with a better lifetime use than current market equivalents for carbon-dioxide-sequestered, low-value products. These building composite materials can be sold to the booming composite industries. This project kicked off in Q4 2021. Work has begun on solvent-based carboxylation to convert the aromatic hydrocarbon bonds in lignin and lignite to aromatic carboxyl bonds using water-lean solvents.

Co-Funders: DOE

Start Date: 09/01/2021
End Date: 08/30/2024
Status: Active
2021 Funds Expended: **$540,000**
Total Project Cost: **$3,240,000**
Total SCG Cost: **$540,000**
Total Co-Funding: **$2,700,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Caltech CO2 Capture from Oceanwater Using a Highly Efficient Electrodialyzer

Caltech seeks to develop an innovative direct ocean capture technology. Technologies that capture carbon dioxide from oceanwater can change the gas pressure balance between air and water and, thus, drive the removal of carbon dioxide by oceans from the air. Building on an earlier techno-economic analysis, Caltech envisioned an offshore system to capture carbon dioxide from oceanwater, remove it for industrial use or sequestration, and mitigate ocean acidification. The system would input oceanwater, filter it, and then divert a very small fraction to an electrodialyzer. There, the oceanwater would undergo dissociation into a concentrated acid, a concentrated base, and dilute streams through use of an electrodialysis system supported by a bipolar membrane (BPM). During the project, Caltech sought to achieve a current density of >500 milliamperes per square centimeter in the electrodialyzer—the system's most costly operational component. Caltech made significant progress toward that goal, experimenting with a range of materials and configurations until identifying a configuration that achieved a current density of 1 Ampere per square centimeter, the highest current density ever achieved at lab scale in an electrodialyzer. Caltech also re-engineered the BPM to better facilitate the water dissociation reaction and prevent catastrophic membrane dehydration. By the end of 2021, Caltech had demonstrated a lab-scale electrodialyzer capable of carbon dioxide extraction from oceanwater at 93% purity with an electrochemical energy of 1 kWh/kg of carbon dioxide at an applied current density of 3.3 mA/cm^2. In 2022, Caltech will seek to demonstrate the commercial viability of a pilot plant capable of capturing carbon dioxide from oceanwater at a rate of 100 metric tons per year.

Co-Funders: DOE ARPA-E

Start Date: 11/30/2020
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$1,050,000**
Total SCG Cost: **$200,000**
Total Co-Funding: **$850,000**
Benefits:

Captura Oceanwater CO2 Capture Demonstration

In 2021, Caltech created a cleantech startup, Captura Corp, to commercialize its oceanic water carbon dioxide capture system. Captura is proposing a 100 ton/year pilot oceanic carbon dioxide capture unit. Captura fills the critical need to demonstrate an integrated device prototype of the overall system at a large enough scale to assess the cost levers and system scalability. The project goal is to design, develop, and demonstrate the operation of an oceanic carbon dioxide capture system capable of capturing carbon dioxide from ocean water at a capacity of 100 tons/year. The system has an ocean water intake rate of 700 gallons per minute and has a carbon dioxide extraction rate of 100 liters per min. The 100 ton/year prototype system includes a carbon dioxide capture unit with continuous carbon dioxide regeneration back into the effluent water. This enables closed-loop operation of the system in a proof-of-concept demonstration without the need to place the system at a site near the ocean. A preliminary techno-economic analysis indicates that the Captura system can perform oceanic carbon dioxide capture for $500/ton of carbon dioxide at 1,000 tons/year and for $100/ton of carbon dioxide at 1,000,000 tons/year. The project aims to test and validate the energy efficiency of capture, the purity of the captured carbon dioxide, and the stability and durability of key components in the system. The development and operation of the 100 ton/year system will provide vital data for estimating the cost of carbon dioxide capture and the scalability of the technology for a larger scale direct oceanic carbon dioxide capture system.

Co-Funders: N/A

Start Date: 11/01/2021
End Date: 11/30/2022
Status: Active
2021 Funds Expended: **$300,000**
Total Project Cost: **$750,000**
Total SCG Cost: **$750,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Direct Air Capture Using Novel Structured Adsorbents

Electricore aims to advance direct air capture (DAC) technology by combining a vacuum-temperature swing carbon dioxide adsorption process with structured adsorbent beds. The goal of this project is to design, build, and operate a field test unit capable of producing 30 kg/day of a concentrated stream of 95% pure carbon dioxide. This project will validate current state-of-the-art DAC technology and provide valuable testing data regarding operating costs. These will support efforts to reach U.S. Department of Energy cost-per-kg carbon dioxide targets. In 2021, the project team completed all project and procurement planning tasks. Additionally, the project team began work on sorbent selection, testing, and optimization. Prototype development, site preparation, and system commissioning activities are expected to be completed in 2022. The targeted timeframe for field testing to begin is Q2 2023.

Co-Funders: Svante, Climeworks, Wintec, DOE

Start Date: 10/01/2020
End Date: 09/30/2023
Status: Active
2021 Funds Expended: **$198,000**
Total Project Cost: **$3,714,202**
Total SCG Cost: **$300,000**
Total Co-Funding: **$3,414,202**
Benefits:

FLECCS – Rapid Temperature Swing Adsorption (TSA) for CO2 Capture

This project advanced a novel rapid-cycle temperature swing adsorption (TSA) carbon dioxide capture technology for use with natural gas power plants and industrial processes with variable load profiles. The goal was to advance the commercialization of technology that effectively captures carbon dioxide emissions from natural gas power plants and other industrial processes. The team modeled the TSA carbon dioxide capture technology coupled with a natural gas combined cycle power plant in Southern California. Turndown ratios at the plant range from 25% to 100% due to high market penetrations. Technologies that mitigate greenhouse gas (GHG) emissions from fossil power plant flue gas will benefit ratepayers by improving air quality and reducing the carbon footprint of fossil power plants. The project's objectives are to: 1) demonstrate solid-sorbent-based, rapid-cycle TSA system for carbon dioxide capture applications from fossil power plants flue gas; 2) model the coupling of the carbon capture and storage with power plant operation and optimize for maximum net present value in a high renewable energy penetration environment; and 3) perform techno-economic and technology to market (T2M) analysis. In 2021, the project team completed phase-1 modeling and costing methodology and presented them to the U.S. Department of Energy's ARPA-E Program. The team also prepared and submitted the initial T2M plan to ARPA-E.

Co-Funders: DOE ARPA-E

Start Date: 09/01/2020
End Date: 04/01/2022
Status: Active
2021 Funds Expended: **$15,000**
Total Project Cost: **$859,009**
Total SCG Cost: **$70,000**
Total Co-Funding: **$789,009**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Low Temperature Regeneration Sorbents for Direct Air Capture of CO2

This project aims to develop solid sorbent materials that can achieve regeneration at much lower temperatures than state-of-the-art technology currently requires. This project explores structuring these materials into sorbent beds for low-pressure-drop operation to significantly lower the cost of direct air capture (DAC) of carbon dioxide. The objective of the project is to develop sorbent materials for DAC applications with the properties required to ultimately increase the carbon dioxide desorption rate by several orders of magnitude at desorption temperatures of ~80°C. Development activities have so far included sorbent substrate selection, synthesis of DAC sorbents with and without ionic liquid catalyst, testing of sorbents under dry or 100% relative humidity (RH) conditions, and multicycle testing.

Co-Funders: DOE

Start Date: 10/01/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$900,000**
Total SCG Cost: **$100,000**
Total Co-Funding: **$800,000**
Benefits:

PEM CO2 Electrolyzer Scale-up to Enable MW-Scale Electrochemical Modules

Twelve (formerly Opus 12) has achieved state-of-the-art performance for carbon dioxide electrolysis to carbon monoxide. Scaling up the polymer electrolyte membrane (PEM) carbon dioxide electrolyzer system to megawatt (MW)-scale enables industrially relevant applications where tremendous amounts of carbon dioxide can be converted into carbon monoxide and plastics. The next step is scaling up the membrane electrode assembly (MEA) active area to 1,600 cm2. This MEA area is needed to build MW-scale stacks capable of over 800 kg of carbon dioxide conversion per day. Twelve has identified five high-level project objectives needed to support that scale-up: 1) the creation of a high-performing larger (1,600 cm2) MEA and fabrication protocol; 2) a PEM carbon dioxide electrolyzer stack designed for the larger MEA; 3) new experimental methods and theoretical models for the transport layers, MEA, and catalyst characterization to accelerate future MEA development, manufacturing, and quality control; 4) demonstration of industrially relevant performance metrics; and 5) techno-economic and lifecycle analyses quantifying the greenhouse gas emissions reductions and economic competitiveness of electrochemical carbon monoxide production compared to conventional methods. In 2021, the project team identified optimized fabrication protocols to improve device performance. Flow-field optimization and PEM design activities are also underway.

Co-Funders: DOE, Twelve

Start Date: 11/30/2020
End Date: 08/31/2022
Status: Active
2021 Funds Expended: **$340,000**
Total Project Cost: **$3,125,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$2,625,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Plasma Assisted Catalytic Conversion of CO2 and Propane to Propylene

Susteon is developing a novel Catalytic Non-Thermal Plasma technology utilizing metallic and bi-metallic catalysts in a commercially scalable reactor design. This technology can use carbon dioxide as a soft oxidant to produce ethylene and propylene. The key step in this conversion process is the plasma-assisted catalytic formation of carbon monoxide and oxygen radicals from carbon dioxide. The oxygen radicals can subsequently react with ethane and propane to form the unsaturated ethylene and propylene products, respectively. Preliminary techno-economic analysis has shown that achieving yields above 50% for ethylene and/or propylene from this process can provide cost parity compared to existing industrial processes even before any carbon dioxide utilization incentives are included. This project has the following objectives: 1) plasma reaction system modification and setup; 2) catalyst preparation, characterization, and evaluation under relevant operating conditions; 3) carbon dioxide oxidative dehydrogenation in the plasma reactor with and without catalyst; and 4) process modeling. In 2021, the project team selected two catalyst types for further optimization. Work is underway to explore optimization of catalyst activity, selectivity, and stability. Additionally, experiments were performed using a range of plasma power levels to determine the role of plasma power on chemical selectivity.

Co-Funders: DOE

Start Date: 12/01/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,120,000**
Total SCG Cost: **$120,000**
Total Co-Funding: **$1,000,000**
Benefits:

Stanford Energy Efficient Strategies for Capture of Atmospheric CO2

Stanford University has begun developing sorbents that can react with carbon dioxide in the presence of water while also requiring low energy for their generation. Traditional direct air capture systems use basic metal oxides that are known to bind to carbon dioxide strongly and form carbonates that require extremely high temperatures to be converted back into their oxide form. Stanford's goal is to regenerate the metal oxide sorbent's post-carbon dioxide capture to avoid the additional use of heat. Room temperature reactions, however, require more energy to overcome the respective activation barriers. Stanford will develop energy efficient non-equilibrium plasma and plasma-activated reductants to release carbon dioxide bound in carbonates or produce syngas, and thereby regenerate the sorbent. The novelty of this approach is in the exploration of non-equilibrium plasmas that are low-temperature, renewable energy-powered, and that could promise a sustainable way to capture and concentrate carbon dioxide. This project kicked off in Q4 of 2021. Sorbent characterization and testing will be performed in 2022.

Co-Funders: N/A

Start Date: 11/01/2021
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$130,000**
Total Project Cost: **$130,000**
Total SCG Cost: **$130,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Susteon High-Capacity Regenerative Structured Sorbent Development for DAC Applications

In this project, a structured material system (SMS) for capturing carbon dioxide from the air is being developed. The purpose of this project is to optimize the composition of the SMS to maximize carbon dioxide adsorption rate, sorbent regenerability, and carbon dioxide capture capacity. With this project, Susteon will advance the current SMS technology from a technology readiness level (TRL) of 3 to a TRL of 4 to justify its scale-up and pilot test in a subsequent project. The goals of the bench-scale technology project development are: 1) 50% improvement of structured direct air capture (DAC) sorbent carbon dioxide working capacity over the current lab performance; 2) 50% improvement of structured DAC sorbent carbon dioxide capture rate; 3) structured sorbent pressure drop less than 150 Pa; 4) stable carbon dioxide working capacity to ensure a 3 to 5-year replacement cycle; and 5) development of a low-cost scalable fabrication process for sorbent modules. This project kicked off in Q4 2021. Susteon has begun work on optimizing the sorbent using a scalable manufacturing process.

Co-Funders: DOE, Columbia University, Cormetech Inc., Total Energies SA

Start Date: 09/01/2021
End Date: 08/31/2023
Status: Active
2021 Funds Expended: **$25,000**
Total Project Cost: **$1,903,877**
Total SCG Cost: **$25,000**
Total Co-Funding: **$1,878,877**
Benefits:

TCF-19-17862 Integrated Capture and Conversion of CO2 to Methanol (ICCCM) Process Technology (CRADA 449)

SoCalGas supported Pacific Northwest National Laboratory (PNNL) in developing a prototype system that integrates the capture and catalytic hydrogenation of carbon dioxide into methanol in the same solvent and demonstrating its commercial viability. The patent-pending integrated carbon dioxide capture and conversion process has the potential for significant cost savings relevant to the more common approaches to carbon capture, use, and storage. An integrated catalyst-solvent system suitable for combined capture and conversion was first demonstrated using batch reactor processing with a precombustion solvent system. In 2020, the processing was successfully demonstrated when using industrially relevant and scalable continuous-flow reactors. PNNL also demonstrated the conversion of carbon dioxide and hydrogen to methanol with 71% selectivity using one of PNNL's leading post-combustion capture solvents—likely the first time that the formation of methanol has been demonstrated using a post-combustion solvent in the presence of a heterogenous catalyst. In 2021, the team advanced the integrated catalyst-solvent system by improving the catalytic activity required for commercial adoption. A bench-scale reactor was designed and fabricated for utilization in the final demonstration in 2022. The Integrated Capture and Conversion of Carbon to Materials (IC^3M) process for methanol production was patented in 2021 and the route to methane is currently patent pending.

Co-Funders: DOE

Start Date: 02/02/2020
End Date: 04/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,200,000**
Total SCG Cost: **$600,000**
Total Co-Funding: **$600,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

SUB-PROGRAM: RENEWABLE GAS PRODUCTION

Caltech Bench-Scale Photoelectrochemical (PEC) Hydrogen Generator

The objective of this project is to design, develop, and demonstrate a photoelectrochemical (PEC) water-splitting prototype. The goal is to design a prototype with a large active light-harvesting area of approximately one square meter that is capable of operating at greater than 10% solar-to-hydrogen conversion efficiency. The prototype unit was be tested under real-world sunlight conditions and used to generate hydrogen at a peak rate of more than 1 L per min. The project team's objectives included: 1) design and fabrication of custom silicon-based photoelectrodes for the PEC hydrogen prototype; 2) design and construction of ultra-low-cost electrochemical water-splitting assemblies; and 3) integration of the photovoltaic (PV) and electrochemical (EC) units and demonstration of PEC hydrogen production at a peak rate of 1 L per min under real-world conditions. In 2021, the team coupled EC cells with three different types of PV cells to establish baseline results for the integrated medium system in outdoor conditions.

Co-Funders: DOE

Start Date: 11/30/2020
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$300,000**
Total Project Cost: **$1,080,000**
Total SCG Cost: **$300,000**
Total Co-Funding: **$780,000**
Benefits:

H2U Ultra-low-cost, Scalable, Electrocatalysts and Electrolyzers for Cost-Effective Green Hydrogen Gas Production

H2U Technologies Inc. is a startup company exploring high-throughput catalyst discovery technology initially developed under a joint program between the U.S. Department of Energy and Caltech. H2U seeks to develop and identify electrocatalysts synthesized from earth-abundant elements for utilization in modular, scalable, and cost-competitive polymer electrolyte membrane (PEM) based electrolyzers. This project will involve the testing and scale-up of earth-abundant electrocatalysts previously developed and tested at bench-scale. Furthermore, these electrocatalysts will eventually be integrated with novel PEM electrolyzer designs containing approximately 900-square-centimeter active electrode areas. In 2021, the project team completed analysis of current PEM electrolyzer manufacturing processing costs and identified several opportunities to reduce total system costs.

Co-Funders: N/A

Start Date: 03/04/2021
End Date: 03/04/2022
Status: Active
2021 Funds Expended: **$40,000**
Total Project Cost: **$200,000**
Total SCG Cost: **$200,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

HyET Hydrogen – Electrochemical Hydrogen Compression and Purification Skid Procurement

HyET's Electrochemical Hydrogen Purification & Compression (EHPC) technology is based on the selective transport of hydrogen through a membrane electrode assembly. The primary objectives of this project were to procure a pilot EHPC skid to demonstrate the technology and to collect valuable performance data to help improve the efficiency and capital cost of the EHPC system in future commercial applications. The EHPC systems were designed for a nominal hydrogen production capacity of 10 and 100+ kg of hydrogen per day for a pilot and commercial scale, respectively. In 2021, the HyET EHPC skid was delivered to and successfully installed at SoCalGas' Engineering Analysis Center. Preliminary testing was completed and the unit is operating as designed, successfully demonstrating hydrogen extraction. The unit's operation is ongoing and will continue to provide valuable testing data while blending hydrogen, in concentrations from 3 to 15%, with methane in a simulated pipeline environment.

Co-Funders: N/A

Start Date: 03/09/2020
End Date: 10/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$609,500**
Total SCG Cost: **$609,500**
Total Co-Funding: **$0**
Benefits:

HYPOWERS Phase 2 – Sulfur-Resistant CHG Catalyst Development (PNNL CRADA 442)

Pacific Northwest Laboratory (PNNL) has developed Catalytic Hydrothermal Gasification (CHG) technology based on a graphite-supported ruthenium catalyst. This technology effectively converts biomass to methane while maximizing hydrogen consumption. The target biomass for the HYPOWERS project was sewage sludge that contains sulfur compounds. Like other noble metals and many other catalysts, ruthenium is deactivated or poisoned by exposure to sulfur. This project aimed to overcome catalyst sulfur poisoning to enable commercially viable CHG processing during the hydrothermal liquefaction (HTL) of aqueous waste streams by improving the operational lifetimes of catalysts. The project identified potential sulfur-tolerant catalysts active in the sulfided form. These catalysts were synthesized, characterized, and tested in continuous-flow lab-scale CHG reactors using field samples of aqueous products from the HTL of sewage sludge. One sulfided ruthenium-carbon catalyst possesses a stable CHG performance of 480+ hours time-on-stream. PNNL plans to continue improving the activity of the unsupported sulfided CHG catalysts. In 2021, additional catalyst systems were explored for their reactivity and sulfur sensitivity, and a techno-economic analysis was performed to determine overall system cost when including catalyst lifetime, catalyst cost, and available carbon credits.

Co-Funders: N/A

Start Date: 08/01/2019
End Date: 09/06/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$500,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Joint Center for Artificial Photosynthesis (JCAP) Industry Advisor Membership

The Joint Center for Artificial Photosynthesis (JCAP) was established in 2010 by the U.S. Department of Energy as an Energy Innovation Hub. It aims to find new and effective ways to produce fuels using only sunlight, water, and carbon dioxide through a process known as artificial photosynthesis. JCAP is led by a team from the California Institute of Technology (Caltech) and brings together more than 100 world-class scientists and engineers from Caltech and its lead partner, Lawrence Berkeley National Laboratory. JCAP also draws on the expertise and capabilities of key partners from the University of California campuses at Irvine and San Diego and the SLAC National Accelerator Laboratory. The benefits of artificial photosynthesis are many and include increased energy independence and efficient means of storing and dispatching solar energy. Supporting the development of the foundational science and core technologies required for solar-fuel generation is an essential step toward investing in the future sustainable energy industry. SoCalGas served on JCAP's Industry Advisory Board to help guide research toward high-value fuels, specifically methane or renewable natural gas. This project was completed in Q1 2021.

Co-Funders: N/A

Start Date: 01/12/2016
End Date: 01/12/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$502,020**
Total SCG Cost: **$502,020**
Total Co-Funding: **$0**
Benefits:

Kore Biosolids Pyrolyzer Field Test

Kore Infrastructure has developed a commercial-scale pyrolyzer that thermochemically converts biomass to syngas. The produced syngas—a mixture of methane, carbon monoxide, carbon dioxide, and hydrogen—can then be converted to renewable natural gas or renewable hydrogen. The pyrolyzer also has the potential to accept and process waste streams, including forest thinnings, municipal solid waste, and food waste. In order to reduce risk and improve the potential for financing future commercial deployments, this field test will verify component integrity at high temperatures, feedstock throughput, and gas product quality and composition. The project team will demonstrate the operation of feedstock conveyance and drying, pyrolytic conversion, and gas cleanup and cooling. Construction at SoCalGas' Olympic Base was concluded in late 2021. Commissioning activities for the pyrolyzer began immediately afterward. The system will be fully commissioned and tested in 2022.

Co-Funders: Kore Infrastructure, South Coast Air Quality Management District

Start Date: 02/13/2017
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$6,100,000**
Total SCG Cost: **$1,500,000**
Total Co-Funding: **$4,600,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

LLNL Advanced Manufactured Reactors for Microbial Electromethanogenesis Phase 2

The removal of carbon dioxide and contaminants (such as hydrogen sulfide and siloxanes) from raw biogas comprises the majority of the cost of renewable natural gas (RNG) production. This cost is particularly prohibitive for small-scale biogas producers such as dairy farms and feedlots. These small-scale producers, however, make up the bulk of biogas potential. It is therefore important to address the cost barrier to incentivize greater and more widespread RNG production. A more carbon-efficient alternative to carbon removal is conversion. Converting carbon dioxide to methane also upgrades the gas to pipeline-quality standards. Methanogenic microbes can utilize electrical energy to methanate carbon dioxide with high selectivity and energy efficiency. Lawrence Livermore National Laboratory (LLNL) has partnered with Stanford University and SoCalGas to develop a proof-of-concept reactor with a process efficiency of 0.3 g/W-hr. The team plans advanced manufacturing to generate high-surface-area electrode materials. These will reduce energy consumption, increase volumetric productivity, and have scalable surface area. In 2020, LLNL achieved 97-99% single-pass conversion efficiency of carbon dioxide in microbial testing of electro-bio-methanation using both carbon aerogel and stainless-steel electrodes. LLNL further verified that cathode potentials were stable over 50 days of continuous operation in microbial testing. In 2021, LLNL demonstrated reactor compatibility with a range of biogas feedstock purities and achieved efficiency and selectivity milestones targeted for economic viability. Furthermore, LLNL was awarded $1 million in additional DOE BETO funding to advance this technology.

Co-Funders: DOE

Start Date:	09/05/2018
End Date:	10/11/2021
Status:	Completed
2021 Funds Expended:	**$0**
Total Project Cost:	**$767,843**
Total SCG Cost:	**$350,000**
Total Co-Funding:	**$417,843**
Benefits:	

Low Cost/Low Energy Hydrogen and Sulfuric Acid Co-Production via Electrolysis

The production of hydrogen and ordinary Portland cement (OPC) is responsible for approximately 7% of global greenhouse gas emissions—more than cars produce. California is among the top three producers of hydrogen and cement in the United States. Both are difficult to decarbonize given the carbon intensity of production. Emissions occur in two phases of the production process: 1) in burning fossil fuels for energy consumed to make the product and 2) from the chemical reactions that take place in their formulations. Brimstone Energy is developing a technology to produce low-cost hydrogen and cement without process emissions. The Brimstone sulfuric acid electrolyzer consumes <25 kWhr/kg of hydrogen. This is less than 50% as energy intensive as conventional water electrolysis, which is typically used to produce cement. The process could produce more than one million metric tons of low-cost hydrogen from California's cement demand alone. In 2020, Brimstone Energy built a 50 cm^2 sulfuric acid electrolyzer cell capable of producing 25-100 grams of hydrogen per day, dependent on the density of the electrical current. In 2021, Brimstone shifted focus from hydrogen production to making OPC. Brimstone's process can permanently capture and store carbon by converting carbon dioxide in the air into limestone lock, which can cogenerate OPC. Brimstone estimates that its technology can sequester up to one ton of carbon dioxide per ton of cement produced. Future work has been proposed to scale this technology from Technology Readiness Level (TRL) 4 to TRL 6. TRL is a measurement of the commercial viability or readiness of a technology.

Co-Funders: ARPA-E, PG&E, Cyclotron Road, VC

Start Date:	11/01/2019
End Date:	09/30/2021
Status:	Completed
2021 Funds Expended:	**$50,000**
Total Project Cost:	**$3,525,000**
Total SCG Cost:	**$50,000**
Total Co-Funding:	**$3,475,000**
Benefits:	

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Multi-Party CRADA No. CRD-18-00775 Biomethanation to Upgrade Biogas to Pipeline Grade Methane

The purpose of this project is to develop and de-risk an adaptable biomethanation process to upgrade biogas waste streams to renewable natural gas (RNG). The team designed and specified a lab-scale biomethanation bioreactor and the balance of plant needed to produce pipeline-quality RNG from biogas and green hydrogen. The design was based on lessons learned from operating the SoCalGas 700L bioreactor system at the National Renewable Energy Laboratory (NREL). In 2021, NREL designed, and Parr Instrument Company built, the lab scale 20L 18-bar pressure rated bioreactor. The bioreactor is outfitted with multiple ports for sensors. The bioreactor also includes multiple sight glasses for viewing and high-speed camera work on gas mixing. The bioreactor will be installed in the custom 16' trailer that will travel to biogas sites to demonstrate production of RNG. Data from this mobile system will be available to regulators to accelerate the certification of the RNG production pathway from biomethanation. The new bioreactor system is expected to be operational at the end of the 2022 calendar year and deployed to biogas sites in spring 2023.

Co-Funders: DOE, Electrochaea

Start Date: 07/31/2019
End Date: 07/29/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$2,305,000**
Total SCG Cost: **$5,000**
Total Co-Funding: **$2,300,000**
Benefits:

National Renewable Energy Laboratory (NREL) Hydrogen Pathways Study

The NREL hydrogen pathways study entails identifying pathways for wholesale market access to hydrogen production facilities and evaluating each pathway's cost and performance implications. The project considers eight potential regulatory/special pathways for access to wholesale power prices within California and the Western Electricity Coordinating Council. The pathway options include co-location, demand response, direct wholesale participation, and access to federal hydropower. Three critical pathways have been evaluated, including retail Time of Use (TOU), Real-Time Pricing, and direct wholesale market access. Early results indicated that the best-case pathway-direct access to wholesale electricity can provide high-capacity utilization of electrolyzers, and that the production cost of hydrogen has a strong correlation with the average locational marginal price on the grid. Moving from retail TOU to real-time pricing can reduce the cost of hydrogen production by approximately 26%. In 2021, the project team completed a final report that analyzed the net cost of hydrogen production of the optimal operation of electrolyzers. Further, the report included projected wholesale costs under current and near-future modeling timeframes targeting $3 per kg of electrolytic hydrogen. The project was completed in Q3 2021.

Co-Funders: N/A

Start Date: 01/01/2020
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$205,000**
Total SCG Cost: **$205,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

NREL CRADA No. CRD-19-809 P2G Systems Integration & Optimization

Start Date: 05/01/2019
End Date: 09/30/2022
Status: Active
2021 Funds Expended: **$13,959**
Total Project Cost: **$4,400,000**
Total SCG Cost: **$700,000**
Total Co-Funding: **$3,700,000**
Benefits:

Power-to-gas biomethanation and other gas fermentation processes can be challenged by the inherently low solubility of gaseous hydrogen in water. This low solubility limits its availability to the biocatalyst. The processes are also challenged by the high capital cost of the water electrolyzer used to make green hydrogen. With support from SoCalGas, the National Renewable Energy Laboratory (NREL) is working to eliminate expensive hardware that is unnecessary to produce hydrogen for this purpose. By co-locating the electrolyzer with a chemical reactor such as hydrogen, applications can remove aspects of the electrolyzer's sub-systems normally needed to produce pure "dry" hydrogen which is needed for fueling but not for processes like biomethanation. This would avoid tens of thousands of dollars in equipment costs while also improving system efficiency by avoiding losses of hydrogen or additional energy to dry the gas. These improvements resulted in a non-provisional patent application in 2021, with another anticipated for early 2022. During 2021, NREL completed the electrolyzer balance of plant design for the mobile biomethanation system and incorporated these innovations ahead of receiving a 20kW electrolyzer stack from Plug Power. The team also worked with the University of Chicago and Perma Pure on new equipment for the bioreactor to enable NREL's integration innovations. In 2022, the team expects to receive the 20 kW electrolyzer stack, to complete the electrolyzer system build, and to commission the system for deployment at biogas sites in spring 2023.

Co-Funders: DOE

NREL Impacts of Hydrogen Blending in Natural Gas Networks

Start Date: 08/01/2020
End Date: 08/01/2021
Status: Completed
2021 Funds Expended: **$25,000**
Total Project Cost: **$375,000**
Total SCG Cost: **$50,000**
Total Co-Funding: **$325,000**
Benefits:

This project sought to provide an overview of opportunities and challenges for hydrogen blending into natural gas systems within the context of the ongoing energy transition towards 100% carbon-free or renewable energy systems. Project objectives included: 1) analyzing the potential technical impact of hydrogen injection on natural gas facilities; 2) reviewing selected ongoing or announced projects related to hydrogen blending and injection into natural gas networks; 3) performing quantitative analyses on a test transmission and distribution network using a transient flow gas network simulation tool to evaluate hydrogen blending effects on the operation of a facility; 4) comparing the impact of different injection profiles; and 5) evaluating different mitigation measures. Project partners included SoCalGas, the Institute of Gas Innovation and Technology, and Encoord. The project team completed all activities in 2021 and concluded that hydrogen blending into existing natural gas networks may be helpful in reducing carbon dioxide emissions from the gas industry in the short term but has limitations as a decarbonization strategy. Specifically, blending at low levels is likely to be easier to implement but less impactful in terms of emissions and vice versa. To the extent that blending can build operational experience with hydrogen using existing gas infrastructure, however, it is likely to serve as a valuable tool for decarbonization. Alternatively, risks of infrastructure lock-in were identified that could delay the transition from natural gas and/or delay the transition to dedicated hydrogen transportation infrastructure. Additionally, the team explored the technical effects of hydrogen injection on the gas network, particularly at high levels of hydrogen blending.

Co-Funders: DOE, Other Federal Funding

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Scaling of Microbial Power to Gas Conversion for Long Term Operation (M2018-011 Ph I, II)

Start Date: 12/10/2018
End Date: 04/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$805,625**
Total SCG Cost: **$87,720**
Total Co-Funding: **$717,905**
Benefits:

Electricity produced from renewables is becoming a more abundant and common resource. This electricity fluctuates, however, and is generally lost when not used immediately following production. A viable and long-term solution to store this excess renewable energy is needed. One desirable and promising path to storing intermittent, renewable electrical energy is Power-to-Gas technology. The goal of Phase 1 was to test and identify bottlenecks in the long-term operation of microbial electro-methanogenesis for power-to-gas operations. The work comprised three activities: 1) evaluate growth and metabolism of microbial cells during long-term operation of a bioelectro-chemical reactor; 2) data analysis and interpretation with respect to microbial viability and performance, and subsequent recommendations for improved operation; and 3) repeat experiments with incorporated modifications based on the findings from the previous work. Despite the shutdown of laboratory work due to COVID-19, the project team completed phase 1. In 2020, Phase II began, with the goal of identifying the methanogenic archaea most suitable for intermittent electromethanogenesis for further study of the dynamics and robustness of predictable and unpredictable electrical power supplies. In 2021, the project team completed task 1 of phase 2. In Task 1, ***Methanococcus maripaludis*** was identified as the most stable strain for further study of the intermittent process of electromethanogenesis. Task 2 of Phase 2 began in 2021 with the goal of further studying how the strain responds to physical and chemical changes associated with the intermittent operation of an integrated electrosynthesis reactor.

Co-Funders: NYSEARCH Members

Speeding Anaerobic Digestion Through CO2 Microbubbles

Start Date: 06/01/2020
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$80,000**
Total Project Cost: **$300,840**
Total SCG Cost: **$150,840**
Total Co-Funding: **$150,000**
Benefits:

This project aims to introduce carbon dioxide microbubbles to significantly increase methane generation rates in anaerobic digestors. The project is in collaboration with Riverside Water Quality Control Plant, which has sufficient digestion capability to dedicate two one-million-gallon digesters to this trial. One digester will serve as a control and be operated as normal. The second will serve as the experimental digester and have the Perlemax technology implemented into its heat exchanger recirculation loop. Results from the experimental digester will be compared to those of the control to determine if the carbon dioxide microbubbles have a statistically significant effect on digestion rates. Initially, both digesters will start with the same sludge feed rate. The experimental digester will begin with a low flow of carbon dioxide microbubbles. The flow rates of sludge and carbon dioxide will be optimized to maximize volatile solid conversion rates and methane production rates. In 2021, the design and fabrication of the microbubble equipment was completed. Installation, commissioning, and testing of the equipment are planned for 2022.

Co-Funders: CalSEED

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Sustainable Production of Methane from CO2, Water, and Sunlight

The objective of this six-month project was to survey and develop comprehensive technology pathways for sustainable generation of methane from carbon dioxide, water, and sunlight. Carbon dioxide, water, and renewable power sources must all come together synergistically to produce cost-competitive, zero-emission methane at scale. The Joint Center for Artificial Photosynthesis (JCAP) team analyzed quantitative performance data from state-of-the-art materials, components, and devices for both carbon dioxide capture and carbon dioxide conversion to determine the most viable pathways for commercialization. JCAP investigated and compared four main carbon dioxide methanation pathways: thermochemical (via the Sabatier reaction), biochemical, photo-electrochemical, and electrochemical. By applying a standard discounted cash flow method to each technology, JCAP assessed the status of each and compared different technology pathways side by side. The results indicate that thermo-chemical and biochemical methane generation using carbon dioxide captured from point sources and hydrogen produced from low-temperature electrolysis powered by renewables are the most cost-competitive pathways in the short term. Importantly, the study found that at an electricity price of $10/MWh, a cost of $800/ton of methane can be achieved.

Co-Funders: N/A

Start Date: 02/01/2020
End Date: 02/28/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$170,000**
Total SCG Cost: **$170,000**
Total Co-Funding: **$0**
Benefits:

TCF-19-17586 Lawrence Livermore National Laboratory (LLNL) Composite Sorbents – Enabling Economical Biomethane Production

In this project, Lawrence Livermore National Laboratory (LLNL) and SoCalGas worked together to refine and demonstrate a new class of sorbents for upgrading raw biogas to biomethane. This approach offers the potential to significantly reduce cost barriers to biomethane production. This would, in turn, allow small producers to leverage this renewable energy resource to generate revenue. The goals of this project were to determine the economic and technical feasibility of a full-scale demonstration after the two-year project. The focus of the technology maturation activities was to: 1) demonstrate the longevity of the sorbent over an industrially relevant time scale. 2) understand the effects of hydrogen sulfide contamination; 3) scale up production of sorbent, and 4) scale up the system by approximately four orders of magnitude. In 2020, LLNL devised a new composite material formulation compatible with large-scale manufacturing and built and operated a lab-scale unit (LSU). The LSU is a bench-top, integrated, automated sorbent system suitable for long-term (1,000 hour) testing. In 2021, LLNL, planned activities in partnership with Xebec to operate a small-scale pilot (SSP) of the LSU at Xebec's testing facility. Target completion date for the SSP will be in 2022-2023 and LLNL will produce a techno-economic analysis of SSP for future maturation activities.

Co-Funders: DOE

Start Date: 10/15/2019
End Date: 01/29/2023
Status: Active
2021 Funds Expended: **$250,000**
Total Project Cost: **$500,000**
Total SCG Cost: **$250,000**
Total Co-Funding: **$250,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UCI Five Points Solar P2G Feasibility Study

This project aimed to design a renewable gas energy storage system at the Five Points solar power generation site to help the University of California achieve carbon neutrality. One major accomplishment involved evaluating various electrolyzer technologies and commercially available products to determine their feasibility for incorporation into the power-to-gas system design. The team was able to analyze various means of purchasing, selling, transmitting, and distributing gas and power at the Five Points site to determine the most favorable market conditions for the power-to-gas system design. A full report was delivered at the end of the project. A key conclusion of this study is that Power-to-Gas-to-Power (P2G2P) is a cost-effective grid resource for time-shifting renewable power at an eight-hour duration compared to lithium-ion batteries as the alternative resource. This study found that electrolytic renewable hydrogen is likely to meet the target cost range of $2.50/kg to $6.00/kg delivered. The federal government is currently considering tax credits that would make this technology even more cost-effective. The final report called for future research and exploration of the following topics: 1) the reliability and resilience benefits of clean fuel solutions; 2) the potential impact of federal tax incentives on the relative P2G2P economics; and 3) the benefits of serving both the transportation fuel and grid services markets. Although the analysis was specific to the Five Points 60-MW solar farm near Fresno, the results are applicable to similar projects at other locations.

Co-Funders: N/A

Start Date: 04/01/2019
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$95,901**
Total Project Cost: **$95,901**
Total SCG Cost: **$95,901**
Total Co-Funding: **$0**
Benefits:

UCI Transformation of the Natural Gas System Study

The objective of this project is to assess optimal pathways for the adoption of high fractions of renewable gas using the existing, adapted, and replaced natural gas infrastructure. The work draws heavily on ongoing efforts in Europe to address this topic. These include the H21 hydrogen conversion project in the UK and various studies and demonstration projects sponsored by the European Union and European trade organizations. Work to date highlights the importance of understanding the future delivered cost (price) of renewable methane versus renewable hydrogen. If renewable methane can be produced at a similar unit-cost to renewable hydrogen, there is little incentive to invest in infrastructure or end-use adaption; this makes the use of "drop-in" renewable methane the optimal approach. If renewable hydrogen proves to be substantially less expensive, however, the payback time in fuel cost savings for investment in adapted or new infrastructure and end-use devices becomes attractive. Work on refining estimates and uncertainty of the overall cost of alternative approaches continued in 2021. A final report is expected in early/mid 2022.

Co-Funders: N/A

Start Date: 02/21/2020
End Date: 08/31/2021
Status: Active
2021 Funds Expended: **$225,000**
Total Project Cost: **$350,000**
Total SCG Cost: **$350,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UCI Use of the Natural Gas Grid as a Long Duration Energy Storage Resource

The objective of this project was to determine the extent to which the use of the natural gas grid improves the overall cost and environmental performance of the electric grid at high-renewable fractions. Specifically, this project explores alternative uses of the gas grid for long-duration storage and renewables firming. The initial phase of work was to develop a levelized cost comparison of various technologies that provide grid storage for durations longer than 12 hours. Among others, pumped hydro, compressed air, and thermal storage technologies were compared to hydrogen energy storage (HES). The gas grid was used in the comparison for the transmission and storage of blended hydrogen for later reconversion in existing thermal generation resources. The California Public Utilities Commission's capacity expansion model, RESOLVE, was also used to model HES using the gas grid and existing generation. The analysis validated that the gas-grid use case improves the dispatch (lower overall cost and less curtailment) when the renewable gas supply is available for dispatchable power generation at prices below $24/MMBtu commodity price. Further analysis using the grid dispatch model HiGRID assessed the dynamics of hydrogen production and use for renewables firming.

Co-Funders: N/A

Start Date: 08/01/2019
End Date: 10/15/2021
Status: Completed
2021 Funds Expended: **$110,000**
Total Project Cost: **$300,000**
Total SCG Cost: **$300,000**
Total Co-Funding: **$0**
Benefits:

West Biofuels Renewable Gas Separation System and Techno-Economic Assessment

The objectives of this project were to: 1) assess the separation efficiency of gas hydrates in producing high-purity renewable methane from mixed alcohol tail gas; and 2) to develop an integrated techno-economic model to calculate production costs and identify key cost drivers within the West Biofuels biomass-to-mixed alcohol process. Ongoing experiments validated the proof-of-concept by showing that, under appropriate thermodynamic conditions, gas hydrates selectively concentrate methane and higher molecular weight species within the mixed alcohol tail gas stream. Despite this validation, however, both the time necessary for hydrate formation and the lower-than-desired per-stage separation efficiency suggest that alternative or supporting separation processes may be necessary. Modeling efforts have focused on modifying existing NREL mixed alcohol production models to reflect recent process modifications. In 2021, the application of the gas hydrate separations concept in continuous flow arrangement showed promise, meriting further investigation. Furthermore, additional separation technologies—membrane, and pressure swing adsorption—are being investigated to ensure successful project completion. 2022 efforts will focus on data collection from the developed system and implementation of collected data into a prepared model.

Co-Funders: CEC

Start Date: 10/01/2019
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$0**
Total Co-Funding: **$200,000**
Benefits:

GAS OPERATIONS

SUB-PROGRAM: ENVIRONMENTAL & SAFETY

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

A Process-Based Approach to PSMS, Phase II (8.18.f.2)

The project objective is to develop tools using the Business Process Modeling and Notation System (BPMN) to assist utilities with implementing, updating, or validating their Pipeline Safety Management System (PSMS). The PSMS is based on American Petroleum Institute (API) Standard 1173. In Phase I, API 1173 was broken down into its core components and methodologies for consideration as a business process at the enterprise level. The PSMS will be used to identify business units that are critical to an organization's PSMS and how those units interact in the PSMS across the organization. Phase II kicked off in 2021 with the selection of gas utilities to participate in developing and testing the PSMS tools. The next steps are for the team to begin selecting safety elements to map using BPMN with input from sponsors. This will serve as the foundation for the tool development. Upon completion, the project will deliver recommended practices for gas utilities to implement, update, or validate API 1173 PSMS. SoCalGas plans on using the research to benchmark its own PSMS and as a reference for the continuous improvement process required in API 1173 standard.

Co-Funders: OTD Members

Start Date: 12/04/2020
End Date: 08/04/2022
Status: Active
2021 Funds Expended: **$3,103**
Total Project Cost: **$235,000**
Total SCG Cost: **$8,103**
Total Co-Funding: **$226,897**
Benefits:

Aboveground Service Tee Identification and Mapping System (8.20.j)

This project uses three-dimensional electromagnetic technology to locate subsurface metallic infrastructure such as the metal cutter in the polyethylene (PE) service tee. In 2021, project data were used to determine accuracy and effectiveness of the pipe locating technology through identifying the buried PE service tees. Each buried object was classified and assigned an intrinsic and unique fingerprint. The project will classify a wide variety of tees and provide testing and results of geospatial accuracy, including depth of pipe. Sponsors provided tees to be catalogued and prepared for testing which is planned for 2022. SoCalGas can use this to prevent damage of existing buried infrastructure and reduce operations and maintenance costs for "dry" excavations.

Co-Funders: OTD Members

Start Date: 02/01/2021
End Date: 09/30/2022
Status: Active
2021 Funds Expended: **$10,287**
Total Project Cost: **$220,000**
Total SCG Cost: **$25,287**
Total Co-Funding: **$194,713**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Ambient NO2 Modeling for One-Hour Standard (CPS-11-5 and CPS-11-5A)

SoCalGas worked with Pipeline Research Council International (PRCI), Interstate Natural Gas Association of America Foundation, American Petroleum Institute, and other trade associations to build a robust emission dataset that could be used to assess the performance of American Meteorological/Environmental Protection Agency Regulatory Model (AERMOD). AERMOD is the U.S. Environmental Protection Agency's (EPA) compliance tool for estimating impacts from air pollutant emission sources. The results of this assessment will be used to develop recommendations to the EPA to improve AERMOD. To date, the publicly available dataset has proven valuable to other modelers who have begun using it to assess topics related to AERMOD performance and improvement. Analyses comparing the model to observed concentrations have been presented at EPA conferences. PRCI, SoCalGas, and consultants continue to work with EPA modeling staff to review analyses, prepare white papers and a final report, identify pathways to improve the model, and develop a methodology for improving model impact estimates from reciprocating engine sources. In 2021, the EPA provided comments. After consideration of these comments, a final report will be written and published.

Co-Funders: PRCI Members, INGAA, API, INGAA Foundation

Start Date: 01/01/2014
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$3,172,696**
Total SCG Cost: **$354,310**
Total Co-Funding: **$2,818,386**
Benefits:

Applying Heat to Steel Near PE (5.19.s)

The objective of this project is to identify and validate the best practices of applying heat to steel near polyethylene (PE) material. Field welding on steel pipeline components can transfer heat to adjoining PE material and affect its integrity. This study will consider possible worst-case scenarios in the field and the associated parameters needed to create a model that allows the user to simulate field conditions and predict the risk of heat damage to plastic facilities. A preliminary simulation model has been developed with improvements in reducing computational time. The physics behind the simulation model was verified. A standalone heat transfer calculator is being developed and validated. It will include user inputs of critical parameters of welding, heat, pipe size, and local field conditions to calculate and display the maximum temperature at the PE-steel pipe interface. The calculator will also display a graphical representation of the 3D model.

Co-Funders: OTD Members

Start Date: 10/03/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$188,500**
Total SCG Cost: **$100,500**
Total Co-Funding: **$88,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

B31Q Training Documentation Portal (8.20.a)

This objective of this project is to build and implement a prototype online portal where utilities share training documentation and other materials. The project focused on the training for a Pipeline Personnel Qualification Program (PPQP) as described in the American Society of Mechanical Engineers (ASME) B31Q standard. ASME B31Q established the requirements for developing and implementing an effective PPQP. It specifies the requirements for identifying covered tasks that impact the safety or integrity of pipelines, for qualifying individuals to perform those tasks, and for managing the qualification of pipeline personnel. The Expertise Portal was designed to allow users to find existing training materials through a keyword search, or a search of B31Q tasks and the relationship of those tasks to other training materials. The portal is available to project sponsors, and plans are being made to pre-load the B31Q resource list from other sources, including Pipeline and Hazardous Material Safety Administration and Midwest Energy Association. SoCalGas plans to use the research as reference material for its Pico Rivera's Training Facility.

Co-Funders: OTD Members

Start Date: 01/01/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$20,000**
Total Project Cost: **$258,000**
Total SCG Cost: **$40,000**
Total Co-Funding: **$218,000**
Benefits:

Best Practices to Address Odor Fade in High-Rise, Low-Occupancy Buildings (5.17.d)

Odorants are added to naturally odorless natural gas as a warning agent to aid in the detection of leaks via the sense of smell. Odorant fade is a common phenomenon that affects new, unconditioned pipes in high-rise, low-occupancy/low-use buildings. It has been observed in low-gas-flow situations. The objectives of this project are to address odorant fade, a serious safety concern, to develop best practices for odorizing high-rise and low-occupancy/low-use buildings, and to provide a risk mitigation guide. The project investigated the phenomenon in uncoated pipes and coated pipes through laboratory testing of time to saturation and performing failure analyses. The results confirmed that, under low-flow conditions, pipes with rust experienced odor fade. The project team published an interim report with the recommendation that additional testing be added to the project scope to validate the findings. In this supplemental work, the project team will perform a series of pickling experiments on clean, conditioned, and overly conditioned uncoated steel pipe to examine the impact of rust accumulation variability on time to saturation. To date, the test rig has been assembled and the generation and characterization of rust has been completed. The final deliverables are risk assessment procedure and mitigation options for gas utilities to prevent odorant fade in high-rise, low occupancy/low use buildings. Also, the team may leverage the analyses to establish a "pickling calculator" that will help utilities better understand high-risk conditions for odor fade. SoCalGas will analyze and review the results to determine if any modifications are needed to SoCalGas standards.

Co-Funders: OTD Members

Start Date: 04/17/2017
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$16,133**
Total Project Cost: **$364,700**
Total SCG Cost: **$40,776**
Total Co-Funding: **$323,924**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Center for Hydrogen Safety

The purpose of the Center for Hydrogen Safety (CHS) is to foster a global community around hydrogen safety. CHS was launched in April 2020 with the United States Department of Energy as a strategic partner along with the Hydrogen Council and California Fuel Cell Partnership. Hydrogen-natural gas (H2-NG) blends can significantly reduce GHG emissions compared to natural gas alone if the hydrogen is produced from renewable energy sources. CHS supports and promotes the safe handling and use of hydrogen across industrial and consumer applications in the energy transition. A Codes & Standards working group was formed focusing on H2-NG blending in natural gas pipeline systems. Since the formation of this working group, members have discussed the current state of knowledge, existing knowledge gaps, and how CHS can help fill the knowledge gaps. The group focuses specifically on gaps related to hydrogen safety such as safety zones. In 2021, CHS hosted three member meetings and a H2-NG blending workshop. CHS also met with the ASTM D03 subcommittee to review ASTM D03 standards and to determine the impacts from H2 blending.

Co-Funders: JIP Members

Start Date: 11/01/2019
End Date: 11/01/2022
Status: Active
2021 Funds Expended: **$18,271**
Total Project Cost: **$4,265,771**
Total SCG Cost: **$65,771**
Total Co-Funding: **$4,200,000**
Benefits:

Center for Methane Research (6.16.a)

The Center for Methane Research (CMR) is a collaborative program established to provide a centralized, industry-wide, technical and policy support resource. Its focus is on the presence, measurement, and potential impacts of methane in the atmosphere. CMR acts as a liaison between the natural gas industry, university researchers, government researchers, regulators, and other groups to ensure that important methane studies are made available. In this role, CMR also fosters collaborations between these groups. CMR will continue to disseminate technically accurate information to members, collect and analyze data on methane emissions trends and atmospheric concentration levels, conduct new scientific investigations on the role of methane in global warming, and serve as a repository for this information. In 2021, CMR provided summaries for 22 conferences and webinars, 68 papers and other reports, 25 projects and studies, and two white papers. The information and data from CMR help SoCalGas identify gaps in its methane reduction and mitigation strategy. The center also provides a repository of technical information related to methane reduction and mitigation that SoCalGas uses to support policy efforts.

Co-Funders: OTD Members

Start Date: 10/01/2016
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,055,000**
Total SCG Cost: **$75,000**
Total Co-Funding: **$980,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

CEPM for Turbochargers (CPS-14B-08)

The objective of this project is to develop turbocharger performance models from data collected from a variety of past PRCI projects, as well as from new data collected at two compressor stations. The model will provide operators with technology capable of early detection of decreased natural gas engine turbocharger performance. This will enable them to schedule maintenance or repairs before the engine is unable to meet emissions limits. Model development was completed in 2020. Closures related to the ongoing COVID-19 pandemic, however, delayed the collection of additional data needed to refine the model and perform validation testing. In August of 2021, the project team completed data collection and used the information to complete the validation of the performance monitoring model. The models and results are presented in a final report that is currently in PRCI technical committee review for publication. SoCalGas could potentially use the models to support compressor management.

Co-Funders: PRCI Members

Start Date: 01/31/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$102,101**
Total SCG Cost: **$8,653**
Total Co-Funding: **$93,448**
Benefits:

Clothing Performance Guidelines to Reduce Heat Stress for Natural Gas Workers (5.18.r)

Improvements in worker health and safety are a top priority for the natural gas industry. Thermal comfort and heat stress are significant concerns for outdoor workers in the industry. Personal Protection Equipment (PPE), such as fire-resistant clothing, must be worn while working in a flammable atmosphere. This PPE restricts heat dissipation away from the worker. These effects are exacerbated in hot climate conditions. There are currently no industry-wide requirements or standards to guide the selection of fire-resistant clothing to reduce heat strain for workers in hot and stressful working environments. The study found that wearing a lightweight flash suit without a work uniform underneath could lower the risk of clothing related heat stress. The analysis shows that the choice of uniforms and flash suits can have a significant effect on the work-rest cycle. The knowledge gained from the research will help in determining how to properly choose PPE to minimize risks and protect worker safety and health. It will further be used to inform SoCalGas gas standards and operational decision-making that requires a better understanding of fire-resistant clothing and work-rest cycles.

Co-Funders: OTD Members

Start Date: 07/01/2018
End Date: 10/29/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$284,422**
Total SCG Cost: **$10,022**
Total Co-Funding: **$274,400**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Development and Evaluation of High Resolution Historical Climate Dataset Over California (GFO-19-501, Group 2)

Start Date: 06/30/2020
End Date: 03/21/2024
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,368,550**
Total SCG Cost: **$5,000**
Total Co-Funding: **$1,363,550**
Benefits:

Weather forecasting models are used to find utility infrastructure vulnerabilities in extreme weather events. Examples of such events include extremely dry conditions posing wildlife threats and extremely wet conditions causing floods and mudslides. The two climate models currently used for forecasting are: (1) West Weather Research and Forecasting Model for California "dry" simulations, and (2) Desert Research Institute's Weather Research and Forecasting model for California "wet" simulations. A California Energy Commission (CEC) project titled, "Development of High Temporal and Geographical Resolution Characterization of Historical Climatic Conditions in California (CEC GFO-19-501, Group 2)," was awarded to UC San Diego and Scripps Institution of Oceanography. It will assemble climate data from California between 1980 and 2019 to be used to improve both models for forecasting weather conditions. The goal is to provide models that will enable utilities to assess infrastructure risks associated with exposures to short-term and long-term extreme weather events. The datasets will be made available in the cloud to utilities and climate researchers. The model results will also be made publicly available. The project team has started compiling the datasets for higher resolution refinements. SoCalGas is participating on the Technical Advisory Panel for the project.

Co-Funders: CEC

Fuel Reforming and Segregation as an Alternative for Compressor Fuel (GHG SRP CPS-14-07)

Start Date: 03/16/2021
End Date: 03/16/2023
Status: Active
2021 Funds Expended: **$963**
Total Project Cost: **$289,100**
Total SCG Cost: **$12,905**
Total Co-Funding: **$276,195**
Benefits:

This Pipeline Research Council International greenhouse gas strategic research priority (GHG-SRP) project studies the use of hydrogen as a fuel to run compressor engines, and focuses on large bore, slow speed, lean burn engines. Compared to fossil-fueled methane, hydrogen fuel has the advantage of not producing GHG emissions. The first tasks are to conduct a literature review and to produce a whitepaper. These will investigate methane reforming technologies to produce hydrogen fuel, and will explore how hydrogen-blended fuel affects engine operations, performance, and emissions. Methane reforming uses methane as a feedstock in a chemical process to generate hydrogen. In petroleum refining, a steam reformer and water-shift reactor are used to produce hydrogen for desulfurizing fuels. The first phase of this project looks at new and existing steam reforming technologies and compares the advantages and disadvantages of each. From this comparison, a technology will be selected to be used to produce hydrogen for compressor engines for laboratory evaluation, prototype development, field evaluation, and durability assessment. This project will also look at how hydrogen blended fuel will affect engine efficiency, GHG emissions, and NOx emissions. Prior research on methods of controlling the engine to accommodate varying levels of hydrogen and combustion modeling will be investigated. This work dovetails with other projects investigating the reduction of methane in engine exhaust. The goal is to reduce GHG emissions from compressor engines. The results of the study could lead to using hydrogen or hydrogen-blended fuels as a fuel for compressor engines including from SoCalGas's compressor engines.

Co-Funders: PRCI Members

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Gap Identification Between Hydrogen & Natural Gas Pipelines Standards & Practices (5.21.s)

Start Date: 08/01/2021
End Date: 07/29/2022
Status: Active
2021 Funds Expended: **$5,000**
Total Project Cost: **$170,000**
Total SCG Cost: **$5,502**
Total Co-Funding: **$164,498**
Benefits:

Parts 190, 191, and 192 of Title 49 of the Code of Federal Regulations (CFR) address safety and other requirements for the transportation of natural gas by pipeline. Natural gas pipelines are also covered by other safety and industry standards (e.g., American Society of Mechanical Engineers (ASME), International Organization for Standardization (ISO)). SoCalGas has prioritized reducing its carbon footprint and greenhouse gas emissions and is investigating the use of hydrogen-natural gas (H2-NG) blends to achieve this goal. It is, therefore, important to understand how these blends could impact SoCalGas pipeline operations. The primary objective of this Operations Technology Development (OTD) project is to identify gaps in 49 CFR Parts 190, 191, and 192 and other safety and industry standards where pipeline transport of H2-NG blends may not be addressed. To identify potential solutions for these gaps is also an objective. The project approach will be to interview national and international operators of systems with hydrogen. These systems will include natural gas operators investigating, experimenting with, and performing H2-NG blending. The project deliverable will be a whitepaper report which will include a list of all hydrogen and H2-NG codes, standards, and practices; a gap analysis of H2-NG blending; and recommendations for H2-NG blending guidance and best practices. It is anticipated that the results of this research will be used to develop and update SoCalGas standards and best practices for hydrogen and H2-NG blends and improve the safety, reliability, and efficiency of SoCalGas H2-NG operations. The results could also contribute to the development of statewide hydrogen and H2-NG blending standards.

Co-Funders: OTD Members

Gas Imaging Technologies (7.16.b)

Start Date: 02/01/2016
End Date: 07/26/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$308,757**
Total SCG Cost: **$21,757**
Total Co-Funding: **$287,000**
Benefits:

The ability of Optical Gas Imagery (OGI) to quickly identify the source of a natural gas leak while getting an accurate view of methane plume size and trajectory is important to the safety of customers and, with the capacity to quickly quantify the leak rate, would enable prioritization of repair for nonhazardous leaks within the distribution system. The objective of this project was to evaluate the use of portable and semi-portable OGI technologies for various applications such as leak investigation and leak rate quantification. An early phase of the project included the development of a testing matrix to determine the parameters and evaluation conditions for the OGI cameras. This matrix was then applied to the evaluation of two cameras for the leak detection use case to explore the abilities of the systems to locate, image, and quantify emissions from belowground and aboveground (regulator/meter, CNG compressor) leaks. Criteria included: distance from the leak, leak rate, leak area, leak source, temperature, and other environmental factors. A report was written summarizing the technology evaluation and recommendations were provided to the manufacturers. In general, both the buried and aboveground leaks were identifiable when the release rate was large. The cameras struggled to identify smaller releases which are the majority of leaks within the distribution system. In 2020, an updated OGI camera with quantification capabilities was evaluated. The results show that the technology provider needs to further develop its quantification algorithms before this can be considered a viable option. SoCalGas will consider reevaluation once the technology has gone through further development.

Co-Funders: OTD Members

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GHG Improvement in Facility Efficiency (GHG SRP CPS-17-07)

The project objective is to identify compressor inefficiencies at compressor stations. Compressor stations are the leading source of Greenhouse Gas (GHG) emissions for gas utilities. Inefficient operations lead to increases in emissions. This project will investigate technologies that improve operating efficiencies to decrease GHG emissions at compressor stations. The project comprises a literature search of available technologies with the potential to increase operating efficiencies and to decrease GHG emissions. A final report will be published to guide gas utilities in decreasing GHG emissions at compressor stations by implementing technologies that increase operating efficiencies.

Co-Funders: PRCI Members

Start Date: 03/16/2021
End Date: 03/16/2022
Status: Active
2021 Funds Expended: **$1,444**
Total Project Cost: **$88,500**
Total SCG Cost: **$1,440**
Total Co-Funding: **$87,060**
Benefits:

Greenhouse Gases Emissions Reduction (SRP-GHG-01)

Greenhouse gas (GHG) emissions are a global issue and have an impact on the natural gas industry. Pipeline Research Council International established a Strategic Research Priority (SRP) to coordinate the efforts across all technical committees. The SRP goal is to provide a roadmap of projects researching means to significantly reduce GHG emissions from the natural gas transmission system. This information will provide the natural gas industry with GHG reduction solutions to implement and reduce its carbon footprint. The SRP funded and started eight projects in 2021: Regulatory Support for GHG Emission Reductions (CPS-11-09), Continuous Monitoring and Diagnostics for Facility Efficiency (CPS-14-06), Methods to Reduce Pipeline Blowdowns to Effectuate Repairs/Inspections (MATR-3-15), Flow Sensors for Continuous Monitoring and Diagnostics for Equipment Efficiency Monitoring (MEAS-5-28), Methane Leak Detection and Quantification (PL-1-08), and CPS-14-05 CFD Study of Prechamber Ignition Mechanism for GHG Reduction. More details can be found in the individual project summaries for: Fuel Reforming and Segregation as an Alternative for Compressor Fuel (CPS-14-07), Improvements in Facility Efficiency (CPS-17-07), and Reciprocating Engine Exhaust Methane Slip Reduction (CPS-17-08). In addition to the projects that started in 2021, two ideas are being considered for projects under GHG SRP: Low-Cost Instruments to Detect/Quantify Leaking Seals, Packings, or Dump Valves, and High Flow Sampler Replacement.

Co-Funders: PRCI Members

Start Date: 01/01/2021
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$7,063**
Total Project Cost: **$3,838,835**
Total SCG Cost: **$32,339**
Total Co-Funding: **$3,806,496**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Improved Catalyst Regeneration Process (CPS-13-01A)

Start Date: 01/01/2020
End Date: 04/28/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$41,300**
Total SCG Cost: **$20,650**
Total Co-Funding: **$20,650**
Benefits:

Oxidation catalysts are effective at reducing carbon monoxide, formaldehyde, and other volatile organic compounds from the exhaust of natural gas engines used at transmission and underground storage facilities. These contaminants reduce catalyst performance, and in the absence of other interventions, the reduced performance eventually requires that the catalyst be replaced. Catalyst regeneration, however, removes the contaminants from the catalyst and is an alternative to replacement. Historically, catalysts have been regenerated using chemical washing. This technique, though, only restores a small percentage of catalyst effectiveness (15-20%). In this project, tests were conducted to determine if using a combination of thermal treatment and chemical washing removes more catalyst poisons than chemical washing alone. The results showed that the degraded catalyst could be restored to almost new conditions by combining the processes. Restoring a degraded catalyst is about 90% less expensive than replacing it. This can provide a substantial reduction in the operating costs of compressor engines. PRCI will disseminate the project findings to catalyst manufacturers and service regenerators to benefit utility members who rely on oxidative catalysts for reducing emissions.

Co-Funders: PRCI Members

Improving HCA Classification Methods (8.21.f)

Start Date: 03/01/2021
End Date: 07/29/2022
Status: Active
2021 Funds Expended: **$20,000**
Total Project Cost: **$184,000**
Total SCG Cost: **$37,360**
Total Co-Funding: **$146,640**
Benefits:

The objective of this project is to improve the accuracy of classifying high consequence areas (HCAs) and moderate consequence areas through modern data analysis and data sources. An HCA is defined as an area where a release of natural gas would adversely impact the health and safety of the affected population. The current methodology to define consequence areas is set by Pipeline and Hazardous Materials Safety Administration. This methodology allows for the use of outdated data that do not necessarily consider the dynamic population and development patterns in and around urban areas. Not accounting for these fluctuating patterns in the model creates the potential for some areas to be mis-identified, and exposes the impacted areas, the utility, and the general population to unnecessary risk. This project will explore the use of modern data sources and develop algorithms to automate the quantification of population or building use and size. SoCalGas intends to use this research to enhance our monitoring efforts in locating identified sites along our facilities, and to explore alternative methods of monitoring the pipeline right-of-way for the improvement of safety and compliance processes in accurately identifying HCAs.

Co-Funders: OTD Members

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

In Service Welding onto Methane/ Hydrogen Mixture Pipelines (JIP)

The objective of this Joint Industry Project is to determine if welding onto an in-service pipeline containing a mixture of methane and hydrogen results in an increased risk of hydrogen cracking in the weld seam. If the study identifies an increased risk, mitigation measures will be developed. The ability to safely make in-service welds on pipelines transporting a blend of hydrogen and methane will allow the installation of pipeline components (i.e., full-encirclement repair sleeves and hot tap branch connections) without service interruptions. This project includes welding experiments in different mixtures of hydrogen and methane and at different gas pressures. In 2021, baseline experiments and three rounds of hydrogen-methane experiments have been completed. These results are currently being analyzed, and the next round of testing is being planned. Future testing will include two rounds on thicker pipes and one round on thinner pipes.

Co-Funders: JIP Members

Start Date: 05/14/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$1,594**
Total Project Cost: **$258,594**
Total SCG Cost: **$33,594**
Total Co-Funding: **$225,000**
Benefits:

LDC Focused Gap Analysis & SOTA Study on Decarbonization (M2021-010)

The objective of this project is to complete a Local Distribution Company (LDC) focused gap analysis and the state-of-the-art (SOTA) analysis on decarbonization. This includes a Technology Roadmap to provide a timeline and recommend solutions to address LDC-specific challenges in decarbonization. This research will involve: 1) a literature review of key decarbonization technologies, 2) the execution of the SOTA and a gap analysis for LDC hydrogen blending and renewable natural gas; 3) the production of a decarbonization and hydrogen blending research and demonstration (R&D) roadmap; and 4) the creation of a map using geographic information systems (GIS) to visualize and track projects around the world. The gap analysis will address policies and regulations and assets and technical challenges specific to LDC and SoCalGas. The roadmap will identify specific R&D activities that can be pursued. If the project is successful as envisioned, it will provide a deeper understanding of existing gaps and challenges and provide the information and data to make informed decisions regarding decarbonization to combat climate change. The key deliverables include a decarbonization roadmap report and a GIS-based interactive story map to visualize and track projects in North America or globally. The outcomes of this research will be used in discussions related to SoCalGas's decarbonization strategy, to direct planning efforts, and to prioritize technology development projects.

Co-Funders: NYSEARCH Members

Start Date: 11/18/2021
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$15,150**
Total Project Cost: **$166,675**
Total SCG Cost: **$15,150**
Total Co-Funding: **$151,525**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

ORFEUS Obstacle Detection Technology for Horizontal Directional Drilling (5.16.k.2)

The project objective is to produce a field-proven, market ready, obstacle location technology for use in horizontal directional drilling (HDD) applications. Optimized Radar to Find Every Utility in the Street (ORFEUS) is an effort aimed at developing a safe, cost effective "look-ahead" obstacle detection system for HDD equipment. This project seeks to further develop the technology to bring forward a commercially viable product for identifying obstacles in and around the path of an HDD drill rig, thus reducing third-party damage to underground utilities. The ORFEUS technology incorporates a forward and side looking ground-penetrating radar within the horizontal directional drilling head (HDD). This process would be used to detect obstacles within the (HDD) path during the installation of new underground infrastructures. This technology could lower the risk of damaging substructures during the boring process. Information from the project will also assist the technology developer in further enhancing and improving the detection and communication capabilities of its technology including the HDD bore head radar, communication link, and system software. In 2021 the work efforts continued to redesign the HDD bore head radar and improve the communication link and system software. The project was delayed slightly due to personnel and equipment shortages resulting from the ongoing COVID-19 pandemic. Field testing is still anticipated to occur in 2022.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 12/01/2017
End Date: 03/31/2024
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$4,286,446**
Total SCG Cost: **$62,346**
Total Co-Funding: **$4,224,100**
Benefits:

Performance, Durability, and Service Life of Residential Gas Regulators (5.18.n)

The project objective was to determine the durability and expected service life of common pressure-reducing gas regulators used in residential meter set assemblies by conducting a study on the reliability and failure modes of regulators and conducting life-cycle testing on "used" regulators. Utility sponsors identified causes of service regulator failures, including the following most significant: debris/contaminant buildup, diaphragm rupture triggered by flow surge/over-pressurization, material deterioration due to exposure to severe environmental condition, and pressure fluctuations during service lifetime. Thus, the service lifetime of regulators depends not only on their build quality but also on external factors such as quality of gas and presence of debris/contaminants. The team performed flow and endurance testing on utility-supplied regulators of various ages and observed only one failure. Upon analysis, the team determined that the orifice of the regulator that failed the flow test was blocked by debris that had collected over time, eventually blocking the flow of gas. The project team determined, based on the low failure rate and high performance of the service regulators subjected to endurance and other laboratory testing, that the reliability and durability of service regulators are high. The team has issued a draft final report for review by the utility sponsors. This report includes the recommendation that rather than perform further testing to establish the failure envelope for service regulators, researchers should focus on regulator design improvements to reduce the impact of gas contaminants, the main external cause of failure. SoCalGas will use the research as a reference supporting its material selection processes.

Co-Funders: OTD Members

Start Date: 10/31/2018
End Date: 01/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$295,000**
Total SCG Cost: **$3,865**
Total Co-Funding: **$291,135**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Reciprocating Engine Exhaust Methane Slip Reduction (GHG SRP CPS-17-08)

This Pipeline Research Council International Strategic Research Priority project is a multi-year effort to reduce criteria pollutants and greenhouse gas (GHG) emissions from legacy compressor engines. The project will investigate the effects of quenching the main chamber, nitrogen formation mechanism and pre-combustion chamber size, and an early ignition and seeding radicals in the main chamber. The initial planned literature review has been completed. The team is currently tuning the computational fluid dynamic model that will be used for pre-combustion chamber design and prototyping. Next steps include laboratory and field evaluation of the prototype. The results from this project could be used to retrofit legacy engines and changes in controls, which could lead to reductions in criteria and GHG emissions. Retrofitting legacy engines to reduce GHG and criteria pollutants is less expensive than replacing them. This option benefits ratepayers with a much more cost-effective alternative in combating climate change and improving air quality.

Co-Funders: PRCI Members

Start Date: 03/16/2021
End Date: 03/16/2023
Status: Active
2021 Funds Expended: **$5,295**
Total Project Cost: **$454,300**
Total SCG Cost: **$22,046**
Total Co-Funding: **$432,254**
Benefits:

Remote Gas Sensing For First Responders – Phase 4 (7.15.b.4)

During natural gas leak investigations, first responders need a means to assess gas concentration outdoors and in buildings and manholes. Knowing the gas concentration at multiple locations without the need to be physically present will save time and improve safety. This project aims to commercialize two instruments explored in previous phases of this project; these are the "First Responder" and the "Un-attended Methane Monitor" instruments. In previous phases of the project, a methane detection system prototype was developed to enable a leak investigator to remotely monitor methane levels at multiple points within a site under investigation. There are two objectives of Phase 4. One is to develop pre-commercial-ready units that can be tested by utility members. The other is to develop a wireless communication system to allow a leak investigator to remotely monitor methane levels at multiple points within a site under investigation. In 2021, testing to verify accuracy and stability of methane sensors continued. These testing data are required to establish the calibration interval required for the First Responder device. The project team also worked to develop several housing concepts for the First Responder device. After the housing concept is complete, designs for a charging cradle and an integrated calibration test fixture will be developed, and long-term testing of sensor accuracy and stability will continue. Once this project is complete, SoCalGas will consider evaluating the technology for use in the field.

Co-Funders: OTD Members

Start Date: 09/01/2019
End Date: 10/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$358,000**
Total SCG Cost: **$27,000**
Total Co-Funding: **$331,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Selecting Locating and Excavation Technologies (5.20.b)

Third-party excavation damage to underground pipelines is a safety issue and a leading cause of property damage. The project's goal was to develop a web-based program and database for end-users to assist in developing communication tools between excavators and pipeline operators. The results should reduce the risks of pipeline excavation damage and provide situational awareness of potential accidents. The project found the root causes to be site and operational practices. The research concluded that effective measures to minimize confounding factors could include improving communications between excavators and locators in the one call system and the enforcement of states' damage prevention programs. A web-based program and database was developed for correlating excavation damage incidents to site and operational practices based on incident data from National Transportation Safety Board reports and Pipeline and Hazardous Materials Safety Administration gas distribution, gas transmission, and hazardous liquid records from 1970 to 2019. The web-based program provides end-users with a data management dashboard to integrate, visualize, and statistically evaluate the incidents based on their root causes, operation parameters, and site characteristics. The last remaining task for the project is a project debrief webinar which is scheduled for 2022.

Co-Funders: OTD Members, PHMSA

Start Date: 09/30/2019
End Date: 01/19/2022
Status: Active
2021 Funds Expended: **$3,872**
Total Project Cost: **$759,000**
Total SCG Cost: **$13,872**
Total Co-Funding: **$745,128**
Benefits:

Smart Shutoff Technology for Commercial and Residential Buildings (5.20.k)(CEC GFO-19-502, group 2)

This project is funded by the California Energy Commission (CEC) to improve the safety and integrity of natural gas infrastructure. The objective is to provide the natural gas industry with the necessary hardware and software components to create a full-solution, smart shut-off system capable of detecting and terminating gas flow in response to a hazardous incident such as fire, flood, or gas leak inside a residential or commercial structure. Deployment of smart shut-off systems can provide the localized detection and mitigation needed to prevent hazardous events from becoming excessively dangerous and costly. This project will demonstrate and validate the technologies needed to implement a smart shut-off system, as well as identify any gaps or barriers that need to be addressed prior to commercialization. In 2021 the project scope was modified to better understand the deployment of a Low Power Wide Area Network at scale after identifying knowledge gaps in the communication methodology. In 2021, a Site Readiness Report was prepared along with a draft Hardware Validation Report. Field demonstrations for the Smart Safety Shutoff System are scheduled to begin in 2022.

Co-Funders: OTD Members, CEC

Start Date: 08/04/2020
End Date: 08/04/2023
Status: Active
2021 Funds Expended: **$7,058**
Total Project Cost: **$1,200,000**
Total SCG Cost: **$25,019**
Total Co-Funding: **$1,174,981**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Stanford Natural Gas Initiative Program

The Stanford Natural Gas Initiative (NGI) is a collaboration of more than 40 research groups at Stanford University drawn from engineering, science, policy, geopolitical, and business disciplines that works with a consortium of industry partners and other external stakeholders to generate the knowledge needed to use natural gas to its greatest social, economic, and environmental benefit. It focuses on creating innovative technologies for natural gas production from unconventional sources, alternatives to hydraulic fracking, and offshore methane hydrates. NGI organizes its research portfolio into seven focus areas and operates a seed grant program to encourage new research on natural gas by Stanford researchers. It provides strategic funding to support important research in other areas related to natural gas and energy. In 2021, NGI published three natural gas briefs, two white papers, and nine research papers and conducted multiple seminars, dialogues, meetings, webinars, and workshops.

Co-Funders: NGI Members

Start Date: 01/01/2019
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$75,000**
Total Project Cost: **$1,795,000**
Total SCG Cost: **$225,000**
Total Co-Funding: **$1,570,000**
Benefits:

Study of Natural Gas Dispersion with Blended Hydrogen in Residential Structures (M2021-001)

The goal of this project is to map the dispersion of hydrogen, methane, and hydrogen-methane blends (6% and 20% hydrogen) in an experimental setting. Physical tests and computer simulations will be used in the study. All physical tests were limited to 25% lower explosive limit concentration (LEL) levels, and the Computational Fluid Dynamics (CFD) modeling used 60% LEL as the end point criterion. The primary objective of the modeling effort was to compare the results of the blended fuels with the pure fuels to determine how the gas behavior is altered and how gas detection may be impacted by methane and hydrogen concentration. It was expected that these results would help determine if hydrogen dispersion rates differ from those of natural gas in the event of leakage, and if current gas detection practices are sufficient to protect the safety of utility customers. However, when CFD modeling was completed, the results of the comparison between the blended fuels and pure fuels were inconsistent and a finite conclusion could not be reached. The draft final report was issued in December 2021 for sponsor feedback. After the final report is completed, sponsors will determine how to proceed in 2022.

Co-Funders: NYSEARCH Members

Start Date: 01/31/2021
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$15,460**
Total Project Cost: **$170,065**
Total SCG Cost: **$15,460**
Total Co-Funding: **$154,605**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Subsurface Multi-Utility Asset Location Detection (5.20.a)

The goal of this project is to conduct field trials on, and subsequently commercialize, a continuously locatable, on-pipe, electronic marking system using discrete radio frequency identification to locate polyethylene (PE) pipes. PE pipes are not as locatable as their metal counterparts and locating accuracy could be enhanced by a high-accuracy GPS locating system. Accurate location of buried PE pipe reduces the risk of third-party excavation damage. Ideally, the markers could be integrated into the pipe during the manufacturing process. Operators could use the system to document the location of subsurface plastic pipes, provide accurate GPS coordinates for pipe and points of interest, and assign a quality score to the location data that are then transferred to an operator's GIS. In 2021, the team worked on optimizing the electronic pipe markers based on feedback provided by a technical advisory panel. Based on this feedback, the receiver underwent an upgrade to improve its performance and user interface. The project is behind schedule. Dissenting professional opinions regarding the best method of applying electronic markers have precipitated a revaluation of these methods, and material supply shortages due to the ongoing COVID-19 pandemic have caused delays in the project.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 12/01/2019
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$4,715**
Total Project Cost: **$2,094,494**
Total SCG Cost: **$29,715**
Total Co-Funding: **$2,064,779**
Benefits:

Tracking Software Development for Pipeline Safety Management System (8.21.h)

The objective of this project is to develop tracking software for Pipeline Safety Management Systems (PSMS) based on the American Petroleum Institute's (API) 1173 standard This standard addresses the program development and program performance assessments. The tracking software will develop a Key Performance indicator and a scoring system to assist managers in evaluating the performance of their PSMS program. The software will aid in benchmarking PSMS performance for the continuous improvement process required under API 1173. With the software, utilities will continue to improve their PSMS to benefit ratepayers with a safer and more reliable service.

Co-Funders: OTD Members

Start Date: 11/24/2021
End Date: 05/24/2023
Status: Active
2021 Funds Expended: **$12,000**
Total Project Cost: **$220,000**
Total SCG Cost: **$21,464**
Total Co-Funding: **$198,536**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Virtual Reality (VR) Training: Emergency Response Situations (5.18.t.2&3)

The objective of this project is to develop a Virtual Reality (VR) content library and delivery system that utilities can use to assist in the training of their personnel on operation and maintenance procedures. This project will develop and use realistic, interactive, and immersive VR training modules that provide utilities with several operational advantages and provide guidance on how to deploy them. VR technology will be evaluated to determine if new developments can enhance the VR training experience. The use of VR modules will improve learner retention, improve consistency of training delivered, allow training to be conducted on demand by operations, increase the number of real-life training scenarios available for trainees to experience, and reduce the risk of injury to trainees. Six modules have been developed and are available to sponsors: Emergency Response Situations, Appliance Inspection, Inside Leak Investigation, Outside Leak Investigation and Classification, Facility Locating and Marking, and Pipeline Patrolling. The modules are being updated based upon user feedback and technology improvements. The next step is to create an implementation/deployment guide for SoCalGas.

Co-Funders: OTD Members

Start Date: 11/01/2019
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$55,000**
Total Project Cost: **$806,000**
Total SCG Cost: **$80,000**
Total Co-Funding: **$726,000**
Benefits:

Work Zone Intrusion Detection and Warning System (8.22.g)

The objective of this project is to perform market analysis and testing of Work Zone Intrusion Alarm (WZIA) technologies. Deliverables will include a Cost Benefit Analysis detailing features and pricing of the evaluated solutions and recommendations based on the various work zone scenarios that field crews may encounter. The goal is to improve the safety of employees and contractors working in situations where there is a possibility of work zone intrusion by unauthorized vehicles or pedestrians entering the work zone. Research suggests that implementing WZIA technology aids in the prevention of work zone injuries or fatalities. There is a broad range of functionality and cost between the various available technology solutions, but there is not a well-established marketplace, so further research is needed. The project is expected to kick off in early 2022.

Co-Funders: OTD Members

Start Date: 11/19/2021
End Date: 04/30/2023
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$140,000**
Total SCG Cost: **$9,333**
Total Co-Funding: **$130,667**
Benefits:

SUB-PROGRAM: OPERATIONS TECHNOLOGY

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

3D Visualization Software for Mapping Underground Pipelines and Improving Pipeline Asset Management (8.20.m)(CEC GFO-19-502, group 4)

A significant amount of third-party damage to buried infrastructure is associated with inaccurate or insufficient locating practices. Knowing the location of the buried infrastructure can significantly aid in mitigating these risks and prevent damage. In this CEC co-funded project, GTI will develop 3D visualization software for mapping underground pipelines and improving pipeline asset management. To achieve this, several existing and proven technologies will be combined to create the Locate Technology Platform (LTP). This solution creates a set of business process models that an organization may implement to improve the three-dimensional geospatial accuracy of existing GIS data in both the horizontal and vertical dimensional directions. This platform assists the field users in visualizing infrastructure location data from a variety of viewpoints. Once the LTP is completed, it will be validated in a field demonstration. In 2021, software development began and data fields to be collected were identified. Efforts to create an in-office web application that would display GIS features in a 2D and 3D format from an accessible website are in process.

Co-Funders: OTD Members, CEC

Start Date: 06/30/2020
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$29,349**
Total Project Cost: **$2,088,785**
Total SCG Cost: **$89,349**
Total Co-Funding: **$1,999,436**
Benefits:

Alternative Steel and Composite Material and Liquid Pipeline Systems (5.22.f)

The objective of this project is to establish a framework and corresponding requirements for the installation, inspection, and integrity management of alternative-steel and composite systems in natural gas pipelines. The study addresses: (1) material testing, (2) construction requirements, (3) damage and assessment of defects, (4) degradation of the pipe material, and (5) inspection and maintenance activities. The project is designed to map the requirements under 49 Code of Federal Regulations Part 192. The goal is to identify and address the gaps in implementing a qualification process for non-steel and alternate-steel composites similar to the ones currently used for steel pipes. Pipeline Hazardous Materials Safety Administration held their kick-off meeting in November 2021 where they started forming the Technical Advisory Panel. The next steps are to hold an Operations Technology Development kick-off meeting and to begin evaluating material properties and testing procedures to determine how they might be modified to be applicable for the full range of modern materials.

Co-Funders: OTD Members, PHMSA

Start Date: 12/14/2021
End Date: 12/31/2024
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,008,320**
Total SCG Cost: **$12,706**
Total Co-Funding: **$995,614**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Automation of the Explorer Series of Robotic Platforms Phase I, II, II-a, III (M2017-002)

The Explorer Series is a range of robotic inline inspection platforms used for unpiggable pipelines currently being deployed for the gas pipeline operators. The objectives of this project are to reduce the operational complexity of deploying the Explorer robotic platforms inside the pipeline and increase their overall capability by automating operation and control functions. This research is currently in Phase III. Phase I evaluated the automation potential of the existing hardware and identified required modifications. Phase II implemented software and hardware modifications to enable upstream feature recognition, pipeline mapping capabilities, and autonomous control scripts for simple maneuvers. Phase III focuses on refinements needed to adapt the system for commercialization. The redesign of control modules and components, and the pipeline mapping inertial measurement unit are completed. The full system test has been delayed and is awaiting scheduling. Feature recognition fine tuning is still ongoing. Bend detection, bend orientation, bend start, and alignment have been completed. However, testing on various pipe bends and configurations is still in progress.

Co-Funders: NYSEARCH Members, Invodane

Start Date: 02/28/2017
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$56,380**
Total Project Cost: **$4,212,620**
Total SCG Cost: **$232,255**
Total Co-Funding: **$3,980,365**
Benefits:

Composite Repair Wrap for PE – Phase 2 (2.14.a.2)

The goal of this project is to evaluate a structural reinforcing system for the *in situ* repair of damaged in-service polyethylene (PE) pipe. Mechanically damaged PE piping is typically repaired by removing and replacing the damaged section, but this process can be costly and may require the installation of a gas bypass to avoid customer gas service interruption. Current options for the in-service repair of damaged pipes are few, costly, and not universally accepted. The repair method considered in this study consists of applying a composite reinforcement wrap over the damaged area and applying heat for curing. A practical PE permanent repair system will save time and money while minimizing service disruptions. The early stages of this project saw several equipment issues with the Cycle Pressure Fatigue test rig. These issues delayed the cyclic pressure testing and resulted in a change in the scope of the project regarding the type of testing. The test plan was updated accordingly, and the testing method employed was changed to Long-term hydrostatic strength (LTHS) testing instead of cyclic pressure testing. The LTHS samples are currently being tested.

Co-Funders: OTD Members

Start Date: 05/07/2018
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$75,900**
Total SCG Cost: **$8,576**
Total Co-Funding: **$67,324**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Continuation of Single-Path Ultrasonic Meter Long Term Performance Testing & Monitoring (5.20.e.2)

Start Date: 12/02/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$5,000**
Total Project Cost: **$129,000**
Total SCG Cost: **$5,375**
Total Co-Funding: **$123,625**
Benefits:

The goal of this project is to build upon research identified by Operations Technology Development Project 5.19.h: Single Path Ultrasonic Meter (USM) Performance Testing (Phase 1). The project team will add a smart diaphragm residential gas meter (DRGM) to the earlier accuracy evaluation. An interim report provided performance testing results evaluating the effectiveness of the smart gas meter shut-off valve, enabling 1) comparison of the local distribution company's DRGM metrology results with the two ultrasonic meters (USMs) tested in Phase I, and 2) evaluation of the communication capabilities of the three meters from both Phase 1 and this project. In this project, the team is evaluating the effectiveness of the smart shut-off valve and communication capabilities of all three meters. In 2021, the project identified the locating and mounting mechanisms, completed the setup of simulated power for replicating different levels of battery capacity, and completed accuracy tests on all three meters for an outdoor accelerated life test. At present, all testing for the smart DRGM is complete, while testing for the USMs is ongoing. Test data have been compiled and the interim report is in progress for the smart DRGM. The project was initially expected to be completed by the end of 2021, but COVID-19 restrictions in the lab delayed the project, with completion now estimated for the second quarter of 2022. The next steps are to complete the USM testing and draft the final report. SoCalGas could use this information to supplement its evaluations of new metering technology.

Co-Funders: OTD Members

Data Logger Evaluation Project – Phase II

Start Date: 06/15/2021
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$17,032**
Total Project Cost: **$46,000**
Total SCG Cost: **$46,000**
Total Co-Funding: **$0**
Benefits:

Thermoplastic pipeline joints are produced in the field using pipeline fusion processes (e.g., heat and pressure). High quality joints are critical to the integrity (e.g., safety and reliability) of natural gas pipeline facilities. There is presently no automated data collection process for field fusion operations. All information is recorded manually. This process has significant potential for errors and provides no efficient means of integrating the fusion data into company systems for easy access, thus encumbering review and analysis. Further still, in cases of failures, the fusion data are not readily available for review to aid with the investigative process. The objective of this project is to evaluate a commercially available data logging technology for collecting data associated with the fusion joint process. It is anticipated that the collected fusion data will allow real-time evaluation of fusion parameters such that fusion joints are produced with consistent quality prior to placing in service. The process of data collection, storage, and integration into company systems will be researched.

Co-Funders: N/A

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Enhanced Locating Technologies for Underground Pipelines with Better Accuracy (8.20.I)(CEC GFO-19-502, group 3)

The objective of this CEC-cofunded project is to improve the safety and integrity of underground natural gas pipelines by increasing the accuracy and availability of horizontal and vertical pipeline location information. The approach is based on enhancing and adapting aboveground, large standoff, 3D electromagnetic detection technology to locate buried pipelines. It will supplement the technology with an in-pipe mechanism to focus on congested areas and plastic materials. SoCalGas will focus on transmission infrastructure while Pacific Gas & Electric will focus on infrastructure in congested urban areas. Improved tools are intended to provide access to three-dimensional data in near-real time, and the combined solution is anticipated to apply to most in-field conditions including varying pipeline material, depth, and surface cover. In 2021, gathering and analyzing data from the GTI test site with buried pipes continued. Planning of the 2022 field demonstration at SoCalGas started and a test plan was developed.

Co-Funders: OTD Members, CEC, Other

Start Date: 11/04/2020
End Date: 11/30/2023
Status: Active
2021 Funds Expended: **$9,214**
Total Project Cost: **$2,222,903**
Total SCG Cost: **$26,768**
Total Co-Funding: **$2,196,135**
Benefits:

Evaluation of Methane Detection Technologies with Hydrogen-Methane Blends (In House – Phase 1 & 2)

This evaluation consisted of two phases focused on identifying potential vulnerabilities and solutions to hydrogen-methane (H2-CH4) blend leak detection applications. H2-CH4 blends, consisting of 1%, 5%, 10%, and 20% hydrogen, were used to simulate potential pipeline blend compositions. The first phase successfully identified leak detection technologies that would be compromised by or vulnerable to hydrogen exposure. Phase 1 encompassed all leak detection technologies currently used by SoCalGas which include infrared absorption detectors, thermal conductivity sensors, flame ionization detectors, catalytic sensors, semiconductor sensors, and electrochemical sensors. The team focused on characterizing device sensitivity to hydrogen, on determining device failure modes, and on observing efficacy in detecting and measuring H2-CH4 leaks. The results from Phase 1 were used to identify potential solutions for future H2-CH4 blend leak detection applications. Phase 2 evaluated modern technologies for potential solutions to concerns identified in the previous phase. The results from Phase 2 did not find adequate solutions as these technologies were either still in prototype phase or still showed sensitivities to hydrogen exposure. Additional research and testing will be needed as technologies are developed specifically for H2-CH4 target blend compositions. SoCalGas will look to continue research once new technologies become commercially available.

Co-Funders: N/A

Start Date: 06/01/2020
End Date: 11/15/2021
Status: Completed
2021 Funds Expended: **$36,705**
Total Project Cost: **$46,795**
Total SCG Cost: **$46,795**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Evaluation of Micro-Thermal Gas Metering Technology (5.22.d)

The objective of this project is to evaluate the accuracy and overall performance of micro-thermal gas metering modules while measuring hydrogen-blended natural gas and biomethane gas volumes. The microthermal gas meter module consists of a Micro-electromechanical Systems (MEMS) -based calorimetric microsensor. The MEMS measures the flow of natural gas using the thermal measurement principle. The sensor element is located on a membrane and consists of a micro-heater and upstream and downstream temperature sensors. The temperature distribution characteristics during gas flow are used to determine the gas velocity and the gas volume. It is integrated with signal conditioning electronics including memory for calibration data. Gas utilities are increasingly considering the proposition of transporting fuels of varying constituents. This includes low-carbon-based fuels such as hydrogen-blended natural gas and renewable natural gas. The source of these fuels varies and so does the gas composition. A reliable metering technology that can be easily calibrated to varying gas compositions provides an additional layer of operational flexibility to gas utilities and enables the diversification of gas quality in the network. The project is expected to kick off at the beginning of the second quarter of 2022.

Co-Funders: OTD Members

Start Date: 11/19/2021
End Date: 09/30/2023
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$132,000**
Total SCG Cost: **$13,200**
Total Co-Funding: **$118,800**
Benefits:

GIS Portal Data Quality Improvement

The objective of this project is to test and evaluate a range of tools and to develop recommendations based on the analysis. The tests and recommendations will evaluate the most appropriate set of tools for Gas Distribution field personnel to capture the location of pipeline facilities by using a combination of hardware (e.g., GPS, tablet, underground pipe locator) and GIS software. This project enables real-time kinematic (RTK)-corrected, highly accurate GPS data to be captured by field personnel performing routine activities. The project goal is to implement a streamlined field-captured GPS data workflow into Enterprise GIS and aims to create a method that leads to higher-accuracy positional data. In 2021, the project completed installation of the base station and VPN (Virtual Private Network) was installed on SoCalGas devices. The technology will be tested for the accuracy of positional data from locating devices compared with non-RTK-corrected data. SoCalGas plans to leverage the base stations to provide real-time GPS correction for end users to achieve a higher level of GPS accuracy. The expected project benefits are an improved method to capture field data and transfer them to the mapping system and decreasing the amount of time and number of steps it takes to perform the task.

Co-Funders: N/A

Start Date: 06/01/2020
End Date: 05/31/2022
Status: Active
2021 Funds Expended: **$495**
Total Project Cost: **$60,495**
Total SCG Cost: **$60,495**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Guidance on the Excavation and Backfill Procedures in Areas of Geohazards and High Axial Stresses and Strains (SBD-1-5)

The objective of this project was to provide guidance on procedures for excavation and backfill in geohazard areas (GHAs) where buried pipelines are subject to high axial stresses and strains. The intended benefits include reducing the risk of pipeline damage during mitigation work and increasing worker safety during heavy equipment operation in GHAs where extra caution is required (such as landslides and settlement). Unnecessary restrictions and ineffective precautionary measures were identified to maximize resource efficiency, both in terms of time and cost, and to minimize service interruptions. The guidance document includes measures for the maintenance of site stability, pipeline segment integrity, and worker safety. The project team focused on recommendations in three areas: preparation, excavation, and backfill. Preparation included the geotechnical and integrity assessment of safety for excavation or backfill. Excavation included the determination of the excavation sequence and limits as well as the performance of excavation with monitoring measures to ensure the safety of working personnel and the integrity of the pipeline. Backfill included the selection of suitable backfill materials and procedures for backfilling a trench properly. Proper backfilling aims to minimize the threats from future geohazards and to avoid excessive earth loading to the pipeline segment. SoCalGas plans to use this guidance as a reference for its pipeline operators and contractors when carrying out excavation and backfill in areas of geohazards. SoCalGas may also use this information to make informed decisions to maintain the safety and integrity of pipelines.

Co-Funders: PRCI Members

Start Date: 01/31/2018
End Date: 02/24/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$236,000**
Total SCG Cost: **$9,797**
Total Co-Funding: **$226,203**
Benefits:

In-Situ Ultrasonic Meter Flow Validation for Gas Meters (MEAS-6-17A)

The objectives of this project were to optimize the gas tracer method for field-proving of ultrasonic flow meters and to illustrate the practical uncertainty of the method. The two primary benefits from this project are: 1) reduced measurement uncertainty and, therefore, reduced LUAF gas; and 2) reduced maintenance and operating costs resulting from less frequent meter recalibrations. This project provided a proof of concept for an *in situ* verification method for ultrasonic flow meters in natural gas service. The tested method consisted of simultaneously injecting helium at a minimum of two locations upstream from an ultrasonic flow meter. The locations are a known distance apart. Initial results indicate that the flow verification method is successful in determining gas velocity through an ultrasonic flow meter to within ±5% of the true value. While this level of accuracy is not acceptable as a replacement for laboratory flow calibrations, it may be useful as a field diagnostic tool. This use would reduce meter recalibrations and, as a result, operating costs. Further research is needed before the methodology is introduced into a field demonstration.

Co-Funders: PRCI Members

Start Date: 11/01/2018
End Date: 06/11/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$106,200**
Total SCG Cost: **$4,396**
Total Co-Funding: **$101,804**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

JIP PE Systems Research Program – Phases 1 and 2 (5.16.r, 5.16.r.2)

The objective of the Plastics Joint Industry Program (JIP) is to bring industry stakeholders together to address knowledge gaps in the plastic piping industry. These gaps will then be addressed through research and the development of standards and guidelines designed to enhance the overall integrity of plastic gas distribution systems. The objective of the Plastics JIP program is to enhance and standardize aspects of plastic knowledge and procedures to create a more robust plastic piping system and improve system integrity. The focus of the JIP participants is to identify and discuss industry needs, achieve consensus on prioritization of issues for project research, and participate in the direction and review of the various project efforts. In 2021, JIP's efforts included developing fusion joining preparation best practices, creating polyethylene (PE) pipe ovality and out-of-round standards, investigating the impact of heavy hydrocarbon permeation in PE pipe on mechanical joints, and other needs as identified by the JIP participants.

Co-Funders: OTD Members, JIP Members

Start Date: 10/01/2016
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$455,100**
Total SCG Cost: **$70,000**
Total Co-Funding: **$385,100**
Benefits:

OIML Test Data Summary for New Generation Ultra Sonic Meters (MEAS-6-21)

For many years, Pipeline Research Council International member companies have had interest in the effect of upstream piping configurations on ultrasonic meter performance. Many manufacturers have conducted testing based on OIML R137-1, and documentation for their flow meters often cites conformance with this standard. However, these data have generally only been available by special request and typically are not presented in a way that allows for direct comparisons of meter performance. This project organized and compared non-public-domain data from different ultrasonic meter manufacturers' OIML R-137-1 testing programs for current multipath wetted model ultrasonic meters. All eight ultrasonic meter manufacturers supplied OIML R137-1-compliant datasets. The data that were provided were valid and useful for determining the meter performance relative to various upstream piping configurations. As a result, the data used in this project are applicable for determining the potential meter error for various combinations of upstream piping disturbances, flow meters, and straight piping lengths – both with and without flow conditioning. The final report was approved by the Project Team in December of 2021, and vendor comments are to be added into an Appendix in early 2022.

Co-Funders: PRCI Members

Start Date: 01/31/2018
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$59,000**
Total SCG Cost: **$4,726**
Total Co-Funding: **$54,274**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Technology Testing Assessment Facilities (AMI Smart Metering)

Utilities are frequently challenged to find tools or technologies that increase safety, lower operation and maintenance costs, improve accuracy, and/or replace existing obsolete equipment and tools. SoCalGas test facilities have been constructed to simulate portions of the company's operating system. This enables the evaluation of new tools or technologies without impact on system operations or customers. For this project, team members will evaluate new technologies, tools, and equipment at the SoCalGas Gas Meter Test Rack or at Situation City. Technology performance that passes the minimum requirements may be approved and deployed in company operations. Currently, the Measurement Technology Group is evaluating the functionality and reliability of a residential ultrasonic gas meter and an advanced metering infrastructure (AMI) network. This proof-of-concept pilot project leverages a new AMI network to receive real-time data from gas meters, multivariable sensors, cathodic protection test stations, and an integrated distribution automation system. In 2020, meters were installed for testing. In late 2021, all units were returned to the manufacturer due to concerns of inaccuracy. Testing will resume upon receipt of updated versions of the meters.

Co-Funders: N/A

Start Date: 01/01/2019
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$6,443**
Total Project Cost: **$119,300**
Total SCG Cost: **$119,300**
Total Co-Funding: **$0**
Benefits:

Uniform Frequency Code (5.18.m)

The objective of this project was to develop a best practice (BP) Uniform Frequency Code for radio frequency identification (RFID) devices used to locate buried utilities. This code set a consistent frequency setting for RFID devices based on their respective utility designation, such as gas, electric, or water. The project team successfully drafted, reviewed, and finalized the consensus language required to produce two BPs codes and supporting documentation for publication in the Common Ground Alliance's (CGA) BP Guide, Version 18. The first of these, BP 2.19 Underground Electronic Utility Markers, was added to Chapter 2 – Planning and Design. BP 6.19 As-Built Mapping of Underground Electronic Utility-Markers was added to Chapter 6 – Mapping. In addition to the BPs, the project team drafted Appendix B, "Guidelines for Underground Electronic Utility Marker Technology". These guidelines contain a table of commonly used frequencies for various underground electronic utility markers. CGA's Best Practices is the industry standard for damage prevention in the United States. SoCalGas will incorporate the BPs into its operational procedures. The remaining tasks will be completed in early 2022 with the publishing of the final report and a sponsor close-out webinar.

Co-Funders: OTD Members

Start Date: 07/01/2018
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$135,000**
Total SCG Cost: **$5,322**
Total Co-Funding: **$129,678**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Update ASTM Standard on Soil Compaction Control Using the DCP (5.20.o)

The project goal was to work with the American Society for Testing and Materials (ASTM) committee to review and update ASTM standard D7380-15 (Test Method for Soil Compaction Determination at Shallow Depths Using 5-lb DCP) for its required seven-year renewal. The Dynamic Cone Penetrometer (DCP) was established as an alternative to costly soil compaction density measuring methods. The existing ASTM standard was established in 2008 and renewed in 2015 to standardize the manufacture of DCP devices and the procedure used for soil compaction verification. SoCalGas and many other utilities continue to use the DCP as part of their daily excavation restoration operations. The ASTM committee reviewed the standard for relevance and compliance with ASTM D-18 standards, and the standard was updated in November 2021 based on committee feedback. The updated standard has been published as ASTM Standard D7380M-21. SoCalGas references the ASTM Standard D7380M-21 in Operations Standard documents.

Co-Funders: OTD Members

Start Date: 12/01/2020
End Date: 02/28/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$26,000**
Total SCG Cost: **$4,000**
Total Co-Funding: **$22,000**
Benefits:

Update of PRCI Pipeline Repair Manual (MATR-3-1A)

Technology advancements offer pipeline companies the opportunity to extend the life of assets in place. Such advancements include materials, techniques, products, and procedures. An updated comprehensive Pipeline Repair Manual is needed to document these advances and to provide engineering guidance on the appropriate repair techniques for various defects in pipelines. PRCI's Pipeline Repair Manual is widely used by the natural gas industry. The manual has not been updated or revised since the sixth edition was published in 2006. In the 14 years since the last revision, many codes that govern pipeline repairs have been changed and new codes have been passed. In addition, new and advanced repair technologies and techniques that are available today were not available then and are not covered in the current manual. This project will update the manual by incorporating updated codes, new codes, and current techniques and technologies for repairing pipelines. A final draft of the manual is currently undergoing editorial review. The manual will be published in 2022.

Co-Funders: PRCI Members

Start Date: 06/30/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$9,218**
Total Project Cost: **$177,000**
Total SCG Cost: **$13,827**
Total Co-Funding: **$163,173**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

SUB-PROGRAM: SYSTEM DESIGN & MATERIALS

Alternative Caps for PE Service Tees (5.16.b)

The objective of this project is to develop an alternative cap design for polyethylene (PE) tapping tees. The alternate cap design enables the PE cap to be fused onto the tapping tee tower rather than having a cap that threads onto the tapping tee tower. A threaded cap has more potential for leakage due to inadequate O-ring seal engagement. A fused cap decreases the risks of leakage. The participating manufacturer for the project has designed and developed a fusion cap and tapping tee assembly. The new design has some limitations, and the fitting developer requires alignment tools for performing socket fusion on the tee tower. Due to the cost of alignment tools required for the operation, and the limitations in the design, an alternative design was discussed with the team. A communication was sent out to sponsors to gauge interest in continuing this project. SoCalGas can use this research as a reference to improve the integrity of our PE piping systems and minimize operation and maintenance costs to repair leaks caused by threaded cap design.

Co-Funders: OTD Members

Start Date: 02/15/2016
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$112,400**
Total SCG Cost: **$32,115**
Total Co-Funding: **$80,285**
Benefits:

ARPA-E REPAIR Program (TTSP)

Old cast iron, wrought iron, and bare steel natural gas distribution pipes make up 3% of utility pipes in use, but account for a disproportionate number of gas leaks and pipe failures compared to newer steel pipe. The ARPA-E REPAIR program seeks to reduce natural gas leaks from these pipes by developing a suite of technologies to enable the automated construction of new pipe inside existing pipe. REPAIR will advance the state of gas distribution pipelines by incorporating smart functionality into structural coating materials and by developing new integrity/inspection tools. It will also create three-dimensional maps that integrate natural gas pipelines and adjacent underground infrastructure geospatial information with integrity, leak, and coating deposition data. SoCalGas involvement with the project is through the Testing and Technical Specification and Steering Panel Committee. In 2021, technical input was provided by operators. Draft test plans developed by the Testing and Analysis Team were sent out for comment in preparation for external loading, pressure and pressure testing on cast iron and bare steel pipe.

Co-Funders: N/A

Start Date: 10/01/2020
End Date: 10/01/2023
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$32,554,637**
Total SCG Cost: **$0**
Total Co-Funding: **$32,554,637**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Auto Diagnostic for Ultrasonic Flow Meter (MEAS-6-20C)

This project will develop a process and corresponding software to evaluate whether changes in ultrasonic meter flow-related diagnostics (e.g., profile factor, asymmetry, and swirl) are causing a significant change in the estimated installed measurement uncertainty of the ultrasonic meter station. The American Gas Association currently requires that additional uncertainty due to installation effects be less than ±0.3%. The new software diagnostics tool, which incorporates artificial intelligence and knowledge-based information, will enable gas operators to quantify system imbalances in near-real time. This will reduce lost and unaccounted-for gas volumes used with pipeline gas inventory calculations. The results of this research will be used in the development of a new software diagnostics tool. In 2021, upgrades to the software diagnostics tool were completed and a demonstration was conducted. A draft final report, user guide, and installation manual were issued for review in December with finalization expected in early 2022.

Co-Funders: PRCI Members

Start Date: 03/01/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$118,000**
Total SCG Cost: **$3,819**
Total Co-Funding: **$114,181**
Benefits:

Biomethane Justification Study for Improved/Accepted Gas Quality Standards (7.18.b)

Biomethane derived from landfills, wastewater treatment plants, dairy farms, food waste processors, and other renewable natural gas (RNG) sources is poised to play a larger role in the natural gas system. However, some concerns still exist about injection of RNG into pipelines. This project helped address some of those concerns by setting gas quality acceptance standards for biomethane. As opportunities for biomethane injection into a distribution or transmission pipeline increase, requirements around safety, reliability, interchangeability, and continuity need to be developed and incorporated to keep gas flowing and avoid service interruption. The project objectives were to provide a fact-based, objective study on the quality, analysis, risk, and compositional variability of final end-use grade biomethane, and to provide industry with the sound science and clear facts that demonstrate that biomethane is safe to use from properly processed biomethane interconnect projects. The project deliverables include: 1) a justification document that leverages trace constituent data obtained from past projects; 2) a risk assessment calculator for pipeline component integrity to take user-input data on concentrations of RNG/biomethane gas constituents found in a gas stream; and 3) a risk category of the impact to pipeline infrastructure. The results of this study will be used to complement SoCalGas' RNG quality guidelines.

Co-Funders: OTD Members

Start Date: 03/01/2018
End Date: 11/05/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$300,000**
Total SCG Cost: **$57,508**
Total Co-Funding: **$242,492**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Blending Modeling (Hydrogen)

Hydrogen is considered an important energy carrier of the future for sustainable, reliable, and cost-effective energy. Hydrogen will help secure energy supply by utilizing locally available renewable energy resources such as wind, solar, and biogas. Hydrogen can also contribute to a reduction in carbon dioxide emissions and improvements in air quality by displacing fossil fueled energy sources with hydrogen produced from renewable energies. This project will determine the impact of blending hydrogen or off-spec renewable natural gas (RNG) into SoCalGas pipelines and facilities. Two important variables regarding hydrogen blending are unknown: 1) the amount of time after injection for full mixing to occur, and 2) the distance into the pipe at which full mixing occurs. To determine the achievement of full mixing after injection, the project team will address the following concerns: the distance and time for injecting blended hydrogen or off-spec RNG, blending station designs, placement of monitoring equipment, and concentration of hydrogen on the internal pipe surface. The team will develop computational fluid dynamics models to simulate various scenarios and determine their impacts. This project was delayed due to the COVID-19 pandemic and resource turnover but is on-track for completion in early 2022. In 2021, the project team developed models and began conducting the analysis of the impact of various hydrogen blends on the SoCalGas pipelines and facilities.

Co-Funders: N/A

Start Date: 12/20/2019
End Date: 04/01/2022
Status: Active
2021 Funds Expended: **$3,832**
Total Project Cost: **$149,536**
Total SCG Cost: **$149,536**
Total Co-Funding: **$0**
Benefits:

Common RNG Interconnection Skid Development for Utilities (T-789)

This project would pioneer a digital database (DB) to provide a common framework on renewable natural gas (RNG) interconnection (IC) and allow utilities to select the optimal design for their systems as they inject and transport increasing proportions of RNG. The database would serve as a valuable resource for local distribution companies that are in the initial stages of engagement with RNG producers. Those with well-established relationships with producers would likewise benefit. Initial considerations are that these benefits would include streamlining of the IC process and reduced capital costs. The first step in developing the DB is to develop engineering designs of common RNG IC skids. This project will develop two standard IC skid designs: open-air and enclosed. These designs would leverage a DB of various parameters such as instrumentation, measurement, regulation, gas quality analysis, and safety measures. This would allow a plug-and-play approach that utilities can use to develop an IC skid that best fits their needs. This DB would allow consistent manufacturing and implementation processes to be utilized by the gas distribution sector, thus reducing costs. The IC process involves consideration of gas quality management and the design of customized piping and instrumentation to meet engineering standards. Regulatory requirements precipitate the need for a technoeconomic analysis. At project completion, SoCalGas could use one of the designs or use the information from the project as a knowledge resource for potentially developing its own RNG skid designs.

Co-Funders: NYSEARCH Members

Start Date: 12/14/2021
End Date: 09/30/2022
Status: Active
2021 Funds Expended: **$23,660**
Total Project Cost: **$222,380**
Total SCG Cost: **$24,710**
Total Co-Funding: **$197,670**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Deliver Comprehensive Metal-Loss Assessment Criterion (EC-2-10)

This project integrates and builds on work successfully completed in prior research, which developed a criterion for metal-loss assessment demonstrated in an independent evaluation to significantly reduce data scatter and address bias in contrast to American Society of Mechanical Engineers (ASME) B31G and Modified B31G. The project's objective is to develop a Level 1 and Level 2 metal-loss assessment criterion that is easy to use and covers all pipe grades and construction era. The metal-loss assessment criterion will indicate the risk of leak and rupture, reduce inspection data scatter, and eliminate maintenance that does not affect risk reduction. The outcome of this effort will enable full-scale representative assessments of failure pressure in areas of corrosion damage. These assessments will have less scatter and conservatism than currently exist in ASME B31G, Modified B31G, and other assessment models, without compromising pipeline operational safety. The project has been broken into four phases. In 2021, the project team completed Phase I with the development of a burst pressure predictive model for isolated metal loss which captures the effects of length, depth, width, planar shape, and longitudinal profile. The project also developed and validated a reference stress function that incorporates the effects of pipe material strain hardening. In 2021, the project team prepared a draft Final Report of Phase I. Phase II is ongoing with the criteria to quantify interaction. In 2022, the project team will quantify interaction and coalescence for adjacent metal loss features and evaluate relative to existing full-scale burst test data.

Co-Funders: PRCI Members

Start Date: 04/01/2019
End Date: 08/31/2022
Status: Active
2021 Funds Expended: **$73,854**
Total Project Cost: **$1,587,263**
Total SCG Cost: **$133,902**
Total Co-Funding: **$1,453,361**
Benefits:

Design and Placement of Compact Service Regulators – PHMSA Cofunding (5.22.j)

This project will review existing practices and perform comparative service regulator testing that will result in recommendations and guidance to the natural gas industry on "vent-limiting" service regulators. It will also provide additional options to natural gas utilities for the safe, outdoor installation of regulators and meter sets. This project will determine if "vent-limiting" service regulators offer more options for outdoor installation by having a smaller footprint and, thus, reduced clearance distances in comparison to traditional internal relief valve (IRV) service regulators. The project team will determine safe distance allowances through testing the quantity of gas vented during various regulator operating flow conditions and failure modes, including diaphragm ruptures. Many gas utilities have set a minimum distance to a source of ignition for both indoor and outdoor meters and regulators based on the National Fuel Gas Code's requirement. Field crews must satisfy these clearance distance requirements when installing meter set assemblies, including the regulator, on the outside of a building. These clearance distances, however, were created with standard IRV regulators in mind. New "vent limiting" service regulators, typically with "slam shut" features, are now available from a few manufacturers and being used in a limited fashion by some natural gas utilities. This project, co-funded by the Pipeline and Hazardous Materials Safety Administration, kicked off in November 2021. In 2022, the project team will develop the test plan; establish a Technical Advisory Committee; identify national and international service regulators with "venting limiting" capabilities; and determine service regulators to be included in the test plan.

Co-Funders: OTD Members, PHMSA

Start Date: 11/19/2021
End Date: 05/31/2023
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$489,629**
Total SCG Cost: **$5,733**
Total Co-Funding: **$483,896**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Effect of Hydrogen Blended Natural Gas On Performance of Gas Meters and Diaphragm Type Service Regulators – Phase 1 (5.21.t)

The objective of this project is to study the effect of hydrogen-natural gas (H2-NG) blends, with up to 20% hydrogen by volume, on the durability, safety, and performance of existing gas meters and diaphragm type service regulators commonly used for residential service. Tests include durability, accuracy, leakage rates, and oxidation induction time. The results of the research project are anticipated to aid in understanding: (1) material compatibility impacts on gas meters and regulators in H2-NG blend service; (2) any impact of H2-NG blend H2 concentration on meter accuracy; and (3) associated possible H2-NG blend limits for gas meters and service regulators. SoCalGas could also use the results from this research to contribute to the creation of a statewide hydrogen injection standard. The primary project deliverable will be a final report.

Co-Funders: OTD Members

Start Date: 08/01/2021
End Date: 10/31/2022
Status: Active
2021 Funds Expended: **$27,500**
Total Project Cost: **$350,000**
Total SCG Cost: **$41,666**
Total Co-Funding: **$308,334**
Benefits:

Effect of Upstream Piping on Ultrasonic Meter Bias (MEAS-6-5C)

The objective of this project is to assess the effect of end treatments on the velocity profile and the resulting ultrasonic meter performance. This aligns with the Pipeline Research Council International (PRCI) goal to increase measurement accuracy. If successful, the primary benefit from this project will be reduced measurement uncertainty of ultrasonic meters, thus reducing the amount of unaccounted gas. Experimental test results will be compared to computational fluid dynamics (CFD) modeling results. The project will identify end treatments that allow for cleaning and internal inspection while minimizing the effect on the velocity profile and the overall meter performance. This information could be used to identify end treatment designs that should be avoided because they could impact meter performance. In 2021, the project team selected the end treatments to be tested and decided to include a clamp-on ultrasonic meter model in the test plan. The flow test configuration specifics were finalized, and a contractor fabricated the pipe spools required for testing. The end treatment configurations that will be used to perform CFD modeling were finalized in 2021. Flow testing is scheduled to start in early 2022.

Co-Funders: PRCI Members

Start Date: 11/01/2018
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$236,000**
Total SCG Cost: **$4,971**
Total Co-Funding: **$231,029**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Efficacy of Offline and Online Methodologies to Measure Siloxanes in RNG (MEAS-15-04)

The objective of this project is to determine the precision, accuracy, and sensitivity of the GC-IMS (Ion Mobility Spectroscopy) through the analysis of data from a second field test in partnership with OTD. GTI previously completed laboratory and field testing at a landfill site of the GC-IMS. The project team will further test an online GC-IMS siloxane sensor at a site differing in digester feedstock (such as WWTP) and geographic location from the initial tests to provide a more robust dataset. Following ASTM D8230 Standard Method for the Offline Analysis of Siloxanes in Biogas, periodic grab samples will be taken during the testing period and analyzed at laboratories to compare the online data to offline analytical techniques. Additional renewable natural gas pipeline specifications similar to ones in California are expected to be established. Producers, regulators, and utilities would benefit from validated and standardized measurement methodologies which meet these new, lower specifications. The ability to develop a low cost, low maintenance online analyzer capable of meeting the sensitivity and precision needs of the industry will allow suppliers to ensure near same-time compliance to regulations compared to offline analysis.

Co-Funders: PRCI Members

Start Date: 08/31/2021
End Date: 03/31/2023
Status: Active
2021 Funds Expended: **$14,603**
Total Project Cost: **$118,000**
Total SCG Cost: **$14,603**
Total Co-Funding: **$103,397**
Benefits:

Engine Controller Design Solutions to Address Variable Fuel Consumption of Lead-Burn Engines: Field-based Evaluation (CPS-14-03)

The Project team successfully improved existing Trapped Equivalency Ratio (TER) Air Fuel Ratio Control (AFRC) algorithms for variable fuel composition in lean burn engines, specifically higher levels of ethane as observed in shale gas. The same technique could be used to develop AFRC algorithms for other fuel compositions including renewable natural gas and hydrogen (H2-NG) blends. To validate the TER algorithm, a combustion model was developed using empirical engine data and the GT-Power simulation tool. This model is already being used in new projects looking to reduce unburned methane in engine exhaust, and to determine the implications of burning H2-NG blends. A particularly important finding of this project was the determination that at lower NOx concentrations, the Zeldovich NOx formation model does not account for all the NOx formed in lean burn engines. Further, the existing NOx model struggles in predicting emissions when predominately nitrogen dioxide is present. These findings will support further refinement of the models in predicting NOx emissions. This model refinement can be used to improve AFRC to further reduce NOx and GHG emissions including exhaust methane and optimizing engine efficiency. The model improvement can also be used for hydrogen blend to obtain good combustion control. SoCalGas envisions this work as the precursor to research into blending hydrogen into natural gas.

Co-Funders: PRCI Members

Start Date: 02/28/2018
End Date: 03/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$117,056**
Total SCG Cost: **$30,912**
Total Co-Funding: **$86,144**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Enhance Risk Assessment Tools for Decision Making (9.20.a)

This project was a comprehensive overview of approaches in collecting, normalizing, and utilizing data in machine learning and causal modeling approaches for decision support. The project objective was to develop state-of-the-art data analytics and Bayesian network approaches for assessing and managing complex systems risk. This project applied machine learning, causal modeling, Bayesian networks, and decision science methods to the challenge of data normalization, data analytics, and data synthesis. It established methods to support decision-making processes and situational awareness in the context of infrastructure integrity. The software tool, ANAGRAM (Analytica for Natural Gas Risk Assessment and Management), a decision-support tool, was developed and tested to analyze distribution assets. This tool enables users to explore multiple threats and to simulate millions of possible system outcomes to assess the consequences of risk events and mitigation activities. Decision makers can compare mitigation activities for a collection of assets or assess groups of projects and programs that define complementary or alternative mitigation strategies. In 2021, the project finalized the decision support system with refinements and final documentation from data analyses and engineering systems models to evaluate the cost-effectiveness of different risk mitigation strategies. The final report was sent to project sponsors in December. A wide range of concepts, approaches, and tools is covered in detail to provide a basis for evaluating how to apply the approaches to risk assessment/management efforts.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 01/01/2020
End Date: 01/31/2022
Status: Active
2021 Funds Expended: **$24,000**
Total Project Cost: **$1,739,097**
Total SCG Cost: **$56,567**
Total Co-Funding: **$1,682,530**
Benefits:

Enhancing Strain Capacity of Pipelines Subject to Geohazards (SBD-1-6)

When pipeline segments encounter geohazards that may cause high longitudinal stresses or strains, an engineering critical assessment or risk assessment may be necessary. If pipeline strain capacity is suspected to be inadequate, operators may seek viable options, such as reinforcement of the pipeline segment to withstand the higher stress or strain, especially for girth welds. The objective of this project was to examine the options for enhancing pipeline strain capacity, identify circumstances where these options can be applied, and develop operational procedures to properly apply the options. In Phase 1, the project team performed a full-scale evaluation of the effectiveness of Type B sleeves and weld cap reinforcement to enhance the strain capacity of girth welds. Phase 2 focused on investigating the application of composite repair wrap to reinforce girth weld strain capacity and performing laboratory testing. The project team determined that Type B sleeves are a viable option with no additional requirements beyond current practice needed when the longitudinal stress is below the customary design limit. SoCalGas may use this technique on more modern high-strength piping where the girth weld or the heat-affected zone of the girth weld could be significantly weaker than the pipe. The team published the final report in June 2021.

Co-Funders: PRCI Members

Start Date: 01/31/2018
End Date: 05/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$354,000**
Total SCG Cost: **$14,320**
Total Co-Funding: **$339,680**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Evaluate Higher Strength Consumables for Manual Root Beads in X70 Girth Welds (MATH-5-4)

Start Date: 01/02/2019
End Date: 02/10/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$331,025**
Total SCG Cost: **$8,110**
Total Co-Funding: **$322,915**
Benefits:

Girth weld failures in newly constructed pipelines in North America can be caused by under-matching strength and/or heat-affected zone (HAZ) softening. A contributing factor to under-matching strength is the use of E6010 consumables for the root pass, particularly in thinner materials where the root pass makes up a significant portion of the weld thickness. This project investigated the use of higher strength consumables, E81010 and E7010, for root pass welding to see if undermatching strength could compensate for HAZ softening. Avoiding girth weld failures, either during pre-service hydrostatic testing or soon after the pipeline is placed in service, would have an enormous economic value and prevent negative public perception of natural gas pipelines. The project team conducted weldability tests along with mechanical strength and hardness testing of the welds. The results showed that E7010 and E8010 consumables could replace E6010 for root beads for girth welds on X70 pipes with no susceptibility to cracking. A recommended practice/guideline for using the higher-strength electrodes and a final report were published in January 2021. SoCalGas is evaluating the project findings and performing internal testing of the E7010 and E8010 consumables. Upon completion, SoCalGas will determine whether to create a company-wide procedure and standard for X70 pipe girth welds based on the use of E7010 and E8010 consumables for root beads.

Co-Funders: PRCI Members

Evaluation of Commercially Available On-Line Analyzers for Measurement of Multiple Gas Contaminants (MEAS-9-01)

Start Date: 01/31/2018
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$141,600**
Total SCG Cost: **$15,000**
Total Co-Funding: **$126,600**
Benefits:

The objective of this project is to validate commercially available online analyzers for use by natural gas pipeline operators. The goal is for operators to be able to use a single online analyzer to measure multiple contaminants in the natural gas stream instead of several analyzers each capable of measuring one contaminant. The use of a single analyzer at a biomethane production site to monitor gas quality can save an estimated $50,000 in capital cost and $10,000 per year in operation and maintenance expenses. In Phase 1, commercially available analyzers, each measuring moisture, hydrogen sulfide, and carbon dioxide, were tested with gas mixtures representing both a typical transmission pipeline and an in-house contaminant blend gas. In Phase 2, the laboratory testing results were used to select two analyzers for further testing in a field environment. In February 2021, the two analyzers were installed at the field test site and data collection commenced. The one-year field test of the two models continued through the year and their performance is being compared to the onsite single component measurement instruments to determine the accuracy of measuring all contaminant species. Field testing is scheduled to end in early 2022 when the final data analysis will be completed.

Co-Funders: PRCI Members

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Evaluation of Semi-Automatic FCAW-S Welding Process and Implications to Pipeline Girth Weld Integrity (MAT-1-4)

In this project, members of Pipeline Research Council International (PRCI) seek to develop guidelines for better pipeline welding process control by understanding the impact of welding procedures—such as self-shielded flux-cored arc welding (FCAW-S)—on factors that directly control weld properties. In 2021, the project team identified the mechanisms that are responsible for weld toughness variations and tested changes in weld practices and welding variables. To date, the team has completed three phases of testing, analyzed data, and written final reports. This project is currently in its final phase, with one remaining test to be completed. The project deliverables will provide PRCI member companies with guidance on improving semi-automatic FCAW-S welding practices to optimize weld properties and improve weld reliability in high-strength pipeline construction. This could, in turn, lead to improved pipeline integrity and reduce the cost of pipeline construction and repair.

Co-Funders: PRCI Members

Start Date: 01/01/2016
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$834,968**
Total SCG Cost: **$10,000**
Total Co-Funding: **$824,968**
Benefits:

Expansion of NYSEARCH RANGE Model (M2018-008) – Phase II-a

The objectives of this project are to: 1) improve the ability of the NYSEARCH RANGE model to establish interchangeability boundaries for renewable natural gas (RNG) by characterizing flame lifting; 2) determine appliance performance with hydrogen blends to improve the ability of the RANGE model to establish interchangeability boundaries for Power-to-Gas RNG; and 3) specify a concentration limit for silicon-containing molecules (siloxane) in RNG that will preclude significant performance and maintenance impacts for combustion equipment. The project team completed the RNG flame lifting research through residential appliance burner testing and updated the RANGE model with new correlation coefficients determined through the flame lifting studies. In Phase II-a, the project team investigated a concentration limit for siloxane that will preclude significant performance and maintenance impacts for combustion equipment. To evaluate these impacts, representative residential appliances were selected for testing with a high concentration of siloxane (Round 1). Round 2 testing with a low concentration of siloxane will be performed if performance issues are identified in the Round 1 testing. To close out the project, the team will prepare a final report and a white paper indicating the lower limit of siloxane.

Co-Funders: NYSEARCH Members

Start Date: 09/28/2018
End Date: 04/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$543,869**
Total SCG Cost: **$66,080**
Total Co-Funding: **$477,789**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Fault Displacement Hazard Initiative (UCLA)

The project goals were to develop a suite of robust and reliable models for forecasting the distribution and magnitude of primary and distributed displacements from surface rupture, and to develop guidelines for using the models in engineering applications. Displacements from surface fault rupture can have adverse effects on infrastructure that crosses over or is built on faults. A comprehensive database of fault displacement has been compiled. The database includes 66 earthquakes with magnitudes ranging from 5 to 8. This database is three times larger than the database previously used to estimate fault displacement. Increasing the size of the database allows for more robust statistical analysis of the data for fault displacement estimates to be performed. Results of this research can be integrated into a risk assessment model and provide a method to calculate the risk of pipeline rupture during a seismic event. This project fed into other research co-funded by the California Energy Commission.

Co-Funders: Other Project Sponsors

Start Date: 11/20/2018
End Date: 08/03/2021
Status: Completed
2021 Funds Expended: **$25,000**
Total Project Cost: **$2,415,000**
Total SCG Cost: **$150,000**
Total Co-Funding: **$2,265,000**
Benefits:

Field Manual for Spacing Between Pipelines and AC Grounding Equipment (EC-6-8)

Alternating current (AC) grounding systems for electrical transmission lines have the potential of arcing to nearby natural gas (NG) pipelines where the utilities share a right-of-way. This has long been a common concern between the pipeline industry and electrical utilities. The goal of this project is to develop a field manual that will provide guidance on the minimum safe distances between NG transmission pipelines and AC grounding systems without having to perform a time-consuming and costly grounding study to eliminate arcing. The project includes performing testing, validating test methods, and developing and validating a model with laboratory testing. To date, the project team has completed construction of the soil containment test enclosures for impulse testing of arc sustainment from AC source through different soil types and conditions. The next step is to develop arc models with different types of soil based on the results of wide-scale testing. The results of this project will improve the safety and reliability of the pipeline system as well as electrical transmission lines by placing a safe distance between the two.

Co-Funders: PRCI Members

Start Date: 01/31/2017
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$118,000**
Total SCG Cost: **$9,759**
Total Co-Funding: **$108,241**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Field Test NeverWet & Other Nano-Tech Coatings to Reduce Aboveground Corrosion (5.17.p)

This project investigates unique and promising coatings for challenging aboveground utility corrosion prevention applications. Corrosion is an ongoing threat to the integrity of metallic utility assets. For aboveground assets, one cannot rely on cathodic protection to back up coating protection. Therefore, specifying and applying the most appropriate and best-performing coating system is even more important. The unique and promising coatings that are available in the market have the potential to substantially reduce wet and dry aboveground corrosion in a wide variety of applications. Unfortunately, the NeverWet technology was discontinued, so it could not be included in the field trials. Field testing continues with three coatings being applied per the field test protocol. The project is in the planned "field exposure" phase, with the coatings logging time at their respective application sites. The plan was for the field test to include four seasons of exposure and then to assess performance. Due to COVID-19 restrictions, the field trial was extended. The extra time of exposure will benefit the meaningfulness of the assessments. To date, the applied systems continue to age in the field.

Co-Funders: OTD Members

Start Date: 09/06/2017
End Date: 03/31/2023
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$187,000**
Total SCG Cost: **$1,347**
Total Co-Funding: **$185,653**
Benefits:

Flow Testing of FS500 Meters (MEAS-6-11A)

The goal of this project was to ensure that SICK 4-inch and 6-inch FS500 ultrasonic meters can be installed in an existing meter run pipework without requiring AGA 9 20D upstream piping or flow conditioner. This research expanded the dataset previously collected from the SICK 2-inch and 3-inch FS500 ultrasonic meters to include results for 4-inch and 6-inch meters. Additionally, this research examined the effects of the location of the pressure and temperature measurements used for determining the standard flowrate. The FS500 ultrasonic flow meter has been identified as a replacement for low-pressure rotary meters. This technology addresses significant maintenance and reliability issues associated with all sizes of rotary meters and with 4" and 6" turbine meters. Experimental testing and data analysis were conducted in 2021. The final report was approved by the Project Team and published for purchase in June 2021. Test results confirmed that FS500 meters can be installed directly in place of rotary meters without any reduction in accuracy. Research successfully demonstrated that meter diagnostics can be used to confirm whether the meter is maintaining +/- 1.0% accuracy. Unlike the rotary meter, the FS500 does not block flow on failure, and the cartridge can be replaced in the field without removing the body.

Co-Funders: PRCI Members

Start Date: 07/27/2020
End Date: 07/19/2021
Status: Completed
2021 Funds Expended: **$8,728**
Total Project Cost: **$118,468**
Total SCG Cost: **$22,968**
Total Co-Funding: **$95,500**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Full-Scale Surface Loading Testing of Buried Pipes Vibratory Compactor and Temporary Crossing (ENV-6-2)

The goal of this project was to develop surface loading (SL) criteria for pressurized pipelines with a shallow burial depth that are subjected to dynamic surface loading from vibratory compaction vehicles (VCVs) moving over a variety of temporary crossing configurations. The project team first validated non-vibratory SL results from an earlier Phase 1 project. The project team then conducted full-scale SL testing using the same pipes at the same location as in Phase 1 (ENV-6-1) and with four different vehicle types, including one VCV. Temporary crossing configurations included wooden ground mats, mat bridges, and steel plates. The team compared the results to stresses calculated using the Canadian Energy Pipeline Association (CEPA) SL Calculator. Matting reduced induced stress on the buried pipe but was inconsistent. The team observed peak stress reduction on the pipes using mat bridges with increased support spacing and greater support area. Induced stress in buried pipe was lower using sand backfill than with clay backfill. The study showed that circumferential stress of pipes decreased by an average of 39% when pressure was introduced into unpressurized pipe. The data showed that the pipe-induced stresses from the tests using a VCV with vibration "ON" nearly doubled compared to vibration "OFF." Data also showed that the basic assumptions of the CEPA Calculator were mostly conservative but underpredicted the stresses in a few cases. The team published the final report in June 2021. SoCalGas will use the findings of this project to estimate stresses on shallow piping under vehicle loading, including from vibratory compactors.

Co-Funders: PRCI Members

Start Date: 02/28/2018
End Date: 06/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$147,995**
Total SCG Cost: **$9,899**
Total Co-Funding: **$138,096**
Benefits:

Gas Composition and Quality

This project comprises two parts. First, because renewable natural gas (RNG) from non-conventional sources contains trace constituents that impact pipeline integrity and combustion equipment performance, SoCalGas evaluated whether an on-line or mobile analyzer is needed to continuously measure the trace constituents in biomethane supplies. Currently, spot testing is conducted for Rule 45 with annual, biennial, or quarterly periodicity depending on whether the results are above the limit. Due to the pandemic and limited customer operations, testing at only one RNG receipt point was performed. The results indicate that monitoring during start-up may be warranted, but more study is needed due to the limited sample size. Second, the HYREADY joint industry project (JIP) Program will deliver practical guidelines to support system operators in preparing networks and connected end users for adding hydrogen to natural gas at acceptable risk levels. HYREADY JIP has developed engineering guidelines for preparing natural gas systems with hydrogen/natural-gas mixtures for transmission and distribution systems, end-use appliances, and compressors. In 2021, the project team completed work packages for 1) subsurface storage, which covered capacity, operation, and gas conversion processes, the three aspects of storing hydrogen in natural gas underground storage; and 2) hydrogen injection facility design, which established the minimum requirements for components and materials. In 2022, the HYREADY JIP will continue preparing new guidelines for hydrogen separation and 100% hydrogen distribution networks.

Co-Funders: N/A

Start Date: 01/01/2017
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$4,728**
Total Project Cost: **$175,000**
Total SCG Cost: **$175,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Gas Machinery Research Council (GMRC)

With more than 78 member organizations, Gas Machinery Research Council (GMRC) is a community of natural gas companies dedicated to investigating technical issues within the rapidly evolving gas machinery industry and uncovering innovative solutions that improve the reliability, efficiency, and cost-effectiveness of mechanical and fluid systems. GMRC provides members and industry an opportunity to exchange information and ideas and participate in applied research and technology programs. GMRC accepts proposals relevant to current issues facing the gas machinery industry and seeks to improve the quality and efficiency of pipeline facilities and gas compressor stations. In 2021, GMRC active projects included: Dry Gas Seal Reliability (Phase 4), Virtual Orifice Performance Evaluation, Improvements in Elemental Sulfur Test Methods for Natural Gas, Hydrogen Blending Impacts on Compressor Stations (in partnership with Pipeline Research Council International), Hydrogen Impacts on O-Rings, and Improvements to National Institute of Standards and Technology - Reference Fluid Thermodynamic and Transport Properties Database (RefProp) and Water-Hydrocarbon Vapor Liquid Equilibrium Prediction (Phase 2). Three projects were completed in 2021 and results shared with members.

Co-Funders: GMRC Members

Start Date: 01/01/2019
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$4,160**
Total Project Cost: **$1,464,000**
Total SCG Cost: **$20,160**
Total Co-Funding: **$1,443,840**
Benefits:

Guidance on the Use, Specification and Anomaly Assessment of Modern Line Pipes (MATH-5-3B)

Girth weld incidents—such as leaks and ruptures—have occurred during hydrostatic proof tests and in-service of newly constructed pipelines in recent years. This project developed processes and procedures to assess the risk of similar girth weld incidents in in-service pipelines. These processes and procedures will enable the effective use of resources for mitigation when needed. They will also enable the development of recommendations to minimize the risk of girth weld incidents for near-term construction projects and future pipelines. The improved line pipe specifications and welding practices should lead to strain-resistant girth welds and pipelines resistant to anomalies, such as corrosion and mechanical damage. The project team has completed all guidelines and is writing the final report.

Co-Funders: PRCI Members

Start Date: 01/31/2018
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$5,667**
Total Project Cost: **$743,402**
Total SCG Cost: **$20,292**
Total Co-Funding: **$723,110**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

HAZ Softening Susceptibility Test Development (MATH-5-3C)

Unexpected girth weld failures can occur in newly constructed pipelines, with time elapsed from construction to rupture ranging from a few weeks to a few years. Most failures occur in-service and some during preservice hydrostatic testing. Heat-affected zone (HAZ) softening is one of the contributing factors. Failure is caused by the loss of the mechanical strength (softening) of the pipe around the weld that produces the HAZ where the base metal experiences thermal cycling. HAZ softening occurs in low-carbon or carbon-equivalent steels. This project's objective was to develop a test for the susceptibility of low-carbon steel in the HAZ of a weld. The test characterizes the loss of mechanical strength in the HAZ of the base metals. The project also developed welding procedures that might prevent HAZ softening. The project results will lead to safer pipeline design through better material selection, and pipeline repairs that use welding. The team completed all activities in the second quarter of 2021 and is currently drafting the final report. This project will improve pipeline integrity and safety by helping to avoid pipeline failures related to loss of mechanical strength in HAZ areas of pipeline welds.

Co-Funders: PRCI Members

Start Date: 07/24/2020
End Date: 07/24/2022
Status: Active
2021 Funds Expended: **$2,400**
Total Project Cost: **$218,300**
Total SCG Cost: **$7,400**
Total Co-Funding: **$210,900**
Benefits:

Hot Tap Branch Connections, JIP

Hot tap branch connections have long been an important aspect of pipeline and piping system operations. The objectives of this joint industry project (JIP) are to develop industry best practices for welding stub-on branch connections onto live gas mains (i.e., hot tap), and to provide a guideline that enables the least-complicated procedure to be selected for a given application. The development and use of industry best practices for specifying and installing hot tap branch connections will reduce costs and increase safety and reliability. Previously, the team completed a report on in-service failures and guidance on fitting types and weld spacing. In 2021, the team completed guidance for sleeve landing on corrosion, including how to qualify this and when it is permitted. Procedures for Canadian Standards Association compliant welding were also developed. The results of this JIP may help identify instances where in-service welding may be acceptable and where it should be prohibited. This will allow significant economic and environmental benefits to be realized. Next steps are to continue developing guidance documents and welding procedures.

Co-Funders: JIP Members

Start Date: 12/16/2019
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,050,000**
Total SCG Cost: **$30,000**
Total Co-Funding: **$1,020,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

HyBlend Collaborative Research Partnership (5.21.k)

Start Date: 09/01/2021
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$25,000**
Total Project Cost: **$15,050,000**
Total SCG Cost: **$50,000**
Total Co-Funding: **$15,000,000**
Benefits:

Begun in August 2021, the HyBlend Project is a joint effort of national labs, natural gas operators, and research consortia to evaluate technical and economic considerations associated with transporting hydrogen blends and other low-carbon fuels using existing gas infrastructure. The project team is addressing many topics related to hydrogen blending, including hydrogen compatibility with metals and polymers, life cycle analysis, techno-economic analysis, and building equipment. Five national labs will lead the research. Sandia National Laboratory will lead development of general pipeline integrity guidance for operating natural gas transmission and distribution systems with hydrogen blends by assessing the role of these blends in the degradation of metal pipelines. Pacific Northwest National Laboratory will lead the assessment of hydrogen blends on the degradation of polymer pipelines and material lifespan. Argonne National Laboratory will lead the life cycle analysis of technology pathways for hydrogen blends. The National Renewable Energy Laboratory will lead the quantification of costs and opportunities for hydrogen production and blending within the natural gas system. Oak Ridge National Laboratory will lead the evaluation of residential, commercial, and industrial end uses with hydrogen blends, assessing safety, emissions, reliability, and energy efficiency. In 2021, the team began establishing test conditions and materials and working on a literature review of global research and experience in operating natural gas pipeline systems with hydrogen blends. The team will publish a compilation of reports and white papers at project completion. SoCalGas will use these results to support the development of a hydrogen blending standard and to guide future research.

Co-Funders: OTD Members, DOE, NREL

Hydrogen Blend into Natural Gas – Phase 2: Metallic Materials (6.14.b.2)

Start Date: 04/15/2019
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$240,000**
Total SCG Cost: **$53,760**
Total Co-Funding: **$186,240**
Benefits:

Hydrogen is considered an important energy carrier in the future for sustainable, reliable, and cost-effective energy. The project objective is to conduct physical testing to assess the impacts of 5% hydrogen-blended fuel on metallic materials in the natural gas pipeline system. The project will also develop engineering tools to support performing integrity assessments and determining safety margins for hydrogen blended gas use. The project tasks include a literature review, establishing the use cases of hydrogen blending, selecting and obtaining vintage materials for physical testing, and developing a test matrix and modeling plan to be used for Phase 3. In 2021, a preliminary draft of the literature review was provided to sponsors for review. It includes references to studies documenting hydrogen embrittlement in metals and journal articles and research studies from the last 20 years. The Design of Experiment was started but was put on hold to allow for coordination with other major hydrogen blend efforts – HyBlend and Low Carbon Resource Initiative – to leverage results generated under other projects and prevent duplication of efforts. The next steps are to finalize the literature review and establish the tests and pipe samples needed.

Co-Funders: OTD Members

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Hydrogen Blending Impact on Aldyl-A and HDPE Pipes (5.21.j)

This project will develop a lifetime-prediction model and an associated risk model for Aldyl-A and vintage High Density Polyethylene (HDPE) pipes pressurized with a blend of natural gas and hydrogen. SoCalGas is interested in understanding how the interaction between hydrogen and chemical additives in the resin could lead to chemical degradation and lower resistance to slow crack growth. It is also of interest to understand the physical interaction of hydrogen and materials at the crack tip of micro-fractures leading to accelerated crack growth. It is crucial to understand the impact of hydrogen blends on the existing PE infrastructure to maintain the integrity and safety of gas distribution pipelines. Risk impact due to hydrogen blending must be quantified so operating procedures and associated budgets can be adjusted accordingly. Long-term strength tests, tensile tests, and several material tests will be performed to observe the behavior of the material to the hydrogen/natural gas blend and to develop the lifetime-prediction and risk models. Aldyl-A Pipe samples have been collected and the Oxidation Induction Time and Cross-Polarized Light Microscopy tests are being performed. Construction of the testing apparatus for the Long-Term Hydrostatic Strength tests has been delayed due to supply chain issues with an estimated completion date of early 2022. Once the testing is completed for the Aldyl-A vintage pipe, testing will begin for the HDPE pipe.

Co-Funders: OTD Members

Start Date: 04/08/2021
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$378,646**
Total Project Cost: **$867,800**
Total SCG Cost: **$408,646**
Total Co-Funding: **$459,154**
Benefits:

Hydrogen Embrittlement and Crack Growth (Phase 1a, 1b, 2) and Microstructural Characterization of Steel Pipe

The project objective is to characterize the Fatigue Crack Growth Rate (FCGR) behavior of different grades of steel pipe in a range of hydrogen-natural gas blends. The FCGR will be determined for base metals, longitudinal seam welds, and girth welds at both weld center line and Heat-Affected Zone (HAZ). Each phase or subphase will test one pipe grade: Phase 1a (X70), Phase 1b (X52 and X65), and Phase 2 (vintage X42 and X52). In 2021, Phase 1a was completed. The results showed that the FCGR was accelerated for the various microstructures in the environments (i.e., hydrogen blends) caused by hydrogen embrittlement mechanisms. This led to expanding the scope to include testing for microstructural characterization since defects in microstructure strongly influence crack initiation processes. The complementary microscopy study will be performed for new API X65 steel samples. SoCalGas will use this knowledge to understand the effects of hydrogen embrittlement on steel pipe, and to direct additional research. The testing of Phase 1b is in process. The new X52 testing baseline results of the base metal are showing similar trends as X70 and X65 pipe. Testing continues with an estimated completion for testing of all pipe grades in the fourth quarter of 2022.

Co-Funders: N/A

Start Date: 11/01/2019
End Date: 11/30/2022
Status: Active
2021 Funds Expended: **$394,636**
Total Project Cost: **$1,096,160**
Total SCG Cost: **$1,096,160**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Identification and Development of an Analyzer for Siloxane Measurement (M2018-010) Ph II

Start Date: 01/31/2021
End Date: 08/01/2022
Status: Active
2021 Funds Expended: **$28,940**
Total Project Cost: **$256,203**
Total SCG Cost: **$28,940**
Total Co-Funding: **$227,263**
Benefits:

Siloxanes are man-made organic compounds that contain silicon, oxygen, and methyl groups. Silicon compounds are commonly found in personal hygiene, health care, and industrial products leading to the formation of siloxane in biomethane produced from anaerobic digestion of waste from landfills and wastewater treatment plants. Combustion of renewable natural gas (RNG) containing siloxanes produces a silica deposit on downstream surfaces that can impact the safety and reliability of appliances and efficiency of industrial equipment. Phase I of this project evaluated analyzers in the laboratory and the field. The Phase II objective is to identify a suitable portable technology that can measure low levels of siloxane concentrations (~0.1 mg Si/m3) and test the instrument in a wide range of applications. These tests will develop data and information on the presence of siloxanes in RNG that could be used to develop a standard on acceptable siloxane levels. In 2021, five analyzers were selected and testing began for accuracy and reproducibility using the new American Society for Testing and Materials standard. An interim report of the results will help funders determine the analyzer(s) to be evaluated through field testing.

Co-Funders: NYSEARCH Members

Impact of Blended H2 on Threaded Connections (M2021-007)

Start Date: 08/09/2021
End Date: 03/31/2023
Status: Active
2021 Funds Expended: **$19,011**
Total Project Cost: **$213,092**
Total SCG Cost: **$19,011**
Total Co-Funding: **$194,081**
Benefits:

The objective of this project is to determine if hydrogen blends in natural gas cause any change in 1) the presence or absence of leaks and 2) the leak flow rate for threaded connections. This project consists of four tasks involving threaded connections that conform to National Pipe Thread (NPT) standards. In Task 1, the team is developing test protocols and determining the test sample size. Tasks 2 and 3 includes tests to determine the change in a leak or leak flow rate with a 20% hydrogen blend. In Task 4, the project team will determine the impact of various pipe dope and sealants and if hydrogen blends influence this variable. The team will also perform tests on non-NPT threaded connections. The project kicked off in October 2021 establishing procedures for creating threaded connection leaks and methods to measure leak flow rates with hydrogen blends. SoCalGas will use these data to support the determination of a hydrogen blend limit for natural gas distribution systems that will contribute to a statewide hydrogen injection standard.

Co-Funders: NYSEARCH Members

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Impact of Hoop Stress and Percentage of SMYS on Pipelines (4.20.a)

This project developed a set of criteria for use by operators and regulators for systems governed by U.S. Department of Transportation regulations DOT/PHMSA 49CFR Part 192 Subpart O and Subpart P. Today, these groups rely on industry-accepted stress ratios to ensure that pipeline segment operating stress, due to internal pressure, never exceeds a defined fraction of the specified minimum yield stress—the SMYS. This practice ensures that pipelines behave elastically without permanent deformation. In this project, researchers sought to improve on this methodology by introducing a failure pressure ratio defined as the Operating Pressure (P) / Failure Pressure (Pf). The project included a review of regulations, a literature search, and compilation and review of National Transportation Safety Board and Pipeline and Hazardous Materials Safety Administration (PHMSA) incident data for natural gas transmission and hazardous liquid pipelines from 1970 to 2019. Researchers then developed a model that enabled them to calculate failure and boundary values, define failure mode categories, and, ultimately, create an Excel-based calculator that could calculate failure mode category from pipe attributes and defect geometry. Finally, the researchers developed a set of safety factors to apply to pipelines operating from low to high stress (e.g., 0% to 40% SMYS) and guidelines on how to assess leaks and ruptures within the context of the framework. The new method predicted failure better than other methods currently employed in assessing risk consequences from pipeline failures. The final report was published in March 2021. PHMSA is working with Operations Technology Development to explore related changes in regulation.

Co-Funders: OTD Members, PHMSA

Start Date:	10/21/2019
End Date:	05/26/2021
Status:	Completed
2021 Funds Expended:	**$0**
Total Project Cost:	**$551,902**
Total SCG Cost:	**$10,000**
Total Co-Funding:	**$541,902**
Benefits:	

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Impact of Hydrogen/Natural Gas Blends on LDC Infrastructure Integrity (M2020-002 Ph I, II)

The objective of this project is to determine if blending hydrogen into natural gas will change the physical properties of elastomers in a natural gas delivery system, the most common of which are styrene-butadiene rubber (SBR) and acrylonitrile butadiene rubber (NBR). Both are used as seals in compression applications and as gaskets for flanges in joining pipes and fittings. The lack of data on the effect of hydrogen concentrations in hydrogen/natural gas blends on elastomers in a natural gas infrastructure (e.g., piping, piping components, and appurtenances) may impact the safety and reliability of the gas delivery system. In Phase 1, the team performed exploratory tests using a limited set of test gas mixtures. Phase 2 will involve further tests on field-extracted and virgin materials using an expanded set of test gases. The team completed Phase 1 in April 2021 with a preliminary assessment of the impact of varying hydrogen concentrations in methane/hydrogen blends on the mechanical and physical properties of SBR and NBR elastomers in common use as coupling materials used to join metal pipes. Results from Phase 1 found that unrestrained SBR cubes exhibited a change during creep tests with a dimensional change and a reduction in elasticity. Phase 2 will leverage findings from Phase 1 and test new and vintage materials with a wide range of hydrogen blends (up to 20%), pressures, and temperatures. To date, the team has completed stress relaxation analysis for NBR and SBR materials at 5% hydrogen. The next step is to evaluate 20% hydrogen blends and constant load performance. This project will help determine if and how hydrogen blends will affect the physical properties of typical elastomers and the hydrogen blend level that the existing natural gas system can tolerate.

Co-Funders: NYSEARCH Members

Start Date: 06/30/2020
End Date: 06/30/2023
Status: Active
2021 Funds Expended: **$30,941**
Total Project Cost: **$563,825**
Total SCG Cost: **$43,475**
Total Co-Funding: **$520,350**
Benefits:

Impact of Trace Constituents on Odor Masking (7.21.c)

Natural gas contains numerous chemicals that are removed at gas processing plants prior to injection into the natural gas pipeline system. After treatment, trace amounts of these chemicals still exist in the processed gas. Some of these chemicals may act as odor-masking agents, preventing people from smelling gas leaks. The objective of this study is to identify trace constituents that act as odor masking agents. The results of the study will be used by industry to determine how to mitigate the masking effect of masking agents. The effort will lead to safer gas operations for utility workers and their customers. In early 2021, an odor masking test method was developed to test seven masking agents commonly found from gas processing plants. Testing was completed, and the results are being analyzed to determine if masking effects occurred and, if so, which trace constituent is of concern.

Co-Funders: OTD Members

Start Date: 03/01/2021
End Date: 03/01/2022
Status: Active
2021 Funds Expended: **$15,000**
Total Project Cost: **$150,000**
Total SCG Cost: **$17,578**
Total Co-Funding: **$132,422**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Implementing API 5L RP 5MT, "Pipeline Inspection Documents for Material Traceability and Electronic Test Reports" (8.22.c)

American Petroleum Institute (API) Standard 5L is the standard for transmission pipes used in the natural gas and petroleum industries. This standard governs specifications for seamless and welded steel pipes of different grades. These specifications are validated with tests, and the results are published in a specification report for each type of steel and grade. Suppliers currently provide their reports in paper form. The goal of this project is to develop an electronic form of the report for manufacturers to use. The team will develop a digital template to make the report available to customers electronically. A common standard for electronic reports streamlines industry efforts. The project will also develop a method for verification that the report is from the manufacturer of the pipe. This will improve traceability by providing an electronic signature that ties the test report directly to the manufacturer.

Co-Funders: OTD Members

Start Date: 12/14/2021
End Date: 06/30/2023
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$255,000**
Total SCG Cost: **$13,831**
Total Co-Funding: **$241,169**
Benefits:

Integrity Impact of HAZ Softening on Type-B Sleeves and Hot Tap on Modern Steel (SBD-1-6A)

Heat-Affected Zone (HAZ) softening occurs in girth welds on pipelines. The HAZ area loses mechanical strength which creates a mismatch between mechanical properties of the pipe and the HAZ. Girth welds are not only used in pipeline construction but are also used in some pipeline repairs. Type-B sleeves are one such repair type. The sleeve is welded to the pipeline to repair leaks and damaged section of the pipeline. HAZ also occurs in another repair method, hot taps. This project investigates HAZ softening in Type-B sleeves and hot taps in pipeline repairs. Tests will be performed to test different welding and installation procedures to minimize the loss of mechanical strength in HAZ. A final report will be delivered with recommended welding and installation procedures for using Type-B sleeves and hot taps. This project will enhance pipeline integrity by minimizing pipeline failures.

Co-Funders: PRCI Members

Start Date: 10/13/2021
End Date: 10/13/2023
Status: Active
2021 Funds Expended: **$13,587**
Total Project Cost: **$177,000**
Total SCG Cost: **$13,587**
Total Co-Funding: **$163,413**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Investigate CLSM to Manage Axial Soil Loads on Buried Pipelines

Ground displacements may produce pipeline strains well in excess of the levels produced under normal operating conditions. These excess loads are caused by movement of the pipe relative to the soil, as the pipe restricts the movement of the soil. The project's objective is to investigate the use of controlled low-strength material (CLSM) placed around a pipeline to reduce the axial loads caused by soil friction, and to avoid transferring these large axial loads to vulnerable in-line pipeline components, such as elbows, tees, and service connections. The use of CLSM could significantly reduce the need for costly mitigative measures to repair or replace damaged sections of pipeline due to ground displacement events. This project will investigate the effectiveness of using CLMS to prevent pipeline damage from soil friction loads. The project was delayed due to the pandemic. In 2021, the project team began compressions and axial testing, and completed the final pour of concrete/pipe test specimens. In 2022, the team will complete full-scale pull-out tests in the soil box.

Co-Funders: PG&E

Start Date: 09/01/2020
End Date: 04/30/2022
Status: Active
2021 Funds Expended: **$19,950**
Total Project Cost: **$110,000**
Total SCG Cost: **$55,000**
Total Co-Funding: **$55,000**
Benefits:

Kiefner Interactive Threats Project (T-768)

Federal Regulation 49 CFR 192 Subpart O and supporting standards provide guidance for identifying and assessing individual threats to natural gas pipeline integrity. Although this standard specifically mentions that threat interactions should be addressed, limited industry knowledge on the interactions of various threats and how they influence the overall risk of a pipe segment hindered this work. The goal of this project was to develop risk models that performed a systematic review—using U.S. Department of Transportation reportable incident data and Kiefner's In-House Failure database—of threats that may impact pipeline integrity. The review identified threats that could potentially interact with natural gas pipelines and under what circumstances. The project also quantified the increased likelihood or probability of failure attributable to the interaction of threats and provided a software tool to calculate this increased likelihood. The tool, NYSEARCH/Kiefner Interacting Threats Model (NK-ITM), is an Excel-based application that refines the data to focus on failures on pipe and pipeline components in natural gas systems and features the ability to calculate this increased likelihood. The final version of the report and risk assessment tool incorporates data for new interacting threat incidents occurring in 2019 from the Pipeline and Hazardous Materials Safety Administration database. The project team determined the normalized frequency of failure of more prevalent threat incidents and incorporated them into the algorithm. SoCalGas plans to leverage the NK-ITM updated algorithms and data into its threat evaluation process to improve pipeline safety and reliability.

Co-Funders: NYSEARCH Members

Start Date: 11/30/2015
End Date: 06/01/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$264,837**
Total SCG Cost: **$20,740**
Total Co-Funding: **$244,097**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Living Lab for Hydrogen (M2021-008)

The goal of this project is to analyze and report data on the impacts of hydrogen blending at higher percentages (i.e., greater than 20 vol%) by evaluating safety, maintenance, and emergency response changes on gas distribution infrastructure and appliances. This is a SoCalGas project co-funded by NYSEARCH. The Living Lab demonstration aims to validate the feasibility of blending and injecting 20% or more hydrogen by volume into the existing natural gas infrastructure by simulating system operations with steel and plastic pipelines, a pressure regulator station, a compressor, and various end-use equipment. This project will yield valuable data on impacts to pipeline integrity, measurement, regulation, end-use equipment, and safety and maintenance procedures.

Co-Funders: NYSEARCH Members

Start Date: 12/13/2021
End Date: 06/28/2024
Status: Active
2021 Funds Expended: **$47,667**
Total Project Cost: **$1,222,402**
Total SCG Cost: **$300,000**
Total Co-Funding: **$922,402**
Benefits:

MAOP and Materials Verification – Phase I (4.17.d)

The objective of this project is to provide a software solution to assist operators in compliance with pending maximum allowable operating pressure (MAOP) and materials verification requirements which are part of the Notice of Proposed Rulemaking Integrity Verification Process. This includes enabling the use of Engineering Critical Assessments (ECA) in lieu of a hydrotest, derating, or pipe replacement. It will also support pipe surface-based non-destructive measurements in lieu of cutouts and minimize the number of destructive tests. In 2021, the team developed a set of closed form model solutions for the ASME B31G-modified (wall loss defects) and the Maxey-Folias Leak-Rupture Boundary model. These were shared with the specified maximum yield stress Boundary Project. Work continued to design and develop a modules-based approach for an ECA tools framework. Each delivered module will include a short description of the module, a flowchart that outlines the steps to execute the module, a checklist, and a Windows-based executable (.exe) file for pipeline data entry. The next steps are to continue the development of additional modules, written descriptions, and checklists that support the ECA framework build-out and work on the Final Report.

Co-Funders: OTD Members

Start Date: 09/08/2017
End Date: 08/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$96,000**
Total SCG Cost: **$4,364**
Total Co-Funding: **$91,636**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Material – Suppliers Quality Assurance Program (5.17.g)

The objective of this project is to develop and manage material supplier quality assurance programs. Natural gas utilities are required by Federal and State regulatory agencies (regulators) to implement integrity programs that focus on risk assessment of their systems including purchased material. These regulators hold gas utilities responsible for the quality of the materials installed. The manufacturers producing materials for the industry, however, are not under the same level of scrutiny or regulatory oversight. This project identified and collected comprehensive regulatory and technical requirements specific to products used in natural gas transmission and distribution systems. Under this program, a material supplier quality manual was developed which includes several requirements and procedures designed to aid utilities in receiving quality materials from suppliers. As part of this project, 22 generic material specifications and nine quality procedures were created.

Co-Funders: OTD Members

Start Date: 12/01/2018
End Date: 06/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$431,000**
Total SCG Cost: **$5,000**
Total Co-Funding: **$426,000**
Benefits:

NDE Material Strength Verification for an Index of Long Seam Fracture Toughness of ERW Pipes JIP (MMT)

The Gas Pipeline Advisory Committee and Pipeline and Hazardous Materials Safety Administration have announced that greater verification of material strength will be required in new gas transmission rules. This project was part of a Joint Industry Program (JIP) to develop a nondestructive method to identify the seam type and Charpy toughness of the longitudinal seam on electric-resistance-welded (ERW) pipe joints. This advanced the JIP pipeline material strength verification process and expanded the validation of the Hardness, Strength, and Ductility (HSD) tester for ERW pipes. The nondestructive evaluation (NDE) was based on the HSD Tester, a portable instrument that performs frictional sliding experiments to assess hardness variations and pipe body strength properties. The JIP added strategic value to the process of evaluating the steel grade and quality of existing assets by obtaining tighter confidence intervals from nondestructive testing of the HSD tester. Nondestructive data and conventional destructive lab data for 67 pipe joints, including 65 ERW samples, were reported. In 2021, an additional 14 pipe joints underwent nondestructive and destructive testing. For the HSD testing, the project also completed five testing service projects for SoCalGas totaling 17 samples. A supplemental report was completed summarizing the results. As part of our Gas Safety Transmission Rule (Title 49 CFR 192.607), SoCalGas will leverage the NDE technologies for our materials verification program.

Co-Funders: JIP Members

Start Date: 01/01/2019
End Date: 03/22/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$400,000**
Total SCG Cost: **$50,000**
Total Co-Funding: **$350,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Odor Detection Study for Blended Hydrogen (M2021-005)

Federal regulations require odorant injection into natural gas to provide a first line of defense for consumers to detect natural gas leaks. As utilities transition to new fuels such as hydrogen, there is a lack of data and information on the compatibility of odorants in blended hydrogen with natural gas. This study will investigate several natural gas odorants for detectability and recognizability when hydrogen, at various concentrations, is present. SoCalGas will use the results to adjust odorants in hydrogen to maintain the ability of consumers to detect gas leaks.

Co-Funders: NYSEARCH Members

Start Date: 07/29/2021
End Date: 07/29/2022
Status: Active
2021 Funds Expended: **$21,835**
Total Project Cost: **$294,755**
Total SCG Cost: **$21,835**
Total Co-Funding: **$272,920**
Benefits:

Odor Detection Threshold Study – Phase II, Tasks 1 & 2 (M2016-002)

This project is a continuation of the natural gas odor detection threshold study and uses the odorant thresholds of human detection levels determined in Phase I. The focus of this phase is on understanding how the introduction of conditional factors such as odor adaptation and odor-masking agents affect detection and recognition thresholds of human senses. The two phenomena will be studied in parallel, but the results will be provided independently to better understand the effect of each variable. This study has the potential to inform decision making regarding odorization of natural gas. The contractor has completed the odor adaptation task of the project. The odor-masking effects on odorants by masking agents such as Limonene and Ammonia were delayed in early 2021 due to impacts of the ongoing COVID-19 pandemic It is now proceeding and preliminary thresholds for Limonene were established in the fourth quarter of 2021. The study on the impacts of Ammonia will follow at the conclusion of the Limonene study.

Co-Funders: NYSEARCH Members

Start Date: 11/16/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$468,950**
Total SCG Cost: **$48,100**
Total Co-Funding: **$420,850**
Benefits:

On-Line Biomethane Gas Quality Monitoring – Phase 2, Trace Sensors (7.16.e.2)

The objective of Phase 2 was to validate the market-ready analyzers ranked as most promising in Phase 1 for monitoring unconventional trace constituents (e.g., siloxanes, volatile organic compounds, sulfur, and hydrocarbons). These trace constituents are sometimes found in biomethane if cleanup technologies fail. The project team focused on constituents that are not routinely monitored by on-line instruments but that are critical to gas quality. The validation methodology included preparing artificial biomethane samples with known quantities of trace constituents for analyzer manufacturers to test. Four analyzer manufacturers participated, and each provided their test results, a feasibility assessment, and a proposed product development pathway. Two analyzers were identified as options for Phase 3 which will further develop the analyzer.

Co-Funders: OTD Members

Start Date: 03/01/2018
End Date: 10/01/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$125,000**
Total SCG Cost: **$2,890**
Total Co-Funding: **$122,110**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

On-Line Biomethane Gas Quality Monitoring Ph III (7.16.e.3)

In past phases of this project, validation testing on several on-line biomethane analyzers were performed to identify which would have the potential to detect unconventional trace constituents. Two analyzers were proposed for consideration for further development under Phase III. The goal of Phase III is to perform product development on the selected analyzer and to test the modified analyzer to validate the monitoring of the unconventional trace contaminants. These trace constituents are sometimes found in biomethane if cleanup technologies fail. These unconventional trace constituents are not routinely monitored by on-line instruments but are critical to gas quality. Utilities need technologies to provide real-time gas quality data for these trace constituents. In this phase, the analyzer manufacturer will work to modify their system to incorporate changes identified in Phase II with the goal of commercializing the analyzer. The newly developed on-line analyzer will be tested with continuous gas streams compared to laboratory measurements following standard methods to evaluate precision, accuracy, and operational experience. The deliverable will be a market-ready analyzer, available for field tests, which can monitor the predominant species of ethylbenzene, toluene, siloxanes, organic arsenics, halogenated hydrocarbons, and n-nitroso-di-n-propylamine. Once available, this analyzer could be installed at locations where there is a potential for trace constituents above the limits. The project kick-off meeting was held in November 2021, and sponsors discussed which analyzer should be developed further after reviewing data on cost and maintainability. The next step is to finalize the analyzer selection.

Co-Funders: OTD Members

Start Date: 08/01/2021
End Date: 03/31/2023
Status: Active
2021 Funds Expended: **$39,000**
Total Project Cost: **$267,000**
Total SCG Cost: **$56,439**
Total Co-Funding: **$210,561**
Benefits:

Optimize the Detection and Mitigation of Mechanical Damage (SRP-MD-01)

Detecting and mitigating mechanical damage to pipeline infrastructure is a major concern to the natural gas industry. The Pipeline Research Council International established this Strategic Research Priority (SRP) to coordinate the efforts across all technical committees (Compressor Pump Station, Design Materials Construction, Surveillance Operations Monitoring, Measurement and Underground Storage). The SRP goal is to provide a roadmap of research projects to close the gaps on mechanical damage (MD) research and to produce a comprehensive set of guidelines and tools for managing the threat of MD. The SRP funded one project in 2021: Analysis of Pipeline Operator and Prior R&D Data (MD-2-5). An additional SRP project will be added in 2022: Improvements to Mechanical Damage Engineering Assessment Tool (MD-2-4).

Co-Funders: PRCI Members

Start Date: 01/01/2021
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$3,685**
Total Project Cost: **$2,042,507**
Total SCG Cost: **$3,685**
Total Co-Funding: **$2,038,822**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Pathway to Achieving Efficient and Effective Crack Management (SRP-CM-01)

This research intends to advance critical areas associated with the execution of crack management programs that eliminate crack-related failures. The Pipeline Research Council International established this strategic research priority (SRP) to coordinate efforts across all the technical committees (Compressor Pump Station, Design Materials Construction, Surveillance Operations Monitoring, Measurement, and Underground Storage). The goal of the SRP is to provide a roadmap of research projects to further understand and efficiently and effectively manage cracks in pipelines. Research will focus on four core areas: susceptibility, inspection, management, and assessment and remediation. The SRP funded two projects in 2021: Understanding Why Cracks Fail (MAT-8-3), and Improvement of ILI Capabilities Joint Industry Project (PHASE II) (NDE-4-12).

Co-Funders: PRCI Members

Start Date: 01/01/2021
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$22,702**
Total Project Cost: **$5,193,400**
Total SCG Cost: **$23,819**
Total Co-Funding: **$5,169,581**
Benefits:

Pipeline Integrity Tool Cloud Based Assessment Software Consortium Project (MAT-8A/JCAS-01)

The objectives of this joint industry project (JIP) are to develop an improved model for pipeline seam weld anomalies and to improve the existing Pipeline Research Council International MAT-8A fracture mechanics model and its input parameters. The final product will be cloud-based software that uses probabilistic fracture mechanics (PFM) with the updated MAT-8 model. The new software enables operators to optimize resources through the evaluation of different mitigation scenarios. In 2021, the project team re-scoped the project to include use cases for the probabilistic assessments of cracks on pipelines based on the empirical distribution of crack dimensions without in-line inspection (ILI). The ability to use PFM software to calculate the failure probability of undetected crack populations will be beneficial to the safety of the pipeline. At the conclusion of this project, a report and updated model, in the form of cloud-based software, will be delivered to the project participants. SoCalGas will use these results to make informed decisions when conducting Engineering Critical Analysis (ECA) for a variety of applications such as general fitness for service, maximum allowable operating pressure reconfirmation, and ILI tool validation. The anticipated development of an analysis methodology for undetected populations of cracks in pipelines could assist SoCalGas in performing this type of analysis for ECA without ILI to support regulatory requirements as a result of the Gas Transmission Safety Rule.

Co-Funders: PRCI Members

Start Date: 09/01/2019
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$20,400**
Total Project Cost: **$621,695**
Total SCG Cost: **$67,645**
Total Co-Funding: **$554,050**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Post Fire Debris Flow Studies

This project explored analysis methodologies and modeling options to help determine the path forward for a risk framework for post-fire debris flow risk assessments. Results from the analysis determined that additional study was needed to further develop the approach in determining likely debris flow paths. An additional pilot study using Rapid Mass Movement Simulation (RAMMS) software was chosen to assess the likelihood and extent of debris flows from heavy rain across the Montecito region. RAMMS debris flow model parameters were calibrated using newly released U.S. Geological Survey (USGS) data for the debris flows that occurred in Montecito in January 2018. The USGS data included estimated volume of debris flows from specific basins, peak velocities, and flow properties, and contained shapefiles with the extent of the debris flows. The calibrated model parameters will be used to evaluate the entire Montecito region. Results of this study are documented in the final report titled "Post-Fire Debris Flow Modelling Framework." The framework was designed to require only inputs that are available immediately following a wildfire, namely the USGS post-fire debris-flow hazard assessments and a digital elevation model of the surrounding area. Additionally, recommended friction factors, debris flow volumes, and likelihoods were developed, so a consistent approach could be applied system wide. Recommended areas for future work include testing this methodology on future wildfires and investigating explicit erosion modeling.

Co-Funders: N/A

Start Date: 02/28/2019
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$61,420**
Total SCG Cost: **$61,420**
Total Co-Funding: **$0**
Benefits:

Practical Effects of Rough Walled Pipe in Gas Metering Applications (MEAS-6-5D)

This project investigated the effects of upstream meter tube inner wall roughness on the performance of multipath ultrasonic flow meters through a set of experiments involving three different brands of ultrasonic flow meters. Tests were conducted, with and without a flow conditioner, on 16-inch meters with piping of various surface roughness. These results, along with those of the 8-inch meters, can be used to support changes in the practices currently recommended by industry standards. The results of these tests and of those for the 8-inch diameter ultrasonic flow meters suggest that the surface roughness of the piping immediately upstream from the flow meter or between the flow conditioner and the flow meter has little influence on the accuracy of the meter. The final report was approved by the project team and published in May 2021. In November 2021, Pipeline Research Council International hosted a webinar to share the results of phases 1 and 2 and the project was closed out. Research confirmed that ultrasonic meters should be calibrated with the same type and model of flow conditioner to be installed in the field. The results from this project led to the revision of American Gas Association regulation 9. The revision indicates that the use of exact field piping (with respect to surface roughness) for calibrations and re-calibrations is not required, thus providing flexibility on the piping that is used for meter calibrations.

Co-Funders: PRCI Members

Start Date: 11/01/2018
End Date: 06/25/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$236,000**
Total SCG Cost: **$13,383**
Total Co-Funding: **$222,617**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Practical Girth Weld Evaluation Criteria Considering Weld Strength Mismatch and HAZ Softening (MATH-5-3D)

This project continues work from previous girth weld research projects for which new testing methods and welding guidance documents were developed (MATH-5-3B and MATH-5-3C). This project uses these results to propose revisions to current welding standards - the American Petroleum Standard 1104 and Canadian Standard Association Z662 - to address girth weld strength mismatch. These revisions will improve pipeline integrity, safety, and reliability of pipelines by updating the standards with new testing methods and new procedures for minimizing heat-affected zone (HAZ) softening near girth welds to prevent strength mismatch.

Co-Funders: PRCI Members

Start Date: 10/05/2021
End Date: 04/05/2023
Status: Active
2021 Funds Expended: **$14,350**
Total Project Cost: **$212,400**
Total SCG Cost: **$14,350**
Total Co-Funding: **$198,050**
Benefits:

PRCI Emerging Fuels Institute

The Emerging Fuels Institute (EFI) was founded in April 2021 to address the challenges of transitioning to clean fuels. The EFI will focus on challenges to infrastructure related to hydrogen, renewable natural gas (RNG), carbon capture and sequestration (CCS), ammonia, and biofuels. The EFI will concentrate on the following areas: the integrity of the pipeline system, steel and non-steel components, compressor stations and facilities, pressure control and over-pressure safety devices, design requirements for electrical classification and fire safety, and downhole reservoir and cavern storage. The EFI will also develop a guide to safely convert and operate pipeline systems to transport and store the next generation of fuels. In 2021, the EFI approved eight research projects: 1) NREL HyBlend project on operational and performance impacts of blending hydrogen into the existing natural gas infrastructure; 2) DNV guidelines for integrity management of hydrogen pipelines; 3) ASU and PHMSA development of a knowledge-based system for integrity management of aging pipelines; 4) GMRC analysis of compression system changes with hydrogen blending; 5) Solar turbine retrofit solutions for hydrogen-blend pipelines, 6) NewGasMet project to identify the impact of renewable gases on the accuracy and durability of meters; 7) GTI RNG gas quality database; and 8) Sandia and PRCI study of risks associated with leak scenarios for hydrogen greater than 20% in hydrogen-natural gas blends. SoCalGas will use knowledge gained from the EFI projects to support future hydrogen blending standards and projects to address knowledge gaps related to the use of existing natural gas infrastructure to transport emerging clean fuels.

Co-Funders: PRCI Members

Start Date: 06/15/2021
End Date: 12/30/2022
Status: Active
2021 Funds Expended: **$500,000**
Total Project Cost: **$2,000,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$1,500,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Product and Process Validation Program (5.20.m)

This project will test common products for the natural gas utility industry to validate that they meet industry performance standards. Utility members will have the option to select products from a few suppliers for testing each year. Rather than bearing the entire cost of testing themselves, participating utility members benefit from cost savings through the project's collaborative financial approach. Thus far, the test plan has been developed, and members have selected the product material type, configuration, size, and manufacturers to be tested. In 2021, materials were procured, and testing began. Testing is anticipated to be completed in 2022 along with the publication of the final report.

Co-Funders: OTD Members

Start Date: 09/01/2020
End Date: 04/30/2022
Status: Active
2021 Funds Expended: **$3,491**
Total Project Cost: **$180,000**
Total SCG Cost: **$8,491**
Total Co-Funding: **$171,509**
Benefits:

Review and Evaluation of the Utonomy Smart Regulator, Phase 2 (5.19.k.2)

The objective of this project is to demonstrate the operation and benefits of the Utonomy Smart Regulator (USR) through laboratory testing and field trials. The use of the USR could provide operators with the ability to remotely monitor and control district regulator stations. The project includes both laboratory and field testing with Utonomy as a partner. In 2021, the task of documenting the Products and System Needs Validation and Requirements began. The next steps are to complete the requirements documentation and perform tests at the Fisher Flow Laboratory. An interim report will be prepared after the laboratory testing is complete to determine whether the project should move forward with field trials. This project has potential technical links to company efforts to bring remote monitoring and control to our distribution system. Further, it aligns with the recently published Pipeline and Hazardous Materials Safety Administration Advisory Bulletin titled Pipeline Safety: Overpressure Protection on Low-Pressure Natural Gas Distribution Systems [Docket No. PHMSA-2020-0025].

Co-Funders: OTD Members

Start Date: 01/31/2021
End Date: 01/31/2023
Status: Active
2021 Funds Expended: **$41,500**
Total Project Cost: **$291,800**
Total SCG Cost: **$76,644**
Total Co-Funding: **$215,156**
Benefits:

Revision of the PRCI Hot-tap Model Two Different Base Material (MATR-3-1B)

The objective of this project is to complete the development of the Pipeline Research Council International (PRCI) HotTap Model V5, a thermal analysis model for in-service welding. This project will update version 4.2.1 of the model and software to expand its coverage to include welding of two different materials, and to meet current technology standards. Modeling two different materials could enable a clear understanding of the cooling aspect of the two different materials. The project team has updated the model and incorporated it into the software. Testing is currently in process. Once completed, the HotTap Model V5 will be available to PRCI members for their use. The updated software will allow SoCalGas and utilities in general to better predict weld properties, thereby enhancing the safety and reliability of pipelines.

Co-Funders: PRCI Members

Start Date: 08/17/2020
End Date: 08/17/2022
Status: Active
2021 Funds Expended: **$9,946**
Total Project Cost: **$69,620**
Total SCG Cost: **$19,946**
Total Co-Funding: **$49,674**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Seismic Risk Assessment and Management of Natural Gas Storage and Pipeline Structure (GFO-18-502) (Group 1) – Two Projects Slate/ Berkeley & UCLA

The CEC awarded two projects under GFO-18-502 Group 1. The projects each develop seismic risk assessment software tools using different risk models. SoCalGas is involved in both projects. The first project was awarded to Slate Geotech and UC Berkeley for the production of an open-source analysis tool that is easily usable by regulators and utilities. The tool will implement updated methodologies for assessment of seismic risk to underground and aboveground natural gas infrastructure. The tool will have the ability to identify areas of highest risk overlaid with population information to help regulators and utilities identify areas of highest risk to prioritize seismic retrofit projects. To date, a Beta version of the tool has been developed and is being tested. SoCalGas provided data and technical expertise for this project. The second project was awarded to UCLA. This project considers four hazards: Earthquake ground shaking, fault displacement, landslides and liquefaction and will develop a comprehensive set of fragility curves for pipelines and an open-source risk assessment tool based on probability-based methodology. To date, the project is about 75% complete, and several fragility models have been developed. SoCalGas is participating on the TAP for this project.

Co-Funders: CEC, LBNL

Start Date: 06/01/2019
End Date: 06/30/2023
Status: Active
2021 Funds Expended: **$3,393**
Total Project Cost: **$5,207,752**
Total SCG Cost: **$13,000**
Total Co-Funding: **$5,194,752**
Benefits:

Steel Transmission Pipeline System Analysis

This project establishes families of pipes within the SoCalGas system according to the tolerance level of specific hydrogen-natural gas blends, which is based on susceptibility to hydrogen-related threats at various operating conditions. By analyzing various parameters, this project will develop an advanced probability-of-failure (POF) model as a function of pressure, both without hydrogen blending and with various levels of hydrogen blending. Some of these parameters include material type, manufacturing process, prior pipeline inspection, operating histories, lab testing results, and existing POF framework. By comparing the POF of various pipelines with and without assorted hydrogen blends, this project will help SoCalGas determine where replacements may be needed to accommodate hydrogen blends or provide guidance on selecting targeted areas for future hydrogen blending.

Co-Funders: N/A

Start Date: 05/24/2021
End Date: 09/30/2022
Status: Active
2021 Funds Expended: **$159,195**
Total Project Cost: **$600,000**
Total SCG Cost: **$600,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Storage Well Casing Inspection Tool Sizing Accuracy

The project team performed a statistical analysis on available data from SoCalGas and the wider industry to establish sizing accuracy for ultrasonic technology (UT) and magnetic flux leakage (MFL) downhole inspection tools. UT and MFL tools are used to inspect storage well casings. Several existing tools have a tolerance gap, and do not have the developed tool performance specifications for measurement accuracy of defects in length, width, and depth dimensions. Proper evaluation of the remaining strength and life of storage well casing requires a thorough understanding of the tool's measurement accuracy. A linear regression model was used to quantify the systematic error (bias) and random error (scatter) of the tools. The project results will be used to apply tool tolerances to the inspection measurements of storage well casings by downhole inspection tools using UT and MFL sensors. A report was issued in October 2021. The results of this analysis gave SoCalGas a better understanding of the accuracy of storage well casing inspection tools, and the Storage Integrity Management Program Assessment team the ability to account for tool accuracy when calculating the remaining life of storage well casings.

Co-Funders: N/A

Start Date: 01/31/2021
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$35,000**
Total Project Cost: **$35,000**
Total SCG Cost: **$35,000**
Total Co-Funding: **$0**
Benefits:

Study on the Impact of Trace Constituents in RNG on Natural Gas Grids and Consumer Appliances (M2020-008)

The objective of this project is to study the impact of Trace Constituents (TCs) in Renewable Natural Gas (RNG) and traditional pipeline gas to address any potential safety or maintenance risks on local distribution company infrastructure and consumer gas appliances. The project involves a literature search and study on all TCs in RNG. The project team will identify gaps in the literature and then address them in preliminary laboratory tests to identify set limits for six TCs of concern. These limits will assist SoCalGas in determining whether RNG specifications need or do not need modification. The project team will distribute them in a white paper. In 2021, the team modified the scope to include an impact study on critical TC concentrations. To date, the team has completed the literature review, gap analysis, and impact study. In 2022, the team will complete development of the test plan, with testing planned to start in early 2022. If the project is successful in determining safe TC limits, SoCalGas plans to use the results to request changes in its Rule No. 45, the Standard Renewable Gas Interconnection, which governs business specifications and RNG tariffs.

Co-Funders: NYSEARCH Members

Start Date: 01/15/2021
End Date: 10/31/2022
Status: Active
2021 Funds Expended: **$71,390**
Total Project Cost: **$606,810**
Total SCG Cost: **$71,390**
Total Co-Funding: **$535,420**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Systemize 20 Years of Mechanical Damage Research (PHMSA) (MD-5-1)

The goal of this project is to provide a summary of work supporting the current state of knowledge related to mechanical damage. Its focus is on formation and behavior, detection and characterization, assessment and management, remediation and repair, and recommended practices and standards. The results of this body of work will provide a consolidated review of previous research over the past 20 years, characterizing the achievements made as well as opportunities for improvement. In 2020, the project team completed the literature collection and review task. In 2021, the project progressed steadily towards the assembly of a historic view of mechanical damage research. The project team will complete review of the assembled draft component parts of the summary document in the first quarter of 2022.

Co-Funders: PRCI Members, PHMSA

Start Date: 09/30/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$733**
Total Project Cost: **$493,982**
Total SCG Cost: **$1,766**
Total Co-Funding: **$492,216**
Benefits:

T&T Component Counterfeit Detection, Two Way Product Communication Using GS1 Standards (8.17.b.4)

This project builds upon other research supporting PHMSA's Tracking and Traceability initiatives. The project objective is to develop a process to screen natural gas piping system components for counterfeits and to develop a mobile system software for communicating quality control concerns about piping system components directly to the component manufacturer in near real-time. Components used to construct natural gas delivery systems may pass initial hydro testing, but failures a few years into service have been linked with counterfeit components. The industry needs tools to scrutinize products used in natural gas piping systems to confirm that they are authentic and that the components are supplied with quality control test reports that are representative of the components received for use. Deliverables for this project include: (1) a Final Report documenting the system, (2) a prototype demonstration of the system's ability to detect counterfeit components with map-based reporting program, and (3) a narrative of the requirements to deploy the system for commercial operation. The project kick-off is scheduled for early 2022.

Co-Funders: OTD Members

Start Date: 11/01/2021
End Date: 05/01/2022
Status: Active
2021 Funds Expended: **$7,500**
Total Project Cost: **$229,000**
Total SCG Cost: **$13,263**
Total Co-Funding: **$215,737**
Benefits:

Trace Constituent Database (7.18.h)

Currently, no gas quality (GQ) database (DB) exists for the natural gas industry that includes information on methods, measurement related issues, and actual concentrations of trace constituents. This project created an online, searchable GQ DB available to sponsors that contains major, minor, and trace constituent concentrations for natural gas and renewable natural gas. In 2020, the project team completed the GQ DB with access via multiple Power BI reports containing interactive data visualizations and raw data tables. The team also conducted a webinar with sponsors to demonstrate the functionality of the GQ DB and solicited feedback that shaped the final version of the report application. In 2021, the team prepared reports covering a variety of target constituents and fuel gas properties. SoCalGas uses this GQ DB as an informational guide for trace constituents.

Co-Funders: OTD Members

Start Date: 09/03/2018
End Date: 06/14/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$162,000**
Total SCG Cost: **$8,684**
Total Co-Funding: **$153,316**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Tracking and Traceability for Transmission, Pipe Materials, Phase 4 (Additional Demos) (5.14.d.4)

The objective of this project was to develop a traceability process that can be used by any pipeline operator, pipe fabrication mill, pipe coating mill, and distributor to transfer and receive asset traceability information. In this phase, the project team conducted a field study on steel material traceability to develop a standard data model and protocols for transferring material test report and certificate of compliance records electronically from pipe manufacturers to pipeline operators. The results were submitted to an American Petroleum Institute (API) Working Group for incorporation into a recommended practice for steel pipe. In September 2021, API reviewed and published the first edition of API Recommended Practice 5MT - Pipeline Inspection Documents for Material Traceability and Electronic Test Reports. Operators will be able to reference this recommended practice when purchasing pipes from pipe mills to deliver material traceability data in a standardized, electronic format. The last task for this project is to prepare a final report.

Co-Funders: OTD Members

Start Date: 02/08/2018
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$265,000**
Total SCG Cost: **$31,346**
Total Co-Funding: **$233,654**
Benefits:

Tracking and Traceability Marking Standard for Transmission Components – Phases 1 & 2 (8.17.b, 8.17.b.2)

The objective of Phase I of this project is to enable the capture of key information required for documenting and geospatially modeling new or repaired gas transmission systems to support the latest Pipeline and Hazardous Materials Safety Administration (PHMSA) regulatory requirements. The objective of Phase II is to use the Phase I marking standard to capture key information required for physically documenting and geospatially modeling new or repaired gas transmission systems to comply with the latest PHMSA requirements. Under Phase I, GTI completed the pilot with a natural gas utility barcoding all components at either of the manufacturing facilities, distributors, or from stock components drawn from the utility storeroom. During the Phase I pilot, data created from the scan were saved by writing them to a PDF report. While the report is very informative, it does not support the export of information for a modern GIS system. This resulted in a complete re-architecture to the mobile systems to digitally record all of the information that resulted from a barcode scan. The knowledge gained from the pilot was used to develop the next phases of the project and improve the processes. In II, a pilot program was established for the demonstration of marking guidelines and its integration with Global Standards 1 (GS1) synchronization network. GTI established dedicated databases that manage the mobile systems that are better prepared for future pilot projects, so that any product data loaded into Global Data Synchronization Network will load into the iOS application. As of 2021, Phase I and Phase II are complete, and efforts continue in Phase IV. The next steps are for the distribution of Phase I and Phase II Interim Reports.

Co-Funders: OTD Members

Start Date: 01/01/2017
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$645,000**
Total SCG Cost: **$58,707**
Total Co-Funding: **$586,293**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Universal Analytical Technique for Siloxane – Phase 2 (7.16.g.2)

The objective of this project is to develop a universal, industry-wide sampling and analysis procedure for measuring the presence of siloxanes in biomethane. The project team is developing this procedure in collaboration with the American Society for Testing and Materials (ASTM) Committee on Gaseous Fuels. In Phase 1, the team developed and published the ASTM Standard D8230 for the Measurement of Volatile Silicon-Containing Compounds in a Gaseous Fuel Sample Using Gas Chromatography with Spectroscopic Detection. ASTM requires that an Interlaboratory Study Program (ILS) be performed within five years of the procedure publication date. In Phase 2, the team will complete the ILS and field-test an online siloxane analyzer. In 2021, the scope of work was expanded to include a second field site for Pipeline Research Council International's research project, MEAS-15-04. The team will collect periodic grab samples during the testing period for analysis at laboratories following ASTM D8230 procedures to compare the on-line data to data produced using off-line analytical techniques. In 2021, the team continued the ASTM D8230 inter-laboratory study by finalizing details on the laboratory participation list for the ILS and continuing to plan field evaluations.

Co-Funders: OTD Members

Start Date: 05/01/2019
End Date: 04/30/2023
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$253,000**
Total SCG Cost: **$49,608**
Total Co-Funding: **$203,392**
Benefits:

USC BioGas Study Phase I & II

The goal of this project was to investigate the effect of ammonia mixed with natural gas at various concentrations on typical pipeline materials. The intent was to mimic renewable natural gas (RNG)—which is derived from biogas and processed to meet pipeline natural gas quality specifications (> 92% methane)—or from its combustion for power and energy production. Phase I of this project focused on determining exposure effects on pipeline brass-alloy-containing materials and devices and the impact of their exposure to ammonia as a potential constituent of RNG. The Phase II study evaluated the impact that ammonia presence in RNG may have on appliance and/or equipment performance. It also investigated the impact on emissions (e.g., carbon monoxide or nitrogen oxides (NOx)) from combusting ammonia/RNG mixtures. The project team determined that ammonia content is directly proportional to NOx emissions. Thus, NOx emissions are the most significant limit to ammonia content in RNG. The experimental results point to the need for thorough clean-up of the RNG prior to its injection into the natural gas network. The study has been completed and the final report is out for peer review. One additional piece from Phase II included in the final report was a literature review on the impacts of mercury in typical pipeline and equipment infrastructure material.

Co-Funders: N/A

Start Date: 08/01/2018
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$209,765**
Total SCG Cost: **$209,765**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Wellhead Seals Best Practices (US-3-01)

Wellhead seals are a key component of underground gas reservoirs and salt-cavern storage wells. They function to seal the well from the external environment and to separate stored fluids contained within the well. Loss of integrity of these seals, or seal failures, are a common occurrence in the storage industry. The objective of this project was to develop a best-practices document providing operators with guidance on how to properly choose and maintain wellhead seals to minimize failures. In this study, data related to wellhead sealing were compiled through a literature review, discussions with wellhead service providers, and a survey distributed to PRCI members and others in the storage industry. Meaningful parameters related to the success and failure of seal components were identified through the evaluation of these data. Results were combined from all elements of the research study to provide seal and wellhead design recommendations specific to the seal type, seal material composition, and seal hardness along with wellhead hanger style, spool design, and flange modification suggestions. The knowledge gained from the research will help operators determine how to properly select and maintain wellhead seals to minimize failures. SoCalGas will use the results as a reference when developing integrity inspection procedures and gas standards, as well as to inform any operational decision-making that involves wellhead seals.

Co-Funders: PRCI Members

Start Date: 07/30/2020
End Date: 04/08/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$59,000**
Total SCG Cost: **$4,609**
Total Co-Funding: **$54,391**
Benefits:

SUB-PROGRAM: SYSTEM INSPECTION & MONITORING

AC Earth Faults (9.16.d)

The objectives of this project were to develop methods to quantify the extent to which buried gas pipelines are exposed to ground or earth faults from nearby high-voltage alternating current (AC) power systems and to examine the risks created by this exposure. A ground fault occurs when straying electrical current takes a pathway directly to the earth (ground). These faults can damage pipeline coatings. A model demonstrating where earth faults are likely to occur will improve knowledge of fault "hot zones." This, in turn, allows utilities to conduct risk assessments and plan inspection and mitigation efforts. The project team successfully modeled and analyzed AC fault risk scenarios which were then used to enhance the AC PowerTool software. This tool is now available to operators to analyze risk profiles and investigate their best options for risk mitigation. SoCalGas's Integrity Management and Engineering Departments work with powerline operators in California to address AC fault protection and to mitigate the impacts of stray current interference. Also, SoCalGas will review the results of this project to potentially incorporate techniques and analysis to address possible AC fault failures that could impact our pipelines.

Co-Funders: OTD Members

Start Date: 10/01/2016
End Date: 04/16/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$289,200**
Total SCG Cost: **$70,000**
Total Co-Funding: **$219,200**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Advanced Computed Tomography for Pipeline Inspection (PHMSA) (NDE-2-11)

The project team is working to deliver a validated data set and a process to evaluate the use of Computed Tomography (CT) as a non-destructive technology for measuring crack and seam weld anomalies in steel pipe. Validating the CT technology will enable the pipeline industry to establish a set of reference standards that can be used for a wide range of purposes. These include technology development and qualification, personnel training, and competency testing. The reference standards will allow non-destructive testing to characterize crack profiles and can be used on a repeated basis. This is a significant advancement for the pipeline industry and will advance training, technology development, and integrity management programs. An essential element in this program is acquiring pipeline materials. Modern pipeline materials can be used, but the preference is to use vintage pipe, especially pipes having low-frequency Electric Resistance Welding seam welds. The Pipeline Research Council provided a final draft report to Pipeline and Hazardous Materials Safety Administration (PHMSA) for their review. PHMSA comments will be considered and addressed before the report is published.

Co-Funders: PRCI Members, PHMSA

Start Date:	09/30/2019
End Date:	03/31/2022
Status:	Active
2021 Funds Expended:	**$4,472**
Total Project Cost:	**$990,000**
Total SCG Cost:	**$14,472**
Total Co-Funding:	**$975,528**
Benefits:	

Advanced Through-Tubing Casing Inspection for UGS Wells (US-4-04)

The objective is to advance the sensor technology in through-tubing inspection tools' ability to detect, measure, and characterize metal loss features. This project is looking to work with PRCI to offer a Multi-String Well Integrity Platform that provides a circumferential measurement of corrosion and isolation of external casing strings. The proposed solution will be a fully combinable, advanced sensor technology. The combo will be capable of acquiring data in a single run without pulling out the production tubing. The development of this technological advancement will significantly save UGS operators time and cost by providing the means to evaluate well integrity and effectively plan well intervention activities. SoCalGas would utilize the results to manage well integrity as outlined in each field's Storage Risk Management Plan. The project kick-off meeting was held in November 2021 highlighting the general project objectives, work scope, schedule and responsibilities. The overall project execution plan and regular project meeting schedule were also discussed.

Co-Funders: PRCI Members, PHMSA, Others

Start Date:	09/30/2021
End Date:	09/30/2024
Status:	Active
2021 Funds Expended:	**$72,473**
Total Project Cost:	**$1,760,777**
Total SCG Cost:	**$272,473**
Total Co-Funding:	**$1,488,304**
Benefits:	

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Airborne Automated Threat Detection System-Monitoring and Surveillance of Imminent Threats Through Remote Sensing (ROW-3-1&A)

Start Date: 11/30/2018
End Date: 04/30/2022
Status: Active
2021 Funds Expended: **$5,982**
Total Project Cost: **$377,683**
Total SCG Cost: **$10,982**
Total Co-Funding: **$366,701**
Benefits:

The goals of the project are to develop, demonstrate, and validate the use of automated pipeline patrol and surveillance technologies on an aircraft platform to enhance detection of third-party activities, ground movement, and interferences that could potentially affect pipeline infrastructure. The project generated data from multiple sensors deployed on aerial patrol. These data were analyzed to assess the capabilities and limitations of airborne sensing systems for automated pipeline patrol. The project has made significant progress in validating the performance of an automated Right-Of-Way (ROW) monitoring and surveillance system, operating on a long-range, long-endurance, beyond visual-line-of-sight, unmanned aircraft. Data were provided through remote sensing, in near-real time. Flight activities are continuing and scheduled for completion in 2022. These will include testing of the final multi-spectral, multi-threat sensor system proposed on both manned and unmanned aircraft. Project results will provide pipeline operators with performance data and information on the capabilities and limitations of airborne sensing systems for automated pipeline patrol, and provide options to improve surveillance of pipeline ROW corridors.

Co-Funders: PRCI Members

Alternate Crack Sensor (M2016-004 Phase 1, 2, 3, & IV)

Start Date: 07/01/2016
End Date: 05/31/2022
Status: Active
2021 Funds Expended: **$70,190**
Total Project Cost: **$2,124,014**
Total SCG Cost: **$274,084**
Total Co-Funding: **$1,849,930**
Benefits:

The project team developed and commercialized a sensor probe system for crack detection in longitudinal seam welds (SWs) in 20"-26" diameter natural gas pipelines. In Phase 1, the team developed a concept to integrate the crack sensor probe with the Explorer robotic inspection platform. The concept used two probes: one for finding SWs and one for scanning for cracks. In Phase 2, a prototype was built and field-tested. The sensor successfully identified cracks in all SWs except for electric resistance welds (ERWs). In Phase 3, mechanical designs were refined to improve weld sensor ride and data quality, especially over protruding SWs. Further, the ERW SW detection was improved, such that the data proved consistent and accurate when detecting girth SWs, allowing a smooth operation of orientation transitions between pipeline segments. Data Analysis Tools were improved through testing and fine-tuning the integration of the weld sensor data to the analysis software. At the completion of Phase 3, sponsors elected to continue onto a Phase 4 where the focus is to improve the existing system (developed in Phase 1-3 of this program) with revisions to the mechanical design, weld detection capability, and integrations with the Explorer 20/26 robot and operation. The deliverables are to be a revised circumferential MFL sensing system able to detect long SW anomalies as documented in the early phases, an alternative sensor probe for improving detection of low signature long SW, and established specifications of operation. Phase 4 kicked off in August 2021 and began testing to increase the sensitivity of the weld and material detection and modifications to the sensor housing to reduce the weight were made.

Co-Funders: NYSEARCH Members

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Casing Corrosion Logging Tool (US-3J)

Start Date: 04/01/2019
End Date: 08/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$324,035**
Total SCG Cost: **$50,000**
Total Co-Funding: **$274,035**
Benefits:

Many storage field operators have a preferred technology to inspect and manage the integrity of downhole well casings. However, there has been no clear understanding of the relative benefits and/or advantages of the technologies. The objective of this project was to define the differences and advantages associated with each inspection technology currently available for storage field applications. Three casing corrosion logging tools were tested to further evaluate their performance in detecting and sizing various metal loss features in casing specimens. Physical burst tests with capped-end conditions were conducted on twenty specimens selected from the logged casing joints to benchmark the burst prediction models. Advanced finite element analysis was performed to evaluate the effect of *in situ* downhole load conditions on the remaining burst capacity of corroded casing. A reliability-based framework was outlined to demonstrate the process of quantitatively addressing various uncertainties associated with the inputs required in the remaining burst strength calculations for downhole casing integrity management. The knowledge gained from the research will aid in determining the appropriate technology to more accurately characterize downhole metal loss conditions. SoCalGas will further use the information to develop integrity inspection procedures and gas standards, and in any operational decision-making that involves gaining better understanding of downhole casing conditions.

Co-Funders: PRCI Members, PHMSA

Cathodic Disbondment Detector – Phase 2 (4.12.c)

Start Date: 03/24/2017
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$261,000**
Total SCG Cost: **$40,031**
Total Co-Funding: **$220,969**
Benefits:

The utility industry needs tools that can assess underground metallic pipes from aboveground. Excavation is expensive and has potential risks. Any technique that provides insight prior to excavation will help to optimize utility resources. In Phase 1, a commercial pipeline inspection tool was acquired and evaluated. The technology assessed coated steel pipe with the goal of identifying areas with disbonded coating. In Phase 2, additional field tests assessed features in coated steel pipe from aboveground. After the features were identified, the technology was validated and confirmed with excavations. SoCalGas identified eight candidate sites for the field evaluation of which seven were surveyed and five were excavated for validation. The post-excavation analysis showed one excavated area where the tool and utility surveys were in good agreement. This aligned with the overall test results which showed that the data aligned particularly in cases where there was strong signal current on the pipe and good soil conductivity. In other instances, particularly where signal current on the pipe was weak, the system was not able to generate survey results with a high degree of confidence. The results from several other excavated areas identified an issue with the test location selection that will inform future test points. Additional surveys and field measurements were originally planned for 2021 but were canceled because the technology being evaluated is no longer available. A draft final report has been sent for review by sponsors.

Co-Funders: OTD Members

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Computed Tomography (CT) Fundamentals with Calibration and Reference Standards for Pipeline Anomaly Detection (NDE-2-12)

The main project objective is to establish the relationship between new Nondestructive Examination (NDE) test measurements and established standardized tests for fracture toughness. Computed tomography (CT) is positioned to greatly enhance the pipeline industry's ability to accurately detect and measure cracks and crack-like features. By employing CT, operators will be able to size cracks and crack-like features without having to destroy them for confirmation purposes. This will allow In-Line Inspection (ILI) operators access to a set of truth data from which they can improve their tool performance. This research will validate a new technology that determines material fracture toughness through NDE in-ditch testing. The data could be combined with the "binning" of pipe joints that is currently performed using ILI tools. This combination reduces the need to perform costly pipeline cutouts and associated shutdown of the pipelines to prepare machined samples for laboratory Charpy V-notch tests. Project completion was delayed due to the decision to test additional samples and testing delays due to weather. The draft final report is under review with an expected publication in early 2022.

Co-Funders: PRCI Members

Start Date: 06/16/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$3,997**
Total Project Cost: **$311,929**
Total SCG Cost: **$8,687**
Total Co-Funding: **$303,242**
Benefits:

Database of All Burst Tests for Corrosion, Cracking, Dent, and Interacting Defects (EC-02-11)

The objective of this project is to develop and populate a database of burst tests for corrosion, cracking, dent, and interacting defects including fatigue tests. To validate improvement in defect assessment or modeling, burst tests and fatigue tests are usually done. These tests are time consuming and expensive, and finding the appropriate pipe samples for testing is also challenging. The project would develop a uniform format for burst test data collection and support future defect assessment and modeling efforts. The benefit of this project is to provide consistent and relevant data for future Pipeline Research Council International (PRCI) studies in defect assessment and growth modeling. The outcome is a database of burst tests and fatigue tests with open access to members.

Co-Funders: PRCI Members

Start Date: 11/19/2021
End Date: 05/31/2023
Status: Active
2021 Funds Expended: **$8,780**
Total Project Cost: **$147,500**
Total SCG Cost: **$8,780**
Total Co-Funding: **$138,720**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Determine the Impact of Human Factors in the Performance of In-Service NDE (NDE-2-7)

This is a multi-phase project. In Phase 1, the human impacts of training program quality on Nondestructive Examination (NDE) performance were evaluated. In Phases 2 and 3, further investigation of human factor effects on NDE performance for conducting Magnetic Particle Inspections and Ultrasonic Thickness Testing on pipeline components was performed. This research assessed the potential impact of human factors (i.e., transfer of knowledge, teaching, and learning) on the performance of in-service NDE of pipeline integrity. Accurate damage assessments cannot occur when the accuracy or variability of the NDE is not well understood, especially when the NDE performance is impacted by a human operator. The last phase of the project, Phase 4, will deliver an assessment of the human variabilities in performing NDE, and standard procedures to assess NDE operator performance. This project has been delayed due to COVID-19 restrictions preventing in-person meetings. The training curriculum has continued to be developed, and the in-person training and finalization of the work is planned for first quarter 2022.

Co-Funders: PRCI Members

Start Date: 01/31/2017
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$437,878**
Total SCG Cost: **$25,000**
Total Co-Funding: **$412,878**
Benefits:

Eclipse Scientific Red/Green Light Tool for NDE of PE Pipe Butt Fusion Joints – Phase 1-a (M2019-010)

Polyethylene (PE) pipes can be joined by melting both ends and forcing the ends together to form a butt-fusion (BF) joint. The integrity of the BF joint is important for long-term performance. This project will develop an automated non-destructive examination (NDE) tool to inspect the integrity of BF joints which does not require operators with specialized training in NDE. NYSEARCH members have invested considerable resources into NDE development for PE pipe through extensive testing with The Welding Institute. Eclipse Scientific has developed the automated NDE constructs of pass/fail (green/red) for performing PE joint pipe interrogation. This project has received a portion of the defected BF joint samples developed under the M2019-009 project to continue the integration of automated defect recognition within NDE pass/fail (green/red) characterization. The next step is to incorporate NDE PE joint defect acceptance criteria into the automation process to begin calibration of the pass/fail threshold. The development of this technology will improve the integrity of BF joints constructed by SoCalGas since any defect in the joint would be identified prior to placing the pipe into service.

Co-Funders: NYSEARCH Members

Start Date: 01/31/2020
End Date: 03/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$153,790**
Total SCG Cost: **$13,670**
Total Co-Funding: **$140,120**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Electromagnetic Time Domain Reflectometry (EM-TDR) for Pipeline Integrity (M2021-004 Ph I)

Electromagnetic Time Domain Reflectometry (EM-TDR) is a mature technique developed to identify and locate faults in metallic cables. Lawrence Berkeley National Lab proposes to adopt the EM-TDR technique to the inspection of transmission natural gas pipelines. Variations in materials and pipeline geometry have a significant effect on this technique's performance and tuning. This project will evaluate method feasibility for the intended application, and if successful, it will lead to additional phases to develop and test an engineering prototype, a pre-commercial prototype, and ultimately result in commercialization. This technology would allow for SoCalGas to obtain more information on difficult-to-access portions of pipelines that are currently assessed by External Corrosion Direct Assessment (ECDA). If this tool is applicable to pipelines as outlined in the proposal, EM-TDR could be used to provide further assessment of carrier pipe within cased segments, as well as other crossings where ECDA techniques are not available. This tool would be used to supplement and enhance existing ECDA inspection techniques.

Co-Funders: NYSEARCH Members

Start Date: 05/01/2021
End Date: 05/31/2023
Status: Active
2021 Funds Expended: **$28,850**
Total Project Cost: **$339,000**
Total SCG Cost: **$28,850**
Total Co-Funding: **$310,150**
Benefits:

Energy Harvesting for Recharging of Explorer Robotic Platforms Ph II (M2016-009)

In-line inspection of metallic pipelines uses a robot to support sensors and travel along the pipeline while navigating through obstacles. At present, power is provided by onboard batteries that have a limited capacity. The goal of this project was to develop and commercialize an on-board module capable of harnessing energy from the flow of natural gas inside the pipeline to power the Explorer family of robotic inspection platforms. This would extend the inspection range capabilities of the robots. Phase I focused on the energy extraction module & Phase II on the iterations of the power-generating module prototype. Earlier in the project, successful power generation results were achieved in a laboratory flow chamber and, subsequently, with a live pipeline test. Next, manufacturing and assembly of a new, redesigned energy harvesting module was completed. In 2021, testing of the redesigned harvester was completed and the final report was published. As a result, the vendor will soon carry out several deployments of this system alongside commercial jobs for the Explorer 20/26 robot. These deployments will provide additional information on system performance and reliability. The goal is to have the system fully and commercially deployed in late 2022. Concurrently, SoCalGas will evaluate the technology for potential demonstration within the company.

Co-Funders: NYSEARCH Members, PHMSA

Start Date: 10/01/2016
End Date: 06/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$1,631,721**
Total SCG Cost: **$171,265**
Total Co-Funding: **$1,460,456**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Energy Harvesting in Gas Industry Applications (M2016-006) – Phase I/II

The project goal is to carry out a feasibility study to identify technologies that generate 3-5 watts of power by harvesting energy from available "background" resources (e.g. vibration, flow, temperature differences, etc.). This would provide power to sensory and related devices in areas where utility power is limited, or non-existent, and remove the need for replacing batteries. Phase I identified four potential technologies. Phase II will evaluate the technologies for practicality and commercial availability. The evaluation has been completed for three technologies: Thermal Energy, Pressure Differential/Fluid Flow Energy, and Fuel Cell Energy. In 2021, the project team evaluated Vibration Energy with piezoelectric energy harvesters. Piezoelectric generators (energy harvesters) convert normally wasted vibration energy in the environment to usable electrical energy. Off-the-shelf piezo strips were purchased and tested over a broad excitation and load range to determine if they could charge a small battery. This project is in the process of completing the last set of tests and will be closing out in the next few months.

Co-Funders: NYSEARCH Members

Start Date: 12/01/2016
End Date: 04/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$293,235**
Total SCG Cost: **$27,931**
Total Co-Funding: **$265,304**
Benefits:

Explorer Wireless Range Extender (M2021-006)

The results of a previous project—the Energy Harvesting research initiative (On-Board Power and Thrust Generation for the Explorer Family of Robots for the Inspection of Unpiggable Natural Gas Pipelines – M2016-009)—demonstrated the potential of Explorer tools to inspect longer segments of pipeline. However, increased range can lead to loss of wireless communication at large distances. The goal of this project, which began in August 2021, is to extend the wireless communication range of the existing Explorer In-Line inspection robot while it is deployed in the pipe. The team identified a targeted range of about two miles, which is roughly four times the current range. To date, the project team has completed development of a basic concept of Wi-Fi module and preliminary mechanical design. Two wireless protocols are currently underway, and work continues on the retrieval process. Moving forward, the team will focus on the electrical and software stage, as well as the mechanical stage. The electrical and software stage involves performing standard tests on mesh and repeater concepts and comparing the results to the performance of the current Explorer. It will also include determination of a more precise power budget for a full-size Wi-Fi module (targeting a minimum of 72 hours) and selecting the appropriate network type. The mechanical stage includes designing calculations for motor, flow resistance, and magnetic holding force. In the final stages, the team will compile all results, issue a feasibility study report, and prepare a proposal for the next phase of the project. SoCalGas will benefit from this project by being able to use the commercialized prototype to increase the efficiency of its pipeline inspection and reduce the overall cost of inspection.

Co-Funders: NYSEARCH Members

Start Date: 08/09/2021
End Date: 12/30/2022
Status: Active
2021 Funds Expended: **$10,695**
Total Project Cost: **$109,610**
Total SCG Cost: **$10,695**
Total Co-Funding: **$98,915**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Extending Energy Harvesting to Other Explorer Sizes – A Feasibility Study (M2021-011)

The goals of this project are to perform a feasibility study on the scaling ability of the Explorer 20/26 Energy Harvesting (EH) system to other platforms and to determine the performance envelope for the Explorer 10/14, 16/18, and 30/36. This project has five tasks. Task 1 is to perform a level analysis on the robot to determine power consumption under various operational conditions and the levels of energy and tow force that can be generated for each pipe size and robot. Task 2 is to investigate the mechanical design of the EH system and the design impact on the overall weight of the robots. Tasks 3 and 4 will involve evaluating the amount of power and energy that can be generated for the varying sizes under a variety of operating conditions and modifying the electronics. Results from earlier research will be used as the starting point. Task 5 will determine the potential impact that the EH technology will have in the commercial deployment of the various Explorer robots, the anticipated commercial benefits to the end user for different inspection scenarios and will develop an action plan for fleet implementation. The deliverable will be a feasibility study report outlining the key parameters for an EH system for other pipe sizes of the Explorer fleet, and the technical obstacles that need to be overcome for such systems to be successfully developed in future phases. Finally, recommendations on the next steps will be presented. This project allows SoCalGas to potentially use this system, once commercialized, on smaller pipes that extend for long distances.

Co-Funders: NYSEARCH Members

Start Date: 11/15/2021
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$19,395**
Total Project Cost: **$193,948**
Total SCG Cost: **$19,395**
Total Co-Funding: **$174,553**
Benefits:

High Resolution MFL for Explorer Series of Robotic Platforms – Feasibility Study (M2021-009)

The purpose of this project is to do a feasibility study of a high-resolution magnetic flux leakage (MFL) sensor for integration on the Explorer robot platform. The focus is on assessing various sensors available in the market, selecting a sensor, and optimizing the resulting system for maximum efficiency and interchangeability among the various robots. Using smaller sensors allows for higher spatial and circumferential resolution, sizing accuracy at higher resolution, and higher detectability of smaller defects, thus allowing higher confidence levels in the measurements made, leading to reduced operations and maintenance costs, and greater safety of operations. This project has four tasks. Task 1 is to determine the best sensor for the application at hand, while considering potential solutions to implementation issues (i.e., sensor control, data transfer). Task 2 is to identify various concepts for sensor positioning and design schemes and select the best one. Task 3 is to build a benchtop prototype system based on the design selected in Task 2 to validate for optimal integration into the magnetic bars and performance (data collection and transfer, sensor resolution, defect sizing resolution, etc.). Finally, Task 4 is to summarize the results and propose potential solution(s) for implementing the new Hall sensors on the MFL module. Improving, refining, or adding to the options available with the Explorer family of robotic platforms benefits SoCalGas pipeline integrity.

Co-Funders: NYSEARCH Members

Start Date: 11/15/2021
End Date: 09/30/2022
Status: Active
2021 Funds Expended: **$23,900**
Total Project Cost: **$215,084**
Total SCG Cost: **$23,900**
Total Co-Funding: **$191,184**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

ILI-Based Generic External Corrosion Growth Rate Distribution for Buried Pipelines (EC-01-13)

The goal of this project is to provide the industry with generalized in-line inspection (ILI)-based corrosion growth rate distributions (not fixed values) and associated causal factors. The distributions will be based on actual data from successive ILI runs provided by Pipeline Research Council International (PRCI) members. The project will develop a probabilistic model for the estimation of corrosion growth rates via successive ILI runs. Analysis of in-the-ditch inspection data will be performed to determine statistical corrosion depth distributions. A review of literature for various corrosion growth rate estimation schemes will determine if any of the existing models can be utilized to supplement the successive ILI run comparisons. In 2021, operators started providing the data needed to build the model. The next step is to run the model to generate the generic external corrosion growth rate curves. A better understanding of corrosion rates along the pipeline would result in more accurate reassessment intervals. Member companies will be able to optimize re-assessment intervals for in-line inspections for metal loss.

Co-Funders: PRCI Members

Start Date: 06/23/2021
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$19,308**
Total Project Cost: **$193,662**
Total SCG Cost: **$19,308**
Total Co-Funding: **$174,354**
Benefits:

Improve Dent/Cracking Assessment Methods (PHMSA) (MD-5-2)

This project enhances previously developed tools which are currently being adopted by the American Petroleum Institute's (API) Recommended Practice (RP) 1183: Assessment and Management of Dents in Pipelines. RP1183 is designed to help maintain the structural integrity of pipelines by addressing mechanical issues. It gives operators the tools needed to ensure that pipeline infrastructure is safe, reliable, and efficient. The project objective is to improve API RP1183's ability to support Mechanical Damage integrity assessment and management by: (1) improving indentation crack formation strain estimates, (2) determining the impact of ILI dent and interacting feature sizing variation, and (3) defining dent fatigue life assessment safety factors. In 2021, the work completed included the evaluation of the impact of ILI dent and interacting feature sizing variations, dent fatigue life safety factor calculation for dents interacting with metal loss, and sample example calculations for restraint parameter dent fatigue life analysis. The next step is to complete the draft final report.

Co-Funders: PRCI Members, PHMSA

Start Date: 09/30/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$933**
Total Project Cost: **$459,643**
Total SCG Cost: **$1,576**
Total Co-Funding: **$458,067**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Improve ILI Sizing Accuracy (PHMSA) (NDE-4-19)

This project involves understanding the probability of detection of immediate pipeline defect conditions by In-Line Inspection (ILI). The industry target is 100% detection of critical integrity conditions. It is important to understand the probability of identifying immediate conditions. This will minimize the number of missed defects without increasing the number of false indications, optimize the number of excavations needed for operation pipeline safety, and allow for more efficient utilization of resources. The ILI Technology Providers completed the delivery of the ILI reports for the Initial (blind) Test in early December 2021. The ILI Technology Providers were asked to detect and characterize a blind set of metal loss anomalies to evaluate detection, identification, and sizing capabilities for each defect type. The ILI performance evaluation is in progress. Providers are currently comparing ILI results with their truth data counterparts. The next steps are to continue with ILI testing and to meet with ILI technology providers to evaluate gaps and identify any opportunities for improvement.

Co-Funders: PRCI Members, PHMSA

Start Date: 09/30/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$2,251,100**
Total SCG Cost: **$5,000**
Total Co-Funding: **$2,246,100**
Benefits:

Low Flow EMAT ILI Tool Demonstration (QIii)

Under previous research projects, electromagnetic acoustic transducer (EMAT) Sensors for Small Diameter and Unpiggable Pipe & Remaining Wall were developed for commercialization. Many In-line-Inspection (ILI) technologies use a Magnetic Flux Leakage (MFL) detection method to measure wall loss on metallic pipelines due to internal or external corrosion. This multi-phase project developed an EMAT sensor and robotic platform for small diameter unpiggable pipelines capable of identifying smaller defects than traditional MFL tools. Building upon this research, a free-swimming version of the tool has been developed. Free-swimming tools are an interest by subject matter experts as the tools are propelled by the flow of internal pipeline pressures. This project will demonstrate the capabilities of the 12" free-swimming EMAT tool with a field demonstration inspecting a SoCalGas pipeline. If the demonstration is successful, SoCalGas will have another option for performing pipeline inspections on pipelines unpiggable with traditional tools.

Co-Funders: N/A

Start Date: 11/26/2021
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$200,000**
Total SCG Cost: **$200,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

MEC Pig ILI Tool Design Study for Multiple Pipe Diameters (NDE-4-21)

The goal of this project is to explore using a Magnetic Eddy Current (MEC)-Pig that was developed for 8-inch-diameter pipelines with pipes of other diameters. The MEC-Pig developed for in-line inspection (ILI) has been successful in detecting small volumetric detects, spots that are hard to inspect, cracks in stainless steel, duplex materials, thick wall small-diameter gas lines, and plastic and concrete lined pipes. This project will look at applying the technology in a modular format covering 8-10", 12-16", 18-24", and over 24" pipes, as well as assess the technology's performance. The modular concept would decrease the number of Pigs needed for utilities with multiple diameter transmission pipes and could reduce capital costs for inspection. Since MEC technology is capable of inspecting pipes with linings or coatings, the technology has the potential for future application in pipes that are converted for hydrogen or other emerging fuels that use coatings to prevent corrosion or cracks. If successful, this project will decrease current inspection costs and improve pipeline integrity and provide a tool to meet future inspection needs. The project has been delayed due to contractual issues but is planned to start in early 2022.

Co-Funders: PRCI Members

Start Date: 11/02/2021
End Date: 05/02/2022
Status: Active
2021 Funds Expended: **$10,000**
Total Project Cost: **$95,969**
Total SCG Cost: **$10,000**
Total Co-Funding: **$85,969**
Benefits:

Modeling and Assessing PE Assets with 3D Scanning Technology

This project evaluates different use-cases for 3D scanning technology, particularly modeling Polyethylene (PE) fittings and PE failures to support the failure analysis process. SoCalGas has identified the following potential use cases: to model components where manufacturer drawings are not readily available, to model pipe or fittings *in situ*, and to model failures as an alternative to destructive testing. In 2021, the project team completed a laboratory assessment of the technology and initial field pilots. The 3D Scanner System successfully captured the deviation from the axis on fused plastic components. The time to prepare, scan, and process is dependent upon the complexity of the plastic asset but averages 30 minutes total. At the very minimum, when conducting field measurements on belowground facilities, the 3D Scanner System needs an 18-inch clearance as well as clearance from wrappings/tape. The team expanded the scope of work to include an *in situ* failed plastic component measurement in the field before asset removal. The team will compare the field measurements with traditional laboratory measurements. The outcome of this research will demonstrate the deviation from axis of belowground failed components before/after removal.

Co-Funders: N/A

Start Date: 10/30/2020
End Date: 04/06/2022
Status: Active
2021 Funds Expended: **$7,009**
Total Project Cost: **$23,589**
Total SCG Cost: **$23,589**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Modernize the Assessment of Pipeline Water Crossings (ENV-4-1A)

The objective of this project is to improve the capabilities of existing streamflow monitoring techniques and engineering assessment and risk tools which are used for managing the integrity of pipeline crossings over waterways and the planning of new crossings. The tasks include field verification of scour and erosion prediction for hydrology hydraulics and fluvial geomorphology; field validation of Vortex-Induced Vibration (VIV) initiation within waterways for pipeline limitations and VIV avoidance criteria; and building and testing of a prototype website-based alerts dashboard. This project may allow operators to determine which crossings require operational (e.g., monitoring) or engineering (e.g., mitigation) controls to lower the probability of future flooding hazards that can lead to containment loss, and to screen locations for future crossings. The results can supplement guidance for API RP 1133, Managing Hydrotechnical Hazards for Pipelines Located Onshore or Within Coastal Zone Areas. Seven final reports were delivered to PRCI members. These covered the development of risk assessment procedures and tools; additional hydrotechnical hazard pipeline integrity; monitoring techniques for determining critical return period flood alert triggers; potential monitoring techniques and technologies for real-time rainfall and flooding; fluvial geomorphology equations and mechanics; web-based monitoring dashboard; scour equations and field verification methods; and field validation of VIV initiation within waterways. Six of these were published. An eighth final report was drafted for the Field Validation of VIV Initiation Within Waterways and issued in December 2021 for review by the project sponsors.

Co-Funders: PRCI Members, PHMSA

Start Date: 01/01/2019
End Date: 09/30/2022
Status: Active
2021 Funds Expended: **$8,428**
Total Project Cost: **$740,035**
Total SCG Cost: **$24,119**
Total Co-Funding: **$715,916**
Benefits:

Monitoring Solution for Pipeline A/C Interference

Increasing energy demand has led many electric utilities to increase capacity. In some cases, this can cause AC interference and ground/earth faults, which occur when straying electrical current takes a pathway directly to the ground. This increases risk for buried gas pipelines within shared rights-of-way. These faults can also damage pipeline coatings. Thus, utilities need a wide variety of technologies and methodologies to identify and then mitigate or minimize any AC threats to pipeline integrity. SoCalGas's Integrity Management department is developing an AC interference procedure to identify, monitor, and mitigate this risk on segments along its pipeline. One of the key components in addressing AC interference is identifying powerline loading trends. Unfortunately, powerline load information is not readily available. This project will evaluate and demonstrate a technology that collects powerline load data independent of electrical utilities. The resulting data could support risk analyses to determine if AC interference events occurred and if there is a need for continual monitoring and/or mitigation. In addition, the data collected may be used with the AC PowerTool software developed in the OTD AC Earth Faults project completed earlier in 2021.

Co-Funders: N/A

Start Date: 12/14/2021
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$96,759**
Total SCG Cost: **$96,759**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

NJIT Advanced Terahertz (THz) Imaging & Spectroscopy for Non-Destructive Evaluation of Polyethylene Pipes (M2018-009 PhII)

Integrity assessment of polyethylene (PE) pipe butt-fusion (BF) joints has typically been performed via a visual inspection. Technology advancements may be useful in assessing the quality of questionable BF joints and may prevent unnecessary cutout of good BF joints with the appearances of a bad fusion. The objective of this research project is to continue the development of terahertz (THz) time-domain spectroscopy and imaging for the nondestructive evaluation of PE gas pipeline BF joints. Phase II focuses on evaluating the THz capability on BF joint samples that have inclusions at the acceptance criteria threshold. Extensive NDE inspections of specific PE joint defects containing lack of fusion have been performed. Advancement in the birefringent application to the THz NDE process has taken place with improved inspection procedures and analytical signal processing. In 2021, this project received specific PE joint samples containing the defect of lack of fusion to continue development and understanding of applying birefringent filtering to the THz NDE process.

Co-Funders: NYSEARCH Members

Start Date: 07/01/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$583,166**
Total SCG Cost: **$49,580**
Total Co-Funding: **$533,586**
Benefits:

Numerical Modeling and Full-Scale Testing to Evaluate the Performance of Large Scale Standoff Magnetometry (NDE-3-5)

This project builds upon the research performed in NDE-3-4. The research team evaluated the performance of Large Standoff Magnetometry (LSM) technology for pipeline integrity inspections using a test rig that introduced various combinations of loading into a pipe sample. These include internal pressure, axial tension/compression, and bending. The aim is to introduce loading representative of what might be encountered in a geohazard condition. The challenge with the current state-of-the-art LSM technology is the lack of validation data and fundamental research to support the use of LSM technology. In addition to full-scale testing, this project integrates a phase of work involving numerical modeling and laboratory testing. Previously a literature review of magnetic sensor technologies and commercially available products was completed. In 2021, numerical modeling and laboratory testing was completed, and a draft final report was issued for sponsor review.

Co-Funders: PRCI Members

Start Date: 06/12/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$9,680**
Total Project Cost: **$430,405**
Total SCG Cost: **$23,806**
Total Co-Funding: **$406,599**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Optimal Approach to Cost-Effective, Multi-source, Satellite Surveillance of River Crossings, Slope Movements and Land Use Threats to Buried Pipelines (GHZ-2-02)

Regulations require pipeline operators to mitigate geohazard and land use threats to pipeline integrity, particularly on slopes near river and stream crossings. In addition to applicable regulatory requirements, detecting and mitigating geohazard motion and right-of-way (ROW) land use encroachment threats are primary elements of pipeline operators' damage prevention strategies and programs. The goal of this project is to develop improved methods for satellite-based tools and technologies to enhance detection of natural changes, seasonal flooding, erosional effects, channel dynamics, and ground movement affecting pipelines installed near river crossings. Successful completion of this project will identify three leading classes of satellites available in the market to support pipeline integrity programs, enhance operators' risk mitigation programs through more frequent high-resolution detection of risk factors, and ROW surveillance. In 2021, the project continued with the synthetic aperture radar data acquisition for four sites. Validation of change results against field data and high-resolution optical data is underway. A final report was drafted to summarize the results and methods for monitoring of ROWs at river crossings along with the capabilities and limitations of satellite technology.

Co-Funders: PRCI Members

Start Date: 01/31/2018
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$330,814**
Total SCG Cost: **$10,267**
Total Co-Funding: **$320,547**
Benefits:

Pipeline Cleaning Tool for Liquids with Flow (M2017-006 PhII)

The Explorer is a robot capable of inspecting pipes that are difficult to inspect and allow the pipe to remain in service during inspection. However, when liquids are found in the pipeline, inspection must stop until the liquids are removed before proceeding with the inspection. With regulatory-driven due dates, delays in completing inspections can result in non-compliance. This research, if successful, will allow the inspection to be completed without the need to halt for liquid removal. InvoDane will develop and test the capability of the 20/26 Explorer robot to drive and scan through accumulated liquid in the natural gas pipelines. Pre-commercialized liquid-capable drive tracks and magnet bars to implement onto an Explorer 20/26 robot will be designed and tested. InvoDane expects to retrofit an Explorer 20/26 robot with the liquid-capable drive tracks and magnet bars to be used in future commercial inspections with liquid in the pipeline and the modules for future generation robots. SoCalGas could potentially use this explorer for inspecting our natural gas system infrastructure.

Co-Funders: NYSEARCH Members

Start Date: 05/06/2021
End Date: 09/30/2022
Status: Active
2021 Funds Expended: **$79,765**
Total Project Cost: **$339,000**
Total SCG Cost: **$79,765**
Total Co-Funding: **$259,235**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Remaining Life Model and Assessment Tool for Dents and Gouges (MD-4-16)

The objective of this project is to produce a level 1-2 assessment model to analyze fatigue crack growth and predict the fatigue life of mechanical damage from dents and gouges caused by cyclic pipeline operating pressures. The desired outcome of this project is the ability to manage the threat of dents and gouges in pipelines in a prioritized manner and reduce overall cost. The outcome is intended to bridge a current gap in the ability to quantitatively assess fatigue life at dents and gouges in pipelines. The deliverable will be a computer-based assessment tool that will interpret and screen in-line inspection (ILI) and nondestructive examination data. Previously, a technical literature review to identify gaps and an initial model algorithm which confirmed the feasibility of the project was completed. In 2021, the project team determined that dent formation under zero internal pressure was not a factor of concern in crack growth and the fatigue life of mechanical damage. The feasibility study did, however, identify that dent shape from ILI and the strain path to that shape and residual stress are factors, even though many non-unique paths exist for a given dent shape. Based on those findings, the project team started testing and building a model based on dent shape and its strain and residual stress to develop a life model assessment tool. Once developed, the model will undergo validation testing. The results of this project will benefit SoCalGas' integrity management program by enabling the company to prioritize maintenance and repair.

Co-Funders: PRCI Members

Start Date: 02/04/2019
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$351,232**
Total SCG Cost: **$4,679**
Total Co-Funding: **$346,553**
Benefits:

Remote Monitoring of Pipe-to-Soil Readings, AMI Network Integration (5.21.g)

Federal regulations require gas utilities to perform periodic monitoring on the CP system for their steel pipelines. The monitoring requires technicians to manually take pipe-to-soil (P2S) voltage measurements on-site to assess the effectiveness of their CP system and to determine if mitigative measures are needed to correct abnormal conditions. There are commercial P2S monitoring systems that use cellular communications to transmit data from remote locations. This project will assess the use of an existing utility's automated metering infrastructure (AMI) communication system and low-power area wide network (LoRaWan) to decrease the labor cost of monitoring the CP system. The technology will also offer utilities the capability to perform monitoring of their CP systems more frequently. The project team plans to set up the network and measuring device at Gas Technology Institute or a member utility facility for testing. A final report intended to provide procedures for integrating a remote CP monitoring system with an AMI/LoRaWan network will be prepared. This project has experienced delays due to bids from project contractor(s) coming in significantly higher than original proposals. The project is on hold pending a meeting with project sponsors to discuss the options of rescoping or cancelling the project.

Co-Funders: OTD Members

Start Date: 01/31/2021
End Date: 04/30/2022
Status: Active
2021 Funds Expended: **$13,976**
Total Project Cost: **$157,000**
Total SCG Cost: **$13,976**
Total Co-Funding: **$143,024**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Selective Seam Weld Corrosion Detection with In-line Inspection Technologies (NDE-4-13)

The objective of this project is to evaluate and validate magnetic flux leakage (MFL) technologies currently in use by In-Line Inspection (ILI) vendors for detecting selective seam weld corrosion (SSWC). SSWC is a type of corrosion that affects the bondline region and heat-affected zone of the longitudinal seam of a pipeline, forming grooves in the seam. Circumferential MFL technologies can detect the long-seam weld position and accurately detect the presence of corrosion on the long seam. These tools are not generally able to differentiate between SSWC and coincidental corrosion. As technologies and analysis processes have improved, however, ILI providers are better able to detect SSWC. This project will provide pipeline operators with up-to-date knowledge about ILI capabilities to detect SSWC and differentiate it from coincidental corrosion interacting with the long seam weld. This knowledge will help them make informed decisions about managing pipelines with SSWC or corrosion. In 2021, the project team collected pipe samples from utilities with SSWC for testing, but the number of samples was insufficient. The team proposed an alternative approach and received approval to create testing samples by fabricating SSWC samples in the lab. Design of the sample sets was completed in 2021. Manufacturing of the samples will take place in 2022. The results of this project could provide utilities with a tool for detecting SSWC in their pipelines, thereby improving safety and reliability.

Co-Funders: PRCI Members

Start Date: 10/06/2020
End Date: 09/30/2022
Status: Active
2021 Funds Expended: **$18,177**
Total Project Cost: **$810,000**
Total SCG Cost: **$34,713**
Total Co-Funding: **$775,287**
Benefits:

Standard Library of PE Joint Samples with Embedded Defects for NDE Tool Validation – Phase I-a (M2019-009)

The objective of this project is to produce a polyethylene (PE) pipe butt-fusion (BF) joint sample library of joints with known defects. The database could be used to validate current and future NDE technologies claiming to be capable of detecting PE butt fusion defects applicable to the gas industry. NYSEARCH members have invested considerable resources into NDE development through extensive testing with The Welding Institute. A sample library will provide a resource to validate any NDE tool purported to be capable of identifying defects that would impact the integrity of BF joints. In 2021, the designed and fabricated PE joint defect samples were shipped to NYSEARCH and then distributed to various projects where different NDE technologies are being developed and validated.

Co-Funders: NYSEARCH Members

Start Date: 10/10/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$545,200**
Total SCG Cost: **$48,465**
Total Co-Funding: **$496,735**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Technology Development Center (TDC-1-1 & 1-A)

This project provides support for the new Pipeline Research Council International Technology Development Center (TDC) in Houston, Texas which opened in the summer of 2015. The TDC is the result of a major commitment by the energy pipeline industry to address the key issues the industry is facing to ensure the safety and integrity of the vital national and international steel pipeline infrastructure. The TDC provides the industry with an independent third-party site to thoroughly describe the capabilities of current pipeline inspection tools and to guide the development of new technologies needed to push toward the pipeline safety and integrity goal. The TDC enables efficient and timely access to industry samples in support of technology projects and programs. In 2021, The TDC was utilized by PRCI projects, for example, NDE-4-18 Validate ILI Capabilities to Detect/Characterize Mechanical Damage.

Co-Funders: PRCI Members

Start Date: 01/01/2015
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$7,389**
Total Project Cost: **$3,440,727**
Total SCG Cost: **$42,709**
Total Co-Funding: **$3,398,018**
Benefits:

Unmanned Aerial System RD&D

This project was initiated to develop, demonstrate, and provide additional tools and support to pipeline operations through assessment of the aerial imagery potential of small, unmanned aircraft system (sUAS) photography in both difficult-to-access and demanding environments. SoCalGas has demonstrated success as an early adopter of several sUAS applications. Through the systematic application of manufacturer demonstration and laboratory and field testing, the project team addressed many complex issues, including obstacle sensing capabilities, dim lighting photography, potential satellite interference, remote videography, and data handling. The project successfully completed proof-of-concept testing using high-resolution videography and Light Detection and Ranging, a state-of-the-art 3D mapping tool more commonly known as LiDAR, to capture a record of pipeline routes, construction sites, and open trenches. The knowledge gained during this project served as the foundation for on-going sUAS efforts supporting SoCalGas' Leakage Abatement Program.

Co-Funders: N/A

Start Date: 01/01/2018
End Date: 12/14/2021
Status: Completed
2021 Funds Expended: **$26,053**
Total Project Cost: **$440,248**
Total SCG Cost: **$440,248**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Validate In-Line Inspection (ILI) Capabilities to Detect/Characterize Mechanical Damage (PHMSA) (NDE-4-18)

This project expands the current state of knowledge for In-Line Inspection (ILI) system performance to detect and characterize corrosion, welds, gouges, and crack features interacting with dents in the system. This project will develop representative interacting features that will be used to provide an understanding of current ILI tool performance and support improvements in ILI system performance and specifications. The project will generate data to support the development of revised dent response criteria being pursued in Pipeline Research Council's (PRCI) research and development projects. Additionally, it will address recommendations issued to Pipeline and Hazardous Materials Safety Administration (PHMSA) by the National Transportation Safety Board to promulgate new regulations that address dent acceptance criteria. For the PHMSA co-funded work, two strings have been fabricated and assembled at PRCI Technology Development Center facilities. A gauge pig was run through the strings in December 2021. Discussions are underway with ILI vendors about test protocol and test trials which are anticipated to start early 2022. The project is behind schedule due to difficulties in logistics and staff availability resulting from the pandemic. The final project schedule will be confirmed once contracts with ILI vendors for trial schedule and delivery of data have been finalized.

Co-Funders: PRCI Members, PHMSA, Others

Start Date: 09/30/2019
End Date: 03/21/2022
Status: Active
2021 Funds Expended: **$16,125**
Total Project Cost: **$3,012,542**
Total SCG Cost: **$25,722**
Total Co-Funding: **$2,986,820**
Benefits:

Validating Non-Destructive Tools for Surface to Bulk Correlations of Yield Strength, Toughness, and Chemistry (4.14.c.2)

Non-destructive surface testing (NDST) techniques - such as micro-indentation, micro-machining, *in situ* chemistry, and replicate microscopy analysis – can be used to measure the surface and bulk chemistry; surface and bulk mechanical properties (yield and tensile strength, toughness, hardness); and surface and bulk metallurgical grain size of pipeline steels. NDST techniques are of interest because they do not require a pipeline to be taken out of service or require the destructive cut-out of samples from an in-service pipeline. Pending Department of Transportation/Pipeline Hazardous Materials Safety Administration (DOT/PHMSA) regulations would require natural gas pipeline operators to backfill material property records for grandfathered pipeline segments and/or segments with inadequate material records. SoCalGas would benefit from using NDST techniques to comply with such regulations. The objective of this project was to evaluate and validate the accuracy, efficiency, and cost-effectiveness of NDST tools. A Technical Advisory Panel was formed, consisting of the sponsors, the technical team, and eight pipeline operators to refine the project scope, and a project database, pipeline sample library and test matrix were developed. Data analysis and modeling methods were developed, executed, and optimized. NDST toughness evaluation on yield and tensile strength; fracture toughness measurement of the thirty pipe coupon samples; and model generalization and optimization were completed. The final report was published in September 2021.

Co-Funders: OTD Members, PHMSA, Others

Start Date: 09/03/2018
End Date: 08/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$1,054,516**
Total SCG Cost: **$57,874**
Total Co-Funding: **$996,642**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Validation of NDT Technology for PE Pipe (5.20.p)

In this project, the team evaluates the claims of commercially available nondestructive testing (NDT) technologies for polyethylene (PE) pipe and fitting joints. This evaluation includes heat fusion (e.g., butt and sidewall) and electrofusion (e.g., couplings, branch fittings, service tees, etc.) pipe joining methods. It is imperative that industry stakeholders understand the capabilities and limitations of the various NDT technologies to determine whether the technologies are reliable for determining joint integrity. In 2021, a survey was issued to gather information on sponsors' current use of NDT technologies on PE fusion joints. A workshop was held with stakeholders to review the capabilities of existing NDE technologies and to develop a roadmap for next steps in evaluating them. Following the roadmap developed by stakeholders in the workshop, the types of the test samples were chosen. Several NDT technology vendors have shown interest in participating in this study. Based on recent communications with vendors and the methods they use, however, it was determined that appropriate acceptance criteria for test samples should first be developed. Consequently, it has been determined that to provide meaningful evaluations of NDE technologies this project should be re-scoped. The project team plans to gather further information on past work that vendors currently reference to support their inspection methods and develop a new plan to properly obtain the probability of detection for any given NDE method.

Co-Funders: OTD Members

Start Date: 10/01/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$6,054**
Total Project Cost: **$200,000**
Total SCG Cost: **$17,054**
Total Co-Funding: **$182,946**
Benefits:

Xray and Terahertz Development for NDE of PE Pipe by Iowa State University (M2019-007 Phase II)

The results of Phase I demonstrated the capability of X-ray radiography for polyethylene (PE) pipe inspection and paved the way to optimize a portable X-ray system in future phases of the project. X-ray radiography and computed tomography were shown to be complementary to terahertz (THz) methods in different aspects of PE pipe inspections. The objective of Phase II is to advance Iowa State University THz and X-ray NDE technologies with enhanced techniques that can interpret PE butt-fusion (BF) joint defects with 2D and 3D reconstruction imaging. THz and X-ray contour-following fixture construction will be performed, and defective BF samples will be developed and used for scanning, evaluating, and further developing the 2D and 3D scan data interpretation for each defect type. In 2021, the project team worked on redesigning the testing facilities to better handle the testing planned under the project. The project is awaiting The Welding Institute defected BF joint samples to begin testing.

Co-Funders: NYSEARCH Members

Start Date: 01/20/2021
End Date: 01/31/2023
Status: Active
2021 Funds Expended: **$45,400**
Total Project Cost: **$407,019**
Total SCG Cost: **$45,400**
Total Co-Funding: **$361,619**
Benefits:

CLEAN TRANSPORTATION

SUB-PROGRAM: OFF-ROAD

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Arthur D Little Turning Ontario Airport into a Hydrogen Ecosystem Assessment

The objective of this project is to evaluate challenges and opportunities in establishing Ontario International Airport as a hydrogen ecosystem. Hydrogen has significant potential to advance sustainable transportation and aviation, and airports have unique potential to support these advancements. Airport hubs could provide a reliable and resilient supply of electricity for airport facilities, electric vehicle (EV) charging, and battery electric aviation and transportation. The advent of hydrogen and its large-scale use will likely challenge airports to revolutionize infrastructure design and operation. While hydrogen likely will not be used for long-haul aviation on a significant scale before 2050, development of regional and shorter-range zero-emission electric and hydrogen aircraft is expected to be well established by 2035. Furthermore, California has mandated that all new passenger cars and trucks, as well as all drayage and cargo trucks and off-road vehicles and equipment sold in the state, be zero-emission by 2035. This project kicked off in late 2021. The team has identified three key considerations of the assessment. The assessment will: 1) analyze the total energy demand and fuel consumption needed to support zero-emission aviation and transportation; 2) address opportunities and challenges for the deployment of electric and hydrogen aircraft and vehicles; and 3) identify associated infrastructure needs to support the growth of zero-emission transportation. A technical advisory committee will be formed to coordinate among industry experts, utilities, city and community leaders, and local, state, and federal agencies.

Co-Funders: N/A

Start Date:	08/31/2021
End Date:	03/31/2022
Status:	Active
2021 Funds Expended:	**$384,500**
Total Project Cost:	**$409,500**
Total SCG Cost:	**$409,500**
Total Co-Funding:	**$0**
Benefits:	

CALSTART Hydrogen Zero Emission Tugboat Design

CALSTART has assembled a consortium of leading maritime stakeholders to design a hydrogen fuel-cell-powered zero emission tugboat and supporting plans for refueling infrastructure. The consortium includes the following industry leaders: DNV-GL, ABB, Ballard, Chart, Crowley, Jensen, the Port of Los Angeles, and the South Coast Air Quality Control District. CALSTART submitted a proposal in response to the California Energy Commission's GFO-20-604: Hydrogen Fuel Cell Demonstrations in Rail and Marine Applications at Ports (H2RAM) solicitation for Group 3: Design and Feasibility Study of Fuel Cell-Powered Commercial Harbor Craft. Tugboats are an essential component of port operations. Tugboats assist cargo vessels, tankers, and barges in and out of port complexes, and play a role in other applications such as firefighting. Tugboats have extreme power-tonnage ratios, typically two to four times that of normal cargo or passenger ships, and often feature two of each critical part for redundancy. They are highly maneuverable and use diesel engines that produce anywhere from 600 hp to over 20,000 hp and consume over 15,000 gallons of diesel fuel per month. A zero emissions tugboat will advance state and national greenhouse gas emissions reductions goals.

Co-Funders: CALSTART, CEC

Start Date:	01/01/2021
End Date:	12/31/2023
Status:	Active
2021 Funds Expended:	**$100,000**
Total Project Cost:	**$623,309**
Total SCG Cost:	**$100,000**
Total Co-Funding:	**$523,309**
Benefits:	

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GGZEM Harbor Craft Demonstration

In this California Energy Commission funded project, Golden Gate Zero Emission Marine (GGZEM) aims to develop and demonstrate a small, fast, hydrogen fuel cell powered, rigid inflatable boat for a variety of harbor craft use cases. GGZEM further proposes to develop and deploy supporting mobile and portable hydrogen fueling solutions. GGZEM will demonstrate the vessel for six months in San Francisco Bay and Long Beach harbor. The project team will integrate a hydrogen fuel cell used by the automotive industry with a small, approximately 25-foot, commercially available rigid inflatable boat. Vessels under 40 feet in length have a wide variety of uses, including patrol, fire and rescue, fishing, pilot, excursion, ferry and taxi, and recreation. Developing a zero-emission hydrogen fuel cell vessel could help reduce emissions and improve air quality in and around harbors and ports. The vessel will be fueled through novel mobile, portable systems developed by GGZEM for marine vessel fueling and built through the project, using hydrogen sourced from California's retail hydrogen stations. GGZEM will apply their knowledge and experiences from the existing CARB funded 84-passenger hydrogen ferry project to this development. The project contracting was wrapped up in 2021, and work will commence in early 2022.

Co-Funders: CEC, Ocean5 Naval Architects, ZEI

Start Date: 01/01/2021
End Date: 11/31/2025
Status: Active
2021 Funds Expended: **$100,000**
Total Project Cost: **$3,401,178**
Total SCG Cost: **$200,000**
Total Co-Funding: **$3,201,178**
Benefits:

GTI Doosan Hydrogen Drone Demonstration

The objective of the project is to demonstrate Doosan Mobility Innovation's (DMI) hydrogen drones for a variety of applications and evaluate supporting infrastructure needs. The demonstration makes use of two demonstration drones located in Dallas, Texas. The team will demonstrate the drones for: 1) natural gas pipeline inspection; 2) commercial applications such as package delivery and law enforcement activities; 3) demonstration at Austin, Texas as part of H2@Scale Texas and Beyond; and 4) the assessment of DMI's hydrogen infrastructure plans and training to support the drones. Hydrogen drones offer significant benefits compared to their battery electric counterparts. When compared to battery electric drone standards, hydrogen fuel celled drones achieve two additional hours of flight time and drastically reduced refueling times. The new technology is limited by its supporting infrastructure. This project will provide safety protocols, and determine best fueling methods for fueling at commercial hydrogen stations or alternative infrastructure for adoption of hydrogen drones across the United States. The drone was successfully demonstrated to small audiences in Austin, Texas and in Pico Rivera, California. The full demonstration with SoCalGas' Aviation Service Group will commence in 2022 to evaluate hydrogen drones for utility specific needs.

Co-Funders: N/A

Start Date: 09/30/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$170,000**
Total Project Cost: **$250,000**
Total SCG Cost: **$250,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI Hydrogen Fuel Cell Switcher Locomotive Demonstration

GTI and Sierra Northern Railway will design, build, and demonstrate a hydrogen fuel cell, zero-emission, switcher locomotive in the seaport of West Sacramento. The project was awarded funding by the California Energy Commission's (CEC) Grant Funding Opportunity GFO-20-604: Hydrogen Fuel Cell Demonstrations in Rail and Marine Applications at Ports (H2RAM), Group 1: Fuel Cell Demonstrations in Switcher Locomotives and Commercial Harbor Craft. Sierra Northern Railway will replace the diesel engine of a switcher locomotive with a hydrogen fuel cell, eliminating 10,000 gallons of diesel fuel use per year. This will improve local air quality and eliminate corresponding greenhouse gas emissions. The locomotive will be demonstrated on Sierra Northern Railway's short-line operations which serve the railyard and seaport in West Sacramento. It will remain in service after the demonstration period. The integration of advanced fuel cell and battery technologies represents a new platform that will enable commercialization within a few years. The project is in its earliest stages of activity, and ork is progressing to remove legacy diesel drivetrain, to design the fuel cell integration, and to acquire equipment for integration.

Co-Funders: Ballard/Ricardo, CEC, GTI, Railpower, Sierra Northern Railway, SMAQD, UCD, Valley Vision

Start Date: 01/01/2021
End Date: 12/31/2025
Status: Active
2021 Funds Expended: **$179,166.62**
Total Project Cost: **$9,272,470**
Total SCG Cost: **$537,499**
Total Co-Funding: **$8,734,971**
Benefits:

GTI Hydrogen Fuel Cell Yard Truck Port of Los Angeles Demonstration

The objective of this project is to develop and demonstrate the reliability, performance, durability, and total cost-of-ownership of a yard truck fleet at the Port of Los Angeles. This deployment and demonstration is the first of its kind and will pave the way for similar future technologies in this space. Hydrogen fuel cell vehicles have been gaining attention in the transportation space as manufacturers and legislatures look for alternative fuels and technologies to help California meet its goals to reduce greenhouse gas emissions, criteria air pollutants, and toxic air contaminants in freight movement. There will be an extensive technology showcasing effort to maximize the impact of the demonstration. Yard trucks are the single largest source of emissions in all classifications of cargo handling equipment. The project is intended to demonstrate to port terminal operators that fuel cell powered, zero-emissions yard trucks are a safe, reliable, and operationally optimal solution to meet the port's clean air action plan. Two trucks are in demonstration with TraPac. A temporary refueling station was commissioned to replace mobile refueling. The temporary station offers higher efficiency and operational uptime than the original mobile refueler. Upon completion of the demonstration, the project team will report its findings.

Co-Funders: CARB, Others

Start Date: 01/01/2019
End Date: 07/01/2022
Status: Active
2021 Funds Expended: **$111,152.06**
Total Project Cost: **$12,055,413**
Total SCG Cost: **$322,500**
Total Co-Funding: **$11,732,913**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

SUB-PROGRAM: ONBOARD STORAGE

GNA Tri-Generation Feasibility Phase 1 Assessment

Start Date: 06/30/2018
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$48,000**
Total SCG Cost: **$48,000**
Total Co-Funding: **$0**
Benefits:

SoCalGas engaged Gladstein, Neandross & Associates to analyze the potential economic case for the use of a high temperature fuel cell to produce electricity and hydrogen from renewable natural gas (RNG) delivered by pipeline for transportation applications. This "tri-generation" system is based on the FuelCellEnergy SureSource 3000 molten carbonate fuel cell system that produces up to 3,000 kW gross DC output and 1,270 kg/day of hydrogen production. The system additionally produces 0.5 MMBTU/hour of thermal output, which is not considered in this analysis. The system model considers hydrogen fueling at up to 700 bar, DC fast charging of electric vehicles, and net export of electricity to the grid. The analysis includes 10 scenarios: 1) no grid demand with Bioenergy Market Adjusting Tariff (BioMAT); 2) no grid demand without BioMAT; 3) no EV charging with BioMat; (4) no EV charging without BioMat; 5) net metering; 6) steam methane reforming (SMR) only; 7) no grid demand without BioMAT and 0% RNG; 8) no EV charging without BioMat and 0% RNG; 9) net metering and 0% RNG; and 10) SMR Only 0% RNG. These scenarios allow the team to evaluate the economics of various uses for produced electricity including net metering, EV charging, and sale to the grid under the BioMAT program. The scenarios that assume 0% RNG-use result in lower delivered hydrogen prices than their equivalent scenario using RNG. Incremental cost increases from the use of RNG averages $4.40/kg for every additional $10 that the RNG price exceeds the cost of fossil natural gas per MMBTU. This incremental cost reduces to $1.50 per kg for every $10/MMBTU of RNG cost under the SMR scenarios because more of the RNG converts to hydrogen in the SMR scenarios compared to the Tri-gen scenarios.

Co-Funders: N/A

Ingevity ANGP Ford F-150 Medium Duty Truck Demonstration

Start Date: 10/16/2018
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$34,900**
Total Project Cost: **$250,000**
Total SCG Cost: **$250,000**
Total Co-Funding: **$0**
Benefits:

Ingevity demonstrated a bi-fuel truck outfitted to run on renewable natural gas (RNG) stored as adsorbed natural gas (ANG) and gasoline. This ANG-RNG truck relies upon Ingevity's patent-protected, activated-carbon technology for low-pressure storage of: (a) low-grade renewable natural gas (RNG), and (b) high-grade natural gas enriched with renewable hydrogen, on an automotive ANG tank. At ambient temperatures and an operating pressure of 900 pounds per square inch gauge (psig), an ANG storage vessel can hold approximately twice as much RNG as an identically sized tank using conventional compression at 900 psig. The truck was demonstrated over a 12-month period with a local waste-disposal and recycling service customer. In comparison to a conventional gasoline-powered truck, a bi-fuel truck can offset more than 1,200 gallons of gasoline and reduced greenhouse gas emissions by 9.2 metric tons of carbon-dioxide equivalents per year - a reduction of 36%. Due to a favorable price differential of $2.45 per gasoline gallon equivalent between RNG and gasoline, the demonstration partner was able to reduce their fuel costs by 53% during the demonstration, approximately $3,000. Ingevity has commercialized the product and is expanding the technology to vans and other fleets throughout the nation.

Co-Funders: N/A

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Sandia National Labs Metal Hybride Composite Hydrogen Storage for Heavy Duty Vehicles

The objective of this project is to evaluate metal hydride composites as a materials-based storage medium to replace high-pressure hydrogen gas storage on Class 7 and 8 heavy-duty fuel cell electric trucks. The thermodynamic and kinetic properties of metal hydrides allow them to fully regenerate following hydrogen desorption at pressures much lower than 700 bar. For example, metal amides that will be considered in this project can be regenerated at 100 bar, much lower than current onboard high-pressure hydrogen storage tanks (350 bar or 700 bar). Using lower pressure hydrogen could translate into more efficient storage tank designs that weigh and cost less than current high-pressure steel hydrogen storage tanks. Low pressure hydrogen for vehicles can also increase reliability and reduce compression costs at refueling stations by utilizing lower pressure compressors. An additional benefit is that knowledge generated by this project could assist in development of material-based storage for stationary applications such as microgrids and backup power for data centers. Sandia National Laboratory is still conducting its analysis. The scope was expanded to include the exploration of the use of material-based hydrogen storage for rail.

Co-Funders: N/A

Start Date: 11/30/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$200,000**
Total Project Cost: **$575,000**
Total SCG Cost: **$575,000**
Total Co-Funding: **$0**
Benefits:

UTD Next Generation NGV Driver Information System (2.20.F)

The objective of this project is to develop and demonstrate a next-generation natural gas vehicle (NGV) driver information system which provides an accurate miles-to-empty estimate for the vehicle. This is particularly challenging in gaseous-fueled vehicles because the gas sees wide ranges of temperature fluctuation as the pressure changes during fueling and engine operation. UTD's co-funding will leverage the objectives of a separate prime contract award to GTI by the U.S. Department of Energy (DOE) that provides $1,000,000 in federal funds plus $1,000,000 of in-kind partner support. GTI will model the thermodynamics of the vehicle tank(s), the key technical hurdle for this project. Our partner at Argonne National Lab will adapt a previously developed NGV fleet navigation application to utilize the miles-to-empty data to optimize fleet efficiency. At the conclusion of the DOE project, the team will engage potential commercial partners for licensing opportunities.

Co-Funders: UTD

Start Date: 01/01/2021
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$7,700**
Total Project Cost: **$250,000**
Total SCG Cost: **$7,700**
Total Co-Funding: **$242,300**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Technical Support for Clean Transportation Testing, Performance, and Safety (2.21.I)

The objective of this project is to provide technical support for critical clean transportation testing, performance, and safety efforts. These efforts include (but are not limited to) monitoring and participating in relevant compressed natural gas (CNG) and natural gas vehicle (NGV) developments as well as continuing to provide technical expertise to the NGV America (NGVA) Technology & Development Committee. Key updates include a Cummins announcement of the industry-changing 15-Liter natural gas engine for North America. They did this during NGVA's Fourth Quarterly NGV Technology Webinar this year. The webinar provided an in-depth look at the new 15 L engine as well as their developments on hydrogen internal combustion engines. NGVA Annual Meeting and Industry Summit was held in Phoenix, AZ on October 19-21. Safety issues with a Mainstay CNG Module led to a safety bulletin by the Technology and Development Committee. NGV safety incidents are discussed, and root causes are investigated each quarter; additional details on specific incidents are included in this report. GTI continues to focus significant effort on CSA NGV 4.3 (Temperature compensation guideline for compressed natural gas vehicle fueling). GTI is serving as vice-chair of the committee.

Co-Funders: UTD

Start Date: 07/01/2021
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$2,200**
Total Project Cost: **$125,000**
Total SCG Cost: **$2,200**
Total Co-Funding: **$122,800**
Benefits:

SUB-PROGRAM: ON-ROAD

A1 Alt Fuels Fuel Cell Electric Paratransit Shuttle Demonstration

A1 Alternative Fuel Systems will develop and demonstrate four fuel cell electric vehicles at Sunline Transit for 12 months. The vehicles include two class 4 medium paratransit shuttles, a low floor (kneeling) Ford F-53, and a standard floor Ford E-450 The paratransit shuttles will be capable of 175 – 250-mile range per fill up. In addition to the demonstration, A1 Alternative Fuel Systems will test and certify the shuttles at the Altoona Test Center as well as for CARB on-road use. This project will help shuttle and transit fleets meet the California Zero Emission Bus Regulations and upcoming California Zero Emission Truck regulations within the required timeframe. The high-pressure fuel cell system used for the shuttle will be designed to easily integrate into other vehicle types that use the same Ford chassis. Ford's innovative design allows fleet operators to order a factory-built Ford cab and chassis which can be configured as a wide variety of vehicle types such as delivery trucks, work trucks, shuttles, and vans.

Co-Funders: A-1 Alternative Fuels, Hometown, Plug Power, SCAQMD, SEA Electric, Sunline Transit, Turtle Top, Worthington

Start Date: 05/20/2021
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$487,500**
Total Project Cost: **$2,086,608**
Total SCG Cost: **$531,166**
Total Co-Funding: **$1,555,442**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

CALSTART Class 8 Hydrogen Fuel Cell Truck Commercialization Roadmap

The objective of this project is to develop two roadmaps to supplement and support the deployment and demonstration of a CEC funded Cummins Hydrogen Fuel Cell Class 8 Truck for drayage and regional delivery.. The roadmaps to be developed are the Technology Commercialization Roadmap and the Medium- and Heavy-Duty (MD/HD) Hydrogen Fueling and Infrastructure Roadmap, The Technology Commercialization Roadmap will provide market projections and describe market scenarios for the new truck technology. It will also compare fuel cell trucks to equivalent battery-electric vehicles to explore differences in cost, emissions, performance, and operational success between these two zero-emission solutions. The MD/HD Hydrogen Refueling and Infrastructure Roadmap will provide recommendations for strategically locating hydrogen fueling infrastructure and estimate future hydrogen demand for the medium- and heavy-duty trucking industry. It will also analyze the viability of various hydrogen production and delivery pathways to compare centralized production with trucked hydrogen, pipeline delivery of hydrogen, and distributed/onsite production. Both roadmaps are expected to be released by the end of 2022.

Co-Funders: N/A

Start Date: 04/30/2020
End Date: 04/30/2022
Status: Active
2021 Funds Expended: **$166,000**
Total Project Cost: **$216,000**
Total SCG Cost: **$216,000**
Total Co-Funding: **$0**
Benefits:

CALSTART CNG Hybrid Class 8 Truck Demonstration

This study is part of a larger California Energy Commission (CEC) project for Kenworth Truck Company that identified the business case for electric heavy-duty trucks with range extenders. This is an ideal target for alternative fuel technologies. The I-710 corridor runs through a heavily populated area and the pollutants emitted by the drayage vehicles pose significant public health risks to the people living near the corridor. The project team has identified the roll-out plan, early adopters of near-zero-emission heavy-duty trucks, and plans for expansion into other applications. This study serves to update the findings CALSTART released in its 2014 report titled, ***Near Zero-Emission Heavy-duty Truck Commercialization Study***. It further provides a comprehensive analysis of possible outlooks for the drayage truck market in 2035 dependent on a variety of factors. As part of the technology demonstration of the CEC project, CALSTART worked with BAE Systems and Kenworth to demonstrate the performance of a compressed natural gas (CNG), plug-in hybrid-electric drayage truck. The vehicle was tested against two baseline vehicles, a PACCAR CNG vehicle and a Mack diesel vehicle. Three data streams were collected to evaluate the vehicle's performance, emissions, and user acceptance. The Plug-In Hybrid adequately performed the standard drayage duty cycle, completed most trips that the baseline vehicles were able to, reached a maximum daily range of 285 miles (compared to 400 miles), and demonstrated an increase in fuel efficiency. The vehicle was very popular with the drivers and was highly praised during the user acceptance interviews. Due to the inconclusive nature of some of the results and the issues faced during the demonstration, further testing and evaluation is recommended.

Co-Funders: SCAQMD, California Energy Commission, DOE

Start Date: 06/16/2015
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$20,259,820**
Total SCG Cost: **$250,000**
Total Co-Funding: **$20,009,820**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI CNG Plug-In Class 8 Hybrid Truck Development and Demonstration

The objective of this project is to develop and demonstrate a more efficient and optimized energy management platform and controls for natural gas, plug-in, hybrid-electric Class 8 trucks. The Class 8 truck was designed to have improved engine management and controls to optimize fuel economy, with the goal of extending the range and reducing the greenhouse gas emissions. The vehicle was tested against two baseline vehicles, a PACCAR compressed natural gas (CNG) vehicle and a Mack diesel vehicle. Three data streams were collected to evaluate the vehicle's performance, emissions, and user acceptance. Performance data on the Plug-In Hybrid were collected by Kenworth's own telematics system, while data for the two baseline vehicles were collected from a DataHub provided by ViriCiti. Together, these two data streams provided performance data which allowed the project team to analyze the vehicle's ability to perform its duty cycle. Sensors Inc. was contracted to perform Portable Emissions Monitoring System testing on each of the project vehicles and determine the emissions of each. Finally, user acceptance interviews were conducted with some of the vehicle operators and management to determine how the vehicle was perceived by fleet management and individual operators. The final report is under review with the project team and is expected to be published in late 2022.

Co-Funders: CEC, CWI, FEV, US Hybrid

Start Date: 11/01/2019
End Date: 08/31/2022
Status: Active
2021 Funds Expended: **$64,500**
Total Project Cost: **$1,764,631**
Total SCG Cost: **$161,250**
Total Co-Funding: **$1,603,381**
Benefits:

SCAQMD and WVU Alternative Fuel Vehicle Maintenance Study

The objective of this project is to study maintenance-related efforts and corresponding costs of medium- and heavy-duty vehicle engines powered by various alternative fuels across various vocations. The alternative fuels considered in this study are natural gas, propane, electric, and high biodiesel blends This maintenance cost assessment considers the link between operational characteristics of alternative fuel vehicles and how these characteristics affect maintenance and repair activity. The team has proposed to perform a comparative evaluation of vehicle maintenance costs between natural gas and diesel fueled vehicles. Vehicles included in the analysis are Class 6, 7, and 8 vehicles used in goods movement and delivery vocations. The project team will use vehicle maintenance costs of already available fleet information, real-world vehicle activity, and in-use emissions data from another study upon which this project builds. The team further leverages emissions and activity data previously collected and relationships already established in the previous study. In the previous study, in-use emissions were collected for a comprehensive sample of more than 200 trucks and buses from 25 fleet participants in five vocations.

Co-Funders: DOE, SCAQMD

Start Date: 01/01/2020
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,335,682**
Total SCG Cost: **$150,000**
Total Co-Funding: **$1,185,682**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

SCAQMD Ford 7.3L Near-Zero Emission Engine Development

The objective of this study is to develop and commercialize the Ford 7.3L compressed natural gas (CNG) near-zero emission (NZE) Engine for medium-duty trucks. Two developers, Landi Renzo and Agility Power Systems, are developing a CNG NZE variant of the Ford 7.3L CNG engine for medium-duty trucks. Widely untapped, the medium-duty truck market has not seen any near-zero-emission engines available other than the Cummins Westport, Inc. ISB 6.7 engine. The 7.3L engine will be calibrated and certified to 0.02 g/bhp-hr NOx, on par with CWI L9N and ISX12N for heavy duty. These will be the first engines in the medium duty class to reach near-zero emission and will be widely adopted into Ford medium-duty truck platforms.

Co-Funders: SCAQMD, Landi Renzo, Agility Fuel Systems (CNG)

Start Date: 11/30/2019
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$4,379,747**
Total SCG Cost: **$900,000**
Total Co-Funding: **$3,479,747**
Benefits:

SCAQMD Heavy Duty Truck Engine In-Use Emission Study

The objective of this project is to evaluate in-use emissions from heavy-duty vehicles to identify technology benefits and shortfalls and to improve emissions inventory estimates. In-use emissions remains a critical component for measuring the effectiveness of engine, fuel, and aftertreatment technologies as well as the South Coast Air Basin's progress in achieving federal ambient air quality standards. Researchers at the University of California, Riverside and West Virginia University evaluated 219 Class 7 and 8 trucks across five vocations using propane, near-zero propane, compressed natural gas (CNG), near-zero CNG, diesel, non-selective catalyst reduction diesel, diesel-hybrid, battery electric vehicles, and fuel cell electric vehicle. Test phases utilized to capture and analyze emissions included over 200 Portable Activity Monitoring System tests, 100 Portable Emission Measurement System tests, 60 Chassis Dynamometer tests, and eight real-world in-use trailer tests. Preliminary analysis and comparisons show that the 0.2 NOx CNG engines operate at significantly lower NOx levels (<0.1 g/bhp-hr) compared to 0.2 NOx diesel engines. The results of the study can be used to feed information into future research opportunities and regulations.

Co-Funders: CEC, CARB, SCAQMD

Start Date: 11/01/2015
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$3,285,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$2,785,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

SCAQMD Hydrogen Blended Natural Gas in NZE Engine Emissions Study

This research project assesses the criteria pollutant and greenhouse gas impacts of hydrogen natural gas fuel blends on near-zero emissions NOx heavy-duty natural gas engines. Past studies have shown that the addition of hydrogen in natural gas may result in lower engine emissions when combined with optimized engine calibration. The University of California's Center for Environmental Research and Technology will design and build a hydrogen-compressed natural gas (H-CNG) blending apparatus as part of the study and vary hydrogen content from zero to five percent by volume. The first phase of the study focused on the emissions impacts of H-CNG blends compared to the baseline on regulated engine test duty cycles. CWI provided the test engine and aftertreatment systems, as well as engineering and data analysis support including oil sample analysis. A 2005 comprehensive study conducted by the National Renewable Energy Laboratory showed that an H-CNG fueled engine reduced NOx emissions by 50 percent compared with a CNG-fueled engine in a transit bus application. Recent low carbon and renewable fuel initiatives have renewed interest in further decarbonization of natural gas, providing a source of lower carbon content fuel for the transportation sector. The research provides data to justify the initiation of extensive validation work to increase the hydrogen limit for near-zero emission natural gas engines.

Co-Funders: SCAQMD

Start Date: 11/21/2019
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$304,000**
Total Project Cost: **$534,000**
Total SCG Cost: **$304,000**
Total Co-Funding: **$230,000**
Benefits:

UC Davis 2021 STEPS Plus Program Membership

The Sustainable Transportation Energy Pathways (STEPS) Program at the University of California, Davis Institute of Transportation Studies (ITS-Davis) is a four-year multidisciplinary research consortium. It brings together the world's leading auto and truck OEMs, energy firms, new mobility companies, foundations, and government agencies to understand sustainable vehicle and energy solutions. Reports from the 2021 curriculum are posted online and provide valuable insight to the industry. One such report, the "Hydrogen Infrastructure Requirements for Zero-Emission Freight Applications in California" examines two distinctive segments of the medium- and heavy-duty (MD/HD) fuel cell electric vehicle (FCEV) market: the local return-to-base market and the long-haul market. The demand for hydrogen fuel from MD/HD FCEVs is heavily concentrated in California's biggest metropolitan areas: Los Angeles, the San Francisco Bay Area, Stockton, and Sacramento. The location optimization model finds 131 refueling station sites to serve the local FCEVs. Stations with sizes between 1,000 and 5,000 kg-H2/day are the most common in the 2030 scenario. Extremely large stations over 20,000 kg-H2/day often appear near ports, which is consistent with aggressive targets about drayage truck population. A hydrogen refueling network for long-haul fuel cell trucks based on the optimization model consists of 13 stations spread across the state. Overall, hundreds of metric tons of daily hydrogen supply is needed by 2030 to support the local hydrogen fleets. The refueling points vary by size, from 1,000 kg per day to nearly 50,000 kg per day. The STEPS+ 2019-2022 Program continues to develop a deep and broad understanding of the transportation sector in California, the U.S., and around the world.

Co-Funders: N/A

Start Date: 12/01/2019
End Date: 12/31/2021
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$80,000**
Total SCG Cost: **$80,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UC Riverside Hydrogen Blended Natural Gas Engine Durability Test

The objective of this project is to evaluate the impact of hydrogen content in natural gas on the performance and durability of one end use technology, specifically the Cummins L9N 8.9 liter near-zero natural gas engine. Cummins has a set limit for hydrogen content of 0.03% by volume, a long-standing limit probably set based on typical natural gas composition. Since the limit is part of the Cummins specification, using natural gas with hydrogen content greater than 0.03% could void the warranty of the engine. The research team at University of California, Riverside will operate the engine on hydrogen blended natural gas for 500 to 1,000 hours, simulating normal heavy-duty truck and transit duty cycles. After completion of the 500 to 1,000 hours of testing, the research team will disassemble the engine to identify and analyze impacts to engine components, fluids, and performance. The research can provide data to justify the initiation of extensive validation work to increase the hydrogen limit for near-zero-emission natural gas engines.

Co-Funders: PG&E

Start Date: 03/06/2020
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$98,977**
Total Project Cost: **$614,997**
Total SCG Cost: **$489,997**
Total Co-Funding: **$125,000**
Benefits:

UCR RNG and HD Truck Pathways to Achieve Climate Goals Study

Researchers at the University of California, Riverside evaluated the NOx and greenhouse gas (GHG) emissions trends of the heavy-duty transportation sector in California's south coast region under four future scenarios with varying deployment trends of zero- and near-zero-emission vehicles (ZEV, NZEV) over two decades. Modeling analysis using original vehicle population projections and real-world NOx emission factors were used to estimate emissions over the period from 2020 to 2040. Analysis shows that emissions are significantly impacted by the rate of deployment of cleaner technology options. The results further show that very aggressive deployment of low carbon technologies is necessary to achieve 2040 GHG emissions targets. Further still, accelerating fleet turnover was found to be a more important NOx control strategy than dividing the vehicle replacement between NZEVs and ZEVs. The analysis suggests that heavy-heavy-duty NZEVs should be encouraged in the near to mid-term, and even long-term if operated on renewable natural gas. The results were published in the Journal ***Transportation Research Part D: Transport and Environment***. The study will inform future RD&D investments in the overlap of Low Carbon Resources and Clean Transportation sectors. It identifies opportunities for gas technology to address Environmental Improvement and to develop new renewable resources and processes which further supply technologies.

Co-Funders: N/A

Start Date: 11/01/2018
End Date: 05/31/2022
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$100,000**
Total SCG Cost: **$100,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

US Hybrid CNG Plug-In Hybrid Electric Truck Demonstration

The objective of this project is to develop and demonstrate an advanced Plug-In Hybrid Electric Truck (PHET) powertrain with an existing Cummins Westport Inc (CWI) L9N Near-Zero Emission (NZE) Compressed Natural Gas (CNG) engine on a Freightliner Cascadia sleeper-cab truck in a parallel hybrid configuration. The truck was optimized for over 1,000 miles of total range—including 35 miles of all-electric range—along with more than 600 horsepower to accommodate trucks that require more torque and power. The electric motor, coupled with the L9N CNG engine, will exceed the performance of existing 13-Liter diesel engines while reducing carbon dioxide and NOx emissions as well as greenhouse gas reductions on renewable natural gas. The truck was used as a demonstrator for fleets and events. Emissions and performance analysis was completed through dynamometer and road-testing to assess the overall advantage and emissions reduction of the PHET design. The truck is currently going through evaluation and final developments to ensure roadworthiness and safety. Once completed, the truck will be delivered to a host fleet for demonstration.

Co-Funders: SCAQMD, CEC, DOE, US Hybrid, Clean Energy

Start Date: 03/31/2020
End Date: 06/30/2020
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$3,233,836**
Total SCG Cost: **$250,000**
Total Co-Funding: **$2,983,836**
Benefits:

UTD NGV America Technology Committee Participation and Representation – Phase 5 (2.16.0)

NGVAmerica (NGVA) is a national organization dedicated to the development of a growing and sustainable market for vehicles powered by natural gas or biomethane to benefit consumers and the environment. NGVA represents more than 230 companies, environmental groups, and government organizations interested in the promotion and use of natural gas and renewable natural gas as transportation fuels. Its members produce, distribute, and market natural gas and renewable natural gas across the country; manufacture and service natural gas vehicles, engines, and equipment; and operate fleets powered by gaseous fuels. SoCalGas was invited to participate on its committee and to represent natural gas interest.

Co-Funders: UTD Members

Start Date: 06/27/2016
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$208,200**
Total SCG Cost: **$43,200**
Total Co-Funding: **$165,000**
Benefits: N/A

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

SUB-PROGRAM: REFUELING STATIONS

Frontier Energy MC Forumula Protocol for H35HF Fueling Demonstration

The objective of this project is to develop and test the MC Method formula for fueling heavy-duty hydrogen-fuel-cell trucks at 5,000 psi using H35HF (high flow) dispensers to be submitted to the U.S. Department of Energy (DOE) H2@Scale CRADA Call. The MC Method is a lumped heat capacitance model that calculates end of fill gas temp. The MC denotes the heat capacity of the tank system from the equation $m_{(kg)}$ X $c_{(J/kgK)}$. Hydrogen refueling stations and protocols are fully responsible for the safe refueling of any hydrogen-fuel-cell vehicle. Commercial hydrogen refueling stations currently utilize the SAE J2601 Lookup Table (LT) method with limited temperature and pressure boundaries to safely refuel vehicles. The MC method uses actual pre-cooling temperatures of the dispenser as the control input. A key difference between the LT and MC methods for refueling is that the LT method uses feed-forward static controls while the MC method uses feedback dynamic controls. This allows for high-flow scenarios, faster filling, and more accurate filling of fuel cell vehicles. The technology will be optimized for 350bar refueling of heavy-duty fuel cell vehicles, such as transit.

Co-Funders: DOE, Frontier Energy/CAFCP, SCAQMD, Shell, Sunline, Worthington Cylinders

Start Date: 05/20/2021
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$80,000**
Total Project Cost: **$695,000**
Total SCG Cost: **$80,000**
Total Co-Funding: **$615,000**
Benefits:

GTI CNG Smart Station Demonstration

The objective of this project is to address natural gas vehicle total-cost-of-ownership by developing and demonstrating a smart fueling system. The system will include the full suite of necessary technologies to enable consistent full fills of natural gas vehicles. These technologies include a smart vehicle and dispenser, an advanced full fill algorithm, and cost-effective gas pre-cooling using a near-isentropic free piston expander/compressor. This combination of technologies seeks to solve the technical challenges of dispensing uncertainty and heat of compression that results in natural gas vehicles being under-filled. By eliminating under-filling, it may be possible to significantly reduce the number of high-pressure storage vessels onboard a natural gas vehicle resulting in a reduced capital cost of 5-25%. Additional communications hardware has been installed as well as additional testing to improve compressed natural gas (CNG) valve speed. Development of the CNG Smart Station is in progress and is expected to be completed by the end of 2022.

Co-Funders: UTD Members, NREL

Start Date: 01/31/2019
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$80,625**
Total Project Cost: **$1,518,754**
Total SCG Cost: **$268,754**
Total Co-Funding: **$1,250,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI H2 at Scale Hydrogen Refueling Demonstration

The U.S. Department of Energy (DOE) has awarded a project to Frontier Energy, titled Demonstration and Framework for H2@Scale in Texas and Beyond (H2@Scale). The H2@Scale project has two unique research, development, and demonstration tracks aimed at better understanding the potential of integrating hydrogen with multiple platforms throughout the economy. First, the proposed H2@Scale project will include the demonstration of co-located multiple hydrogen generation and multiple hydrogen use applications. Activities include 100% renewable hydrogen generation (steam methane reforming and electrolysis), 100kW fuel cell powering a datacenter, and vehicle and drone refueling. In the second track, the project will leverage the experience from this demonstration, along with research and outreach, to develop a framework for additional H2@Scale pilot opportunities in Texas. To date, major equipment has been specified and ordered, with deliveries scheduled in 2022.

Co-Funders: DOE, Cost Share

Start Date: 11/01/2019
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$90,000**
Total Project Cost: **$11,287,021**
Total SCG Cost: **$483,750**
Total Co-Funding: **$10,803,271**
Benefits:

SoCalGas Coriolis Meter Total Flow Test

The objective of this project is to assess the feasibility of the technology on the integration, automation, and data transmission to a company measurement collection system (MCS) system from a high-pressure (~4,000 psig) Coriolis meter. SoCalGas receives environmental credits under California's Low Carbon Fuel Standard program for compressed natural gas (CNG) dispensed to natural gas vehicles (NGV) as transportation fuel. Non-transportation usages that feed from the system need to be excluded from the main NGV meter. Currently, some of SoCalGas's CNG stations are being used for other purposes. Two main operations that utilize CNG are pipeline safety enhancement plan actvities and customer services. A Coriolis transmitter with display is installed on the system to track the CNG consumption used for non-transportation purposes. The current process is a annual reading taken monthly by field staff and submitted via email. The study proved the feasibility of utilizing the MCS to automate the gas consumption collection with minimum effort in setting up and configuring the electronic devices.

Co-Funders: N/A

Start Date: 08/19/2019
End Date: 11/30/2021
Status: Completed
2021 Funds Expended: **$55.56**
Total Project Cost: **$30,000**
Total SCG Cost: **$30,000**
Total Co-Funding: **$0**
Benefits:

UTD CNG Dispenser Tank Communication (2.19.G)

The objective of this project is to design, build, and demonstrate a prototype smart compressed natural gas (CNG) station that includes a smart CNG dispenser and a smart natural gas vehicle (NGV). The team will develop pre-commercial prototype hardware and protocols that enable the vehicle and station to communicate information about the vehicle's fuel system such as real-time pressure and temperature, tank volume, and age of the CNG fuel system. This information will allow safer, fuller fills of NGVs while also enabling fleets to more accurately track a vehicle's fuel consumption.

Co-Funders: CSA, DOE, UTD Members

Start Date: 09/01/2019
End Date: 09/30/2022
Status: Active
2021 Funds Expended: **$8,143**
Total Project Cost: **$2,785,000**
Total SCG Cost: **$40,714**
Total Co-Funding: **$2,744,286**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD CNG Station Methane Measurement Investigation (2.17.H)

The objectives of this project are to: 1) quantify the leaks and losses of natural gas in the compressed natural gas (CNG) fueling process within a CNG fueling station; 2) evaluate advanced compression technologies; and 3) provide guidance on tracking methods to monitor station leakage performance to maximize operational efficiency and minimize leaks and losses. While natural gas vehicles (NGVs) have demonstrated significant reductions in many criteria pollutants and ozone-forming emissions, methane emissions are a potential risk associated with these vehicles. Methane emissions, however, are not currently well regulated, given that most emissions regulations were developed to target gasoline and diesel fueled vehicles. As CNG vehicles begin to replace increasing numbers of diesel and gasoline powered vehicles, though, it is prudent to understand how they might contribute to criteria pollutants and ozone-forming emissions. The predominant compound in natural gas is methane, and even relatively small amounts of methane leakage at a CNG fueling station can cause concern. New U.S. Environmental Protection Agency greenhouse gas (GHG) standards are expected to regulate total GHG emissions, including methane emissions. Upon completion of the project, the team will release its findings.

Co-Funders: UTD Members

Start Date: 06/01/2017
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$2,500**
Total Project Cost: **$75,000**
Total SCG Cost: **$2,500**
Total Co-Funding: **$72,500**
Benefits:

Yankee Scientific Strategies for CNG and Hydrogen Infrastructure Assessment

Yankee Scientific proposes to develop technical strategies to incorporate compressed hydrogen refueling capabilities at existing CNG refueling stations. Yankee Scientific will look at strategies to implement off-the-shelf components or to convert and share existing CNG station equipment for hydrogen refueling. This will allow fleets to refuel both CNG and hydrogen vehicles as they transition to zero-emissions. The economics of these technologies will be compared with the tube-trailer transport of hydrogen from regional hydrogen generation facilities or from large industrial hydrogen suppliers. Strategies for incorporating the necessary add-on equipment to the existing CNG refueling station will be identified. These will consider the installation of structures and equipment using both standard site construction methods and by installing prefabricated modular add-on systems, if applicable. A capital and operating cost analysis will be prepared to identify the total station conversion costs and fuel delivery costs with each selected strategy for sourcing and compressing hydrogen. Recommendations will be developed for the best strategies for incorporating hydrogen refueling. Contracting was wrapped up toward the end of 2021 and project activities will commence in 2022.

Co-Funders: N/A

Start Date: 05/20/2021
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$50,000**
Total Project Cost: **$148,100**
Total SCG Cost: **$148,100**
Total Co-Funding: **$0**
Benefits:

CLEAN GENERATION

SUB-PROGRAM: DISTRIBUTED GENERATION

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Aisin Residential Fuel Cell Laboratory Testing

The goal of this project is to develop a residential solid oxide fuel cell (SOFC) for commercialization and widespread deployment in California. SoCalGas will acquire two 700W SOFC units from Aisin, to be evaluated by GTI. The units will be modified versions of the commercially available systems in Japan. Modifications will include tuning for U.S. gas composition and adding an external transformer for electrical connectivity in the lab. GTI will work with SoCalGas and Aisin to develop and execute a test plan. Upon completion of the testing, GTI will issue a final report documenting its findings. Aisin will conduct a post-testing evaluation of the units and issue its own report.

Co-Funders: N/A

Start Date: 12/14/2020
End Date: 08/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$350,026**
Total SCG Cost: **$350,026**
Total Co-Funding: **$0**
Benefits:

Bloom Energy Coupled Electrolyzer and Fuel Cell Demonstration

The goal of this project is to demonstrate the coupling of Bloom Energy's new solid oxide electrolyzer cell (SOEC) at an existing Bloom solid oxide fuel cell (SOFC) installation. A 300kW SOEC will utilize grid electricity to generate hydrogen, which will then be blended with natural gas to fuel Bloom SOFCs. Hydrogen blending will take place downstream of the SoCalGas meter, at a manifold that will feed multiple existing SOFC units on the Caltech campus. The tentative blending percentage is 12% hydrogen (Bloom SOFCs can currently accept up to 50% hydrogen blends). The project will include SOEC product development, hydrogen blending design, permitting, and 15 months of operating costs. The demonstration will showcase the potential to decarbonize the natural gas grid and serve as a steppingstone to developing a reversible SOEC/SOFC fuel cell product.

Co-Funders: Bloom Energy

Start Date: 04/19/2021
End Date: 06/30/2023
Status: Active
2021 Funds Expended: **$300,000**
Total Project Cost: **$1,500,000**
Total SCG Cost: **$500,000**
Total Co-Funding: **$1,000,000**
Benefits:

EPRI ORC Waste Heat Recovery Demonstration

The goal of this project is to demonstrate the technical and economic feasibility of a cost-effective organic rankine cycle (ORC) package to recover very low-grade waste heat from natural gas industrial processes. The project team will install a commercially available ORC system at a SoCalGas customer site for monitoring and verification. This will represent the state's first application of ORC technology in an industrial setting. When complete, the project will identify key factors dictating project economics, lifecycle costs, and opportunities for improvement and optimization that could lead to further market adoption and better economics. After experiencing technical issues during commissioning, the project was put on hold. Due to COVID-19 travel restrictions, the manufacturer could not troubleshoot the system in person, so it was removed and shipped to the manufacturer. Performance monitoring will take place once the system is re-installed and commissioned in 2022.

Co-Funders: CEC

Start Date: 12/01/2015
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,168,739**
Total SCG Cost: **$172,000**
Total Co-Funding: **$996,739**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI Marathon/EC Power mCHP Testing and Demonstration

The objective of this project is to test and demonstrate two micro combined heat and power (mCHP) systems—a 4.5 kW Marathon and a 25 kW Lochinvar—with the goal of certifying both systems under CARB-Distributed Generation (DG). The first phase of the project has been completed. During the first phase, GTI worked with the manufacturers to conduct performance and emissions testing of the system in its lab. Working with a third party, GTI confirmed both systems' ability to meet CARB-DG emissions requirements. GTI installed the EC Power system at a commercial bakery within SoCalGas' service territory in 2021. The system will be commissioned in 2022. The Marathon system will be installed and commissioned at an as-of-yet undetermined location in 2022.

Co-Funders: CEC, Marathon Engine Systems, AO Smith Corporation

Start Date: 07/01/2018
End Date: 09/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,667,006**
Total SCG Cost: **$100,000**
Total Co-Funding: **$1,567,006**
Benefits:

GTI Upstart Residential SOFC Lab Evaluation

The goal of this project is to evaluate the performance of the Upgen 10 solid oxide fuel cell (SOFC) system operating on natural gas at GTI's lab. Unlike other SOFC systems, Upstart claims its system is designed to achieve fast start/stop times, while maintaining cyclic durability. GTI will assess the technical performance of the unit and identify any performance issues. The evaluation will include assessing current/voltage/power characteristics, efficiencies, system endurance, stack degradation, load following capabilities, rapid start-up and shut-down cyclability, and emissions. The system experienced some issues during commissioning in Q4 2021. The system will be commissioned and tested in 2022.

Co-Funders: N/A

Start Date: 08/17/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$154,126**
Total Project Cost: **$190,000**
Total SCG Cost: **$190,000**
Total Co-Funding: **$0**
Benefits:

LBNL Metal-Supported SOFC Development

The objectives of this project were to 1) demonstrate Lawrence Berkeley National Laboratory's (LBNL) metal-supported solid oxide fuel cell (MS-SOFC) technology operating with natural gas and 2) determine future technical improvements that are required for commercialization. LBNL has developed MS-SOFCs with unique symmetrical architecture that offer several advantages over state-of-the-art ceramic SOFC models, including inexpensive materials, rapid start-up capability, increased mechanical strength, and high tolerance to thermal cycling. These advantages make LBNL MS-SOFCs uniquely suited for fast start-up, portable, and mobile backup generator applications. The project team performed testing at the single cell level, with cells operated at 700°C and 0.75 V, chosen as a nominal operating point for efficient and durable performance. The project team successfully operated the cells for more than 1,000 hours with over 40 rapid cycles while meeting or exceeding technical targets, which were derived from literature review and assumptions about residential back-up generators. While single cell results can be used to inform and advise the commercial production of natural gas-based backup generators, future research should include scale-up to commercial-size cells and evaluation of stack performance, lifetime, and durability. LBNL will publish the full project results in early 2022.

Co-Funders: N/A

Start Date: 11/01/2019
End Date: 01/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$375,000**
Total SCG Cost: **$375,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Mainspring Energy Ultra-Low NOx Linear Power Generator Demonstration

The goal of this project was for Mainspring Energy to demonstrate its linear generator in a real-world setting. The demonstration took place at a grocery store in Colton, California, a disadvantaged community. Mainspring's linear generator uses a low-temperature reaction of air and fuel to drive magnets through copper coils to efficiently produce electricity with near-zero emissions of nitrogen oxides. The project achieved its desired performance targets over a monitoring period of more than nine months. Dispatchable power was provided 24 hours a day, seven days a week for approximately 80% of the building load. The system produced 230 kW of net AC power when the building load was sufficient and followed the building load when it was less than 230 kW. The efficiency of the unit was greater than forty percent over the building load range, which occasionally dropped below 150 kW, and low-emission operation was achieved and verified by a third party across the building load range. This project, along with parallel research and development, has led to several design improvements which will be incorporated in future systems. The project team issued the final report in late 2021 and will close out the project in Q1 2022. During the project, Mainspring received significant market interest from national and multi-national corporations and raised sufficient capital for a successful and sustained market launch beginning in 2022.

Co-Funders: CEC, Mainspring Energy

Start Date: 01/01/2021
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$70,148**
Total Project Cost: **$2,381,873**
Total SCG Cost: **$100,148**
Total Co-Funding: **$2,281,725**
Benefits:

Noble Thermodynamic Systems Ultra-Efficient CHP using a Novel Argon Power Cycle Development

The goal of this project is to demonstrate the ability of the novel argon power cycle (APC) to provide an 18% increase in efficiency, while eliminating emissions, in an internal combustion engine. The APC was developed by researchers at the University of California (UC), Berkeley. It utilizes a closed-loop internal combustion engine with argon as the working fluid (instead of air), in conjunction with a membrane gas separation unit. The closed-loop nature of the system completely eliminates air pollutants and GHG emissions. The project will take place at UC Berkeley, with work to be completed in two phases: 1) high-fidelity modeling and sub-component development; and 2) full system integration and operation. The team has progressed according to plan, with only a few minor delays due to supply chain issues. In the meantime, the team has completed the development of high-fidelity code simulating the entirety of the technology, integrating carbon capture technology, reciprocating engine power train, and heat transfer mode. Additionally, the team has completed the design of the overall plant and the design and manufacturing of the retrofit kit for the stock diesel engine. Engine performance estimates show engine efficiencies reaching as high as 62% on an engine scale normally delivering no more than 40%. The entirety of the system is under construction and expected to be ready for firing and integration by Q4 2022. The system will be operated for 18 months after commissioning.

Co-Funders: DOE, Private Investors

Start Date: 08/14/2020
End Date: 10/31/2023
Status: Active
2021 Funds Expended: **$150,000**
Total Project Cost: **$5,279,034**
Total SCG Cost: **$500,000**
Total Co-Funding: **$4,779,034**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

QSI Nano-Power Generation System Proof-of-Concept

The goal of this project is to conduct a proof-of-concept test of the QuSwami, Inc (QSI) patented Nano-Power Generation System, running on natural gas. QSI's system utilizes Electricity Emitting Diodes (EEDs), which directly and efficiently generate power from an energy source via gas-phase catalytic reactions on an EED's nano-surface to generate hot electrons. QSI's foundational research shows that direct conversion of chemical energy from gas-phase catalytic reactions has the potential of achieving higher fuel efficiency than most existing electricity generation technologies. The project will include re-designing the reactors to withstand the higher temperatures required for the testing, measuring exhaust composition, and measuring output voltage from the EEDs. This project was on hold for much of 2021 due to COVID-19 restrictions.

Co-Funders: N/A

Start Date: 09/09/2019
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$50,000**
Total SCG Cost: **$50,000**
Total Co-Funding: **$0**
Benefits:

Scaled Power 40kw Turbogenerator Low Emissions Burner Development and Testing

The objective of this project is to further the development of Scaled Power's 40kW Turbogenerator and perform emissions testing. The Turbogenerator was redesigned and fabricated based on lessons learned from a prior project phase. The redesigned system was tested with the existing burner. The system will be integrated with a low-emissions combustor, which utilizes Low Swirl Burner technology developed by Lawrence Berkeley National Laboratory. Once the system is integrated with the new burner in 2022, emissions testing will be performed to determine if the system can meet CARB-Distributed Generation requirements. Scaled Power's Turbogenerator utilizes off-the-shelf automotive components combined with a gearless electric auxiliary power unit to simplify the system and minimize costs.

Co-Funders: U.S. Air Force

Start Date: 07/01/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$464,000**
Total SCG Cost: **$232,000**
Total Co-Funding: **$232,000**
Benefits:

UCI Effect of Hydrogen Addition into Natural Gas on SCR of NOx Lab Testing

The goal of this project is to investigate the impact that hydrogen-blended natural gas has on the performance of selective catalytic reduction (SCR) units for removal of nitrogen oxides (NOx) from flue gas. SCR of NOx is used in several applications such as gas-fired utility boilers, process heaters, gas turbines, and stationary engines. Flue gas composition is known to affect catalyst performance. Since hydrogen is a carbon-free fuel, the combustion products are different than those of a carbon-containing fuel. Introducing a flue gas with a different composition into the SCR unit would affect the chemistry occurring on the catalyst, and, hence, the performance of the catalyst. This might cause a change in the resulting NOx emissions downstream of the SCR unit, which would be released from the stack. In 2021, the University of California, Irvine conducted a literature review and began lab testing. The project team constructed the test burner and conducted experiments to identify stable operating conditions for various hydrogen-natural gas blends. The team also completed baseline testing of the catalysts under various operating conditions with natural gas. The project team will continue baseline catalyst testing in addition to testing with hydrogen-blended fuel in 2022.

Co-Funders: N/A

Start Date: 10/05/2020
End Date: 04/30/2022
Status: Active
2021 Funds Expended: **$80,000**
Total Project Cost: **$195,000**
Total SCG Cost: **$195,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UCI Fuel Flexible Microturbine Generator Development

The objective of this project was to retrofit a commercially available Capstone C65 microturbine to operate on up to 20% hydrogen by volume and then to isolate and determine the most important variables affecting nitrogen oxides (NOx) and carbon monoxide (CO) emissions. This project built upon prior research conducted by the University of California, Irvine and Capstone related to injector design to achieve low emissions at various hydrogen blend levels. This project specifically looked at the impact that hydrogen blend percentage, injector premix port size, and turbine exit temperature had on NOx and CO emissions. The research determined that the injector premix port size was the dominant variable for both NOx and CO. The larger the port, the less impact hydrogen blend percentages had on emissions. This project will help enable the transition to hydrogen in existing microturbines, which is important for reducing greenhouse gas emissions. Understanding and addressing the impact that hydrogen blending has on other emissions is vital.

Co-Funders: N/A

Start Date: 05/01/2019
End Date: 08/31/2021
Status: Completed
2021 Funds Expended: **$20,000**
Total Project Cost: **$100,000**
Total SCG Cost: **$100,000**
Total Co-Funding: **$0**
Benefits:

UCI Fuel Flexible Rotary Engine MicroCHP Development

The objectives of this project are to demonstrate 1) robustness of operation and 2) the extent of low emissions performance as operated on hydrogen-natural gas mixtures using an existing rotary-engine-based ~30kW micro combined heat and power (CHP). This project leverages the California Energy Commission-supported development of a rotary engine operating on natural gas, integrated with a generator and heat recovery systems. The engine is being tested at the University of California, Irvine. A few components (heat exchanger and alternator) have proven to be the weakest links of the system. As a result, the point of objective 1 is to put additional hours on the unit (up to 1,000) to see if the solutions made to address the weaknesses proved effective. To meet objective 2, the project has involved the development of a fuel mixing system to provide up to 20% hydrogen added to natural gas in 1 or 2% increments. In 2021, the team successfully operated the system for 750 hours with no further component failures. The team also prepared the system for hydrogen blend testing. Testing with up to 20% hydrogen will take place in 2022.

Co-Funders: N/A

Start Date: 07/01/2019
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$42,500**
Total Project Cost: **$100,000**
Total SCG Cost: **$100,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UCI Low Cost Sensors for Smart Burners Research

The objectives of this project are to evaluate 1) robustness and accuracy of low-cost sensors for emissions and fuel composition that can be integrated into the overall control system of low-emissions systems (e.g., nitrogen oxides (NOx) from microturbines, "smart" appliances). Two areas of interest are being explored: 1) low-cost sensors for monitoring exhaust emissions and 2) low-cost sensors associated with monitoring the hydrogen content of hydrogen-natural gas mixtures. For the first, a precision test bed featuring the ability to create "synthetic exhaust" will be utilized. Previous work compared candidate low-cost sensors to a standard emissions analyzer and tested them in the actual exhaust of a microturbine generator. While this provided encouraging results in terms of sensor accuracy, the variability in the exhaust NOx from the engine due to changes in ambient conditions combined with the uncertainty of the emission analyzer (+/- 1ppm) resulted in high uncertainty in the evaluation. A better-controlled test environment will solve this issue. For the low-cost hydrogen sensing, the project team considered numerous technical approaches and selected two technologies for evaluation: electrochemical cells and speed of sound sensing. The project team will continue to evaluate both sensors and complete the project in 2022.

Co-Funders: N/A

Start Date: 08/01/2019
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$57,500**
Total Project Cost: **$136,500**
Total SCG Cost: **$136,500**
Total Co-Funding: **$0**
Benefits:

UTD Capstone C200S Microturbine Laboratory Evaluation (2.18.E)

The objective of this project is to evaluate and characterize the performance of the newly launched 200 kW Capstone C200S Signature Series microturbine. According to Capstone, the unit incorporates numerous system and design upgrades including integrated heat recovery, two-stage air filtration, an acoustically enhanced enclosure, and reconfiguration for ease of installation and integration. The unit has a stated electrical efficiency of 33% (LHV). In a combined heat and power format, system efficiency may reach up to 90%. GTI conducted performance testing of the system in 2021 and will issue a final report for the project in Q1 2022.

Co-Funders: UTD Members, Power Flame

Start Date: 07/01/2018
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$185,000**
Total SCG Cost: **$19,800**
Total Co-Funding: **$165,200**
Benefits:

UTD Emerging Rescom Fuel Cells – Laboratory Evaluations (1.20.F)

The goals of this project are to evaluate the merits of at least six residential/small-commercial scale fuel cell systems (<50kW), prioritize them based on fitness for the North American market, and conduct lab testing of a few select systems. GTI has completed the assessment of sixteen fuel cell systems, including alkaline fuel cell, solid oxide fuel cell, and polymer electrolyte fuel cell technologies identified for residential/commercial combined heat and power applications. The merits of those systems were evaluated based on electrical efficiencies, manufacturer reputation, successful field demonstrations, and North American market fit. Based on this prioritization, GTI identified seven systems for potential evaluation in the lab, with two underway. The systems are being evaluated in the lab to characterize their power/thermal capacities, efficiencies, and qualities as well as modulation and cycling capabilities.

Co-Funders: UTD Members, PERC

Start Date: 07/01/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$11,289**
Total Project Cost: **$190,000**
Total SCG Cost: **$27,789**
Total Co-Funding: **$162,211**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD EnviroPower 6kW SmartWatt and BRASH 3kW STRAUM mCHP Boilers – Lab Test (2.19.E)

The objectives of this project are to evaluate the 6kW EnviroPower and 3kW BRASH STRAUM micro combined heat and power (mCHP) self-powered hydronic HVAC boiler systems in the laboratory and to support their development by validating performance and other competitive analysis benchmarking. Evaluation metrics will include power, thermal production, efficiencies, and emissions. Due to delays in contracting and COVID-19, the testing location has changed twice, with the planned location now being GTI's lab. The project team will evaluate the systems in 2022.

Co-Funders: UTD Members, BRASH, EnviroPower

Start Date: 07/01/2019
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$190,000**
Total SCG Cost: **$22,588**
Total Co-Funding: **$167,412**
Benefits:

UTD GRIDIRON Micro-CHP System Demonstration – Phase 2 (2.16.H.2)

The goal of this project is to evaluate and support GRIDIRON (formerly M-Trigen) in the development of cost-effective, self-powered, and uninterruptible space and water heating in the laboratory. Specifically, GTI will be evaluating GRIDIRON's PowerPlant H24 system, which is a smaller version of the HA65 evaluated in Phase 1 of this effort. The H24 does not produce cooling, which results in significantly lower cost. Due to COVID-19 related delays and supply chain issues, GTI will work with GRIDIRON to remotely test the system at GRIDIRON's facility in Texas. The H24 system and GTI's measurement instrumentation were installed in 2021. Testing will take place in 2022.

Co-Funders: UTD Members, M-Trigen, New Jersey Natural Gas

Start Date: 07/01/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$230,000**
Total SCG Cost: **$22,737**
Total Co-Funding: **$207,263**
Benefits:

UTD Long Term Performance and Reliability of CHP and DG Systems Study (2.17.E)

Combined heat-and-power (CHP) applications typically improve energy efficiency, reduce operating costs, and enhance energy resilience for both individual customers as well as the regional power grid. CHP resilience was demonstrated during Hurricane Sandy, when New York schools, hospitals, and apartment buildings with natural-gas-fueled CHP systems were able to generate power and provide places of refuge during the storm and in the weeks that followed. Likewise, natural gas distributed generation (DG) or micro-grids have the potential to generate power during widespread outages or to be dispatched by electric utilities during periods of high electric demand to relieve local grid stress and prevent brownouts. This project builds on earlier studies that developed a methodology for recording and analyzing data to establish baseline operating reliability for DG-CHP systems. These studies quantified operational reliability for various market segments and technology groups and found that natural gas CHP had higher reliability than previously reported.

Co-Funders: UTD Members

Start Date: 07/01/2017
End Date: 04/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$13,333**
Total Co-Funding: **$136,667**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD On-Site Electrical Generation – Thermal Photovoltaic CHP (2.15.A.2)

In this project, researchers demonstrated the viability of the concept of using back-reflective Thermal Photovoltaic (TPV) cells to achieve high-efficiency conversion of natural gas energy to power. The project team conducted bench-scale experiments that demonstrated the potential for designing a compact natural-gas-fired TPV combined heat and power (CHP) system that provides >55% power generation efficiency and allows wide variations in the ratio of power and thermal energy (hot water) generated. The project team designed and built a test facility for the experiments, which consisted of radiant tube burners with heat recovery devices on both ends. The tube was surrounded by a cylindrical reflector to simulate the TPV cells. The experimental effort focused on developing the gas-fired infrared emitter surrounded by a highly-reflective enclosure, since the integrated performance of various TPV cells could then be modeled relatively easily to estimate heat and power generation. The team was able to demonstrate stable combustion at inputs of up to 5 kW and also demonstrated the potential for using back-reflecting PV cells to increase TPV CHP efficiency. The project team also explored design concepts for a 2kW TPV CHP system and initiated development of the test plan to evaluate its performance. Next steps to advance this technology are currently being investigated.

Co-Funders: UTD Members

Start Date: 07/01/2018
End Date: 07/20/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$180,000**
Total SCG Cost: **$22,200**
Total Co-Funding: **$157,800**
Benefits:

SUB-PROGRAM: INTEGRATION & CONTROLS

Blue Frontier Fuel Cell Integrated Air Conditioning System Dynamic Lab Testing

The goal of this project is to expand the development and testing of the Blue Frontier air conditioning (BFAC) system, which is a liquid-desiccant air conditioner that can be paired with a fuel cell CHP to utilize and store "waste" heat to provide space cooling. Phase 1 involved prototype development, static testing, and conducting an extensive analysis of the benefits of the BFAC, which showed significant energy, cost, and emissions savings when paired with a fuel cell CHP system. This phase of the project will expand the scope to include dynamic testing at the University of California, Davis Western Cooling Efficiency Center (WCEC), who has expertise in this type of testing. Testing will evaluate the performance of the BFAC when subjected to dynamic inside and outside conditions (informed by the building types and climate zones modeled in Phase 1) in psychrometric chambers (rooms where environmental conditions can be controlled and simulated). The testing results will be used to update performance models and system design, which will help advance development. The results will also be used to update relevant portions of the Phase 1 technoeconomic analysis.

Co-Funders: CEC

Start Date: 10/18/2021
End Date: 04/30/2022
Status: Active
2021 Funds Expended: **$210,000**
Total Project Cost: **$495,635**
Total SCG Cost: **$250,000**
Total Co-Funding: **$243,635**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Blue Frontier Fuel Cell Powered HVAC Development

The goal of this project is to further the development of the Blue Frontier Air Conditioning (BFAC) system and investigate its integration with a fuel cell CHP system. By using an enhanced liquid desiccant energy storage technology originally developed by the National Renewable Energy Laboratory (NREL), the BFAC recovers and stores the waste heat from the fuel cell in order to provide on-demand cooling. In Phase 1, the team developed baseline models and explored energy cost savings across various building types throughout California. The initial models indicated a high likelihood of commercial success. The models also showed improved economic potential for fuel cells, when paired with the BFAC, by utilizing their waste heat to offset electrical load, effectively increasing their electrical efficiency. In Phase 2, Blue Frontier constructed a prototype system and began in-house performance testing. Initial testing indicates higher system efficiencies than modeled. NREL will perform additional testing in 2022.

Co-Funders: N/A

Start Date: 11/01/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$55,000**
Total Project Cost: **$540,527**
Total SCG Cost: **$540,527**
Total Co-Funding: **$0**
Benefits:

GTI Energy Switch Residential Microgrid-in-a-Box Evaluation

The goal of this project was to evaluate the Energy Switch, a "microgrid-in-a-box" that claimed to be able to provide a few things that the newest generation of residential energy systems on the market do not: 1) full time power factor correction to harmonize with the grid; 2) ability to add external gas fueled generation; and 3) individual load circuit monitoring and load control. The project was split into two phases: 1) market and technology shortcoming analysis; and 2) lab evaluation of the Energy Switch technology. During the first phase of the project, Energy Switch announced that it would no longer be pursuing commercialization of its technology. The project will be closed out after Phase 1 is completed in Q1 2022. Lab testing of a different system identified during Phase 1 may be pursued as a separate follow-on project. The goal of this project was to help overcome the typically custom microgrid solutions that are expensive and prohibitive to widespread adoption. Simplifying the integration of small-scale gas distributed generation has the ability to pave the way for increased fuel cell adoption.

Co-Funders: N/A

Start Date: 01/01/2021
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$48,000**
Total Project Cost: **$50,000**
Total SCG Cost: **$50,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UCI Fuel Cells in Data Centers Research

The objective of this project was to explore the real-world feasibility of using Solid Oxide Fuel Cells (SOFCs) integrated with an absorption chiller to provide power and cooling to a data center. The waste heat from the SOFCs was used to drive the absorption chilling process. The project was conducted in a laboratory at the University of California, Irvine. For the purposes of testing, a standard 42-slot server rack was provided by Microsoft. In order to meet the 12kW power requirements of the server rack, the project team used eight 1.5kW Solid Power BlueGEN fuel cells. A five-ton lithium bromide absorption chiller from Yazaki was selected for cooling. The project team conducted both physical lab testing and modeling for the individual components and integrated systems. The project team showed that the integrated system was able to meet the power and cooling needs of a server rack. They also found that the performance of the integrated system could be optimized by modifying fuel utilization, which would change the stack temperature. If this variable could be controlled dynamically based on fluctuating cooling requirements, energy savings could be maximized. The team calculated a range of 18 – 30% of the primary energy savings compared to a traditional system. However, when the team explored the ability to also provide dehumidification via a liquid desiccant, they found that there was not enough heat generated for both cooling and dehumidification, and that further modifications would have to be made to potentially achieve both.

Co-Funders: Microsoft Corporation

Start Date: 10/01/2019
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$95,000**
Total Project Cost: **$190,000**
Total SCG Cost: **$540,000**
Total Co-Funding: **$350,000**
Benefits:

UCI Fuel Cell Supported Nanogrid Controls Evaluation

The purpose of this project is to evaluate two microgrid control platforms in the context of a fuel-cell-supported residential microgrid ("nanogrid"). This project leverages the results of an ongoing project to develop and test a nanogrid control strategy designed to achieve zero net energy in a residential setting with a solid oxide fuel cell (SOFC), PV solar, and battery storage. The University of California, Irvine (UCI) will work with two microgrid controls vendors to evaluate and further develop the capabilities of its control platform(s). The microgrid controllers will be installed in UCI's laboratory nanogrid, which includes a 1.5kW SOFC, 5kW of rooftop solar, and a 9.8kWh battery. The control platforms will be tested for their ability to meet the dynamic operating requirements developed in the previously mentioned supporting project. In addition to the technical testing, UCI will evaluate the greenhouse gas and criteria pollutant emissions implications of the control strategies and determine the cost and equity implications of the test scenarios as applied to the residential demands of various California climate zones.

Co-Funders: Microgrid Control Companies

Start Date: 10/18/2021
End Date: 04/30/2023
Status: Active
2021 Funds Expended: **$275,000**
Total Project Cost: **$556,653**
Total SCG Cost: **$436,653**
Total Co-Funding: **$120,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UCI Hydrogen Enabled Microgrids for Critical Infrastructure Research

The goal of this project is to demonstrate that hydrogen-based renewable fuels—in concert with a cheap and renewable power supply on the electric grid—provide the best techno-economic and long-term solution to meet both 100% renewable energy conversion goals and stringent reliability requirements for essential services like data centers and hospitals. This project leverages previous and ongoing Microsoft co-funded data center research. The University of California, Irvine will design and optimize a fully integrated energy system for a data center. System design will account for site loads, electrochemical energy conversion and storage devices (fuel cells, electrolyzers, batteries), renewable generation (on- and off-site), and dynamic integration with infrastructure grids (electric, gas, water). Optimizations and comparisons will be based on technical capabilities, achieved reliability, and cost.

Co-Funders: Microgrid Corporation

Start Date: 11/22/2021
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$225,000**
Total Project Cost: **$562,442**
Total SCG Cost: **$362,442**
Total Co-Funding: **$200,000**
Benefits:

UCI Hydrogen Energy Storage and Integration with Dispatchable Power Generator System Design

The objective of this U.S. Department of Energy-sponsored project is to assess the viability of the incorporation of a hydrogen-based energy storage on the University of California, Irvine (UCI) campus to decarbonize the campus' natural gas consumption, primarily in the existing combined heat and power plant. The assessment was informed by the evaluation of potential hydrogen generation options, storage options, and assessment of necessary modifications to the existing natural-gas-fired Solar Titan 130 gas turbine engine at the central plant. UCI carried out technoeconomic analysis to evaluate numerous use scenarios which incorporated capital expenses, constraints regarding access to off-site renewable gas, export limits on power generated, emissions permitting, and current and future rates and commodity costs. In 2021, the feasibility of a hydrogen-based energy storage solution was completed and a recommendation for an overall system (including space requirements, adherence to required setbacks and safety codes, requirements for modifications to the turbine, and projected capital costs) was developed. UCI established a preferred approach including electrolytic hydrogen generation at 2,500 kg/day and associated storage.

Co-Funders: DOE

Start Date: 06/01/2021
End Date: 02/28/2022
Status: Active
2021 Funds Expended: **$50,000**
Total Project Cost: **$250,000**
Total SCG Cost: **$50,000**
Total Co-Funding: **$200,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UCI Integrated SOFC, Solar, and Storage System in ZNE Residential Nanogrid Design

The goal of this project was to design and analyze a residential "nanogrid" that integrates a solid oxide fuel cell combined heat and power (CHP) system, PV solar, and battery storage to achieve zero net energy (ZNE). The project team evaluated sixteen climate zones for component sizing and considered system configurations for four scenarios: 1) All Electric: PV + Battery; 2) All Electric: PV + solid oxide fuel cell (SOFC) + Battery; 3) Mixed Fuel: PV + Battery; 4) Mixed Fuel: PV + SOFC + Battery. Various metrics for achieving ZNE were considered in the analyses, including "Site," "Source," and "Time Dependent Valuation (TDV)" metrics. The project results showed that the All Electric: PV + Battery scenario results in impractical surface area requirements for PV to achieve ZNE. The research shows that ZNE can more practically be achieved by the Mixed Fuel scenarios, where gas is used for heating purposes. The Mixed Fuel: PV + SOFC + Battery scenario resulted in the least reliance on the electrical grid, while still meeting ZNE requirements. The SOFC proved to be beneficial by locally producing electricity at a high efficiency while simultaneously cogenerating heat. The project results show a need for the development of control strategies and systems to dynamically manage energy production, storage, and export. These control strategies can help optimize energy efficiency and limit the amount of mid-day export, reducing the stress applied to the grid. The team is pursuing a follow-on project to develop these strategies and controls.

Co-Funders: N/A

Start Date: 10/01/2019
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$195,000**
Total Project Cost: **$325,000**
Total SCG Cost: **$325,000**
Total Co-Funding: **$0**
Benefits:

UTD DG/CHP for Electric Demand Response (2.19.C)

In this project, researchers will review available demand response (DR) programs and demand-side management (DSM) options and evaluate the potential for life-cycle cost savings for distributed generation (DG) or combined heat and power (CHP) systems. The objective is to develop a technical and economic assessment of opportunities for peak electric DR that can be achieved from DG and CHP installations. The assessment of DR and DSM opportunities will identify operating strategies and other approaches that provide economic benefits for DG and CHP systems. Growth in DG units and micro-grids could improve the resilience for individual facilities and support the reliability of the electric infrastructure and its ability to react to increasingly "peaky" generation from increasing amounts of renewable energy.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$100,000**
Total SCG Cost: **$32,000**
Total Co-Funding: **$68,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD High-Efficiency Combi System Integrating PV and Self-Power – Phase 2 (1.20.G.2)

The goal of this project is to develop and demonstrate a hybrid residential combined HVAC and water heating (combi) system in the laboratory that uses off-the-shelf appliances and novel controls to integrate gas-electric systems with micro combined heat and power (mCHP), energy storage, and renewable energy in order to improve efficiencies, reduce greenhouse gas emissions, reduce operating costs, and increase resilience. GTI has successfully operated the nanogrid to achieve self-powered hybrid residential HVAC and water heating using the mCHP system and thermal/electric energy storage to power the combi system and air source heat pump (ASHP). The nanogrid controller manages the various power sources including mCHP, grid power, and solar PV. By using thermal heat recovery from the micro-CHP system together with the ASHP and supplemented with the tankless heater as necessary, GTI is targeting annual coefficients of performance greater than 1.0 serving heating loads down to 5,000 BTUs per hour. GTI is now implementing a test plan to determine the performance of various system configurations: grid parallel, islanded, and integrated with simulated solar PV generation.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$48,000**
Total Project Cost: **$450,000**
Total SCG Cost: **$95,769**
Total Co-Funding: **$354,231**
Benefits:

UTD Integrated CHP System for Multi-Family Buildings (1.20.J)

The goal of this project is to perform a laboratory evaluation of the EC Power/Lochinvar XGRi25 micro combined-heat and power (mCHP) unit in a multi-family scenario when coupled with best-in-class electric heat pumps (EHPs) responding to individual homes' heating and cooling demand. With integrated smart thermal storage and management capabilities, the XGRi25 along with advanced EHPs will operate as an advanced gas-fired integrated system with annual gas efficiencies greater than 100% for heating, cooling, and hot water loads. The project will integrate the mCHP system with the EHP to communicate and perform in power lead mode, size the appropriate thermal storage for multi-family scenarios, and characterize the space and water heating part-load performance. To date, the team has designed, procured, and commissioned all system components. The integrated system evaluation will take place in 2022.

Co-Funders: UTD Members

Start Date: 06/01/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$15,000**
Total Project Cost: **$250,000**
Total SCG Cost: **$30,000**
Total Co-Funding: **$220,000**
Benefits:

UTD Integrated mCHP System for Multi-Family Building – Phase 2 (1.20.J.2)

The goal of this project is to leverage the results of Phase 1, which integrated a Lochinvar CHP, distributed air source heat pumps, and thermal storage in an integrated energy system (IES). This project will expand the capabilities of the system to further test and demonstrate the capabilities of the IES in a multifamily setting. The project team will integrate electric vehicle charging, PV integration, and hydrogen blending in a microgrid configuration to demonstrate resiliency and efficiency benefits. The system will be designed and evaluated in both grid-connected and islanded configurations.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$70,000**
Total Project Cost: **$480,000**
Total SCG Cost: **$139,249**
Total Co-Funding: **$340,751**
Benefits:

CUSTOMER END-USE APPLICATIONS

SUB-PROGRAM: ADVANCED INNOVATION

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

METRON Energy Virtual Assistant (EVA) Industrial AI Demonstration

This project will demonstrate METRON's "Energy Virtual Assistant (EVA) Factory Solution", which optimizes industrial processes utilizing machine learning. All types of data from industrial equipment (boilers, chillers, compressed air, dryers, etc.) are captured and processed by the METRON-EVA platform. The platform allows for "non-intuitive optimization," real-time access to data, and easy reporting. METRON hopes to achieve a payback period of less than 12 months, and up to 15% total energy savings (electric and gas combined). The goal is to test/demonstrate the technology at up to three (3) locations. Depending on the site, commissioning can be achieved with minimal hardware installation or remotely (if the customer already has monitoring equipment). Frontier Energy will provide independent, 3rd party measurement & verification of savings. In 2021, the project team interviewed several potential host sites and selected a manufacturer of high-performance composite materials and products for the aerospace and transportation industry. The team decided to focus on one pilot site to ensure a successful demonstration rather than three. During the site analysis, the project team identified several pathways for significant energy savings including modifications to perimeters that affected the electricity, steam generation, vacuum pump, compressed air, expansion, and incinerator processes. Both a digitalization roadmap and energy assessment have been delivered to the host site. The host site is considering the implementation of all energy measures for maximal energy savings.

Co-Funders: N/A

Start Date: 08/31/2020
End Date: 03/31/2021
Status: Completed
2021 Funds Expended: **$481,460**
Total Project Cost: **$481,460**
Total SCG Cost: **$481,460**
Total Co-Funding: **$0**
Benefits:

Resource Innovations NA Gas Heat Pump Collaborative

A number of North American utilities, including SoCalGas, are interested in participating in a collaboration to design and implement activities that will accelerate the commercialization and market acceptance of gas heat pumps in North America. The overall goal of this collaboration is to join forces to secure dramatically enhanced market share of gas heat pump technologies and energy efficient gas technologies by working together across a number of North American Local Distribution Companies. In 2021, the collaborative conducted market characterization research through Russell Research. The market characterization research covered valuable insight on supply chain research, consumer sentiment and needs, utility-specific research (i.e., size of the residential water heater market, quantify findings amongst consumers, customer segmentation), and identification of market barriers and opportunities. Further progress has been delayed pending a status update from a related country-wide field demonstration.

Co-Funders: N/A

Start Date: 01/01/2019
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$25,700**
Total Project Cost: **$104,280**
Total SCG Cost: **$104,280**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

SMP Sustaining Membership Program

SMP is a collaborative research and development program with two segments, Utilization and Operations. Its gas utility members support research projects focused on gas delivery, energy utilization, environmental science, and renewable energy. SMP develops the technology through the "proof of concept" phase, at which point the most promising technologies are continued through short- to midterm R&D programs, implemented by organizations such as Operations Technology Development and Utilization Technology Development.

Co-Funders: N/A

Start Date: 10/23/2018
End Date: 12/12/2021
Status: Completed
2021 Funds Expended: **$40,000**
Total Project Cost: **$100,000**
Total SCG Cost: **$100,000**
Total Co-Funding: **$0**
Benefits:

UTD Carbon Management Information System (GTI 21917/22060)

The Carbon Management Information Center (CMIC) is an ongoing GTI collaborative program that is currently funded by 20 natural gas industry members as well as the Propane Education and Research Council. CMIC is developing resources and analytical tools that evaluate opportunities for efficient natural gas and propane systems to improve energy efficiency, reduce greenhouse gas emissions, and lower energy costs for consumers compared to electric and oil options. In 2021, CMIC focused on updates to the CMIC SEEAT and EPAT analytical tools including full-fuel-cycle methodologies, life cycle calculation options, and additional renewable gas options; clearinghouse information on other technical reports, information products, and carbon management activities; macro-analysis of carbon impact of end-use technology options and scenarios; case studies of specific scenarios in targeted service territories; and white papers, analytical reports, presentations, and data for targeted stakeholders and committees.

Co-Funders: UTD Members

Start Date: 01/21/2016
End Date: 07/01/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$2,851,400**
Total SCG Cost: **$280,000**
Total Co-Funding: **$2,571,400**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Gas Fired High Efficiency Liquid Dessicant Air Conditioning and Humidity Control – Phase 2 (1.15.E.2)

Start Date: 06/01/2018
End Date: 11/28/2021
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$415,000**
Total SCG Cost: **$4,000**
Total Co-Funding: **$411,000**
Benefits:

The goal of this project was to develop a gas-fired liquid desiccant dedicated outdoor air system (LDDOAS) that addresses many of the critical issues now facing the HVAC industry. In this project, a research team collaborated with a manufacturer to compare the current state-of-the-art LDDOAS technology with other advanced systems and then to design and experimentally evaluate a breadboard LDDOAS test rig rated at approximately 100 CFM capacity using a novel non-corrosive, non-toxic desiccant. In Phase 1, the project team constructed an experimental gas-fired liquid-desiccant air-conditioning system. In Phase 2, the team performed upgrades to a one-tower test rig and completed liquid desiccant distribution tests. Progress was made on continuous regeneration tests, demonstrating regeneration efficiency as high as 70% while regenerating the desiccant to an appropriate strength. In 2021, the project team conducted rigorous testing of dew point sensors and determined that an energy imbalance detected in earlier testing was not due to instrument accuracy. One theory was that the insufficient mixing of water vapor in the air at the exit of the tower was causing the imbalance. To ensure proper mixing of the air as it exits the tower, the project team constructed a reducer for the top of the tower to increase the velocity and turbulence of the flow. Testing of the modified tower commenced and confirmed that insufficient mixing was causing the energy imbalance. The project will continue into 2022. For the next reporting period, the team plans to begin benchtop tests of the desiccant of different material surfaces, evaluation of a two-tower system, and research into the technical potential of LDDOAS.

Co-Funders: UTD Members, NYSERDA

UTD Investigating Multifamily Infrastructure Challenges – Phase 4 (1.14.J.4)

Start Date: 07/01/2019
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$127,000**
Total SCG Cost: **$1,984**
Total Co-Funding: **$125,016**
Benefits:

The objectives of this project were to evaluate the current position of the natural gas industry in multifamily new construction and develop recommendations for improvement. The goals were to develop concrete market transformation implementation tools and action plans to properly connect with new development decision-makers to keep natural gas viable in new multifamily construction. In earlier research, the project team held interviews with key national-level players active in the multifamily market, including representatives from industry associations, gas utilities, and the building and development community. In this project, the project team continued dialogues with experts in the multifamily new construction market and sought to create actionable tools for UTD members to better serve multifamily homeowners, architects, and builders. Researchers continued to identify concurrent research of import to communicate quantifiable true costs and benefits to key industry, regulatory, and construction-based stakeholders. The project team prepared three case studies and tangible market guidance tools for design and construction professionals, including a curriculum geared toward design professionals.

Co-Funders: UTD Members

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

SUB-PROGRAM: COMMERCIAL APPLICATIONS

CSU Hydrogen Blend on a Caterpillar NSCR Natural Gas Compression Engine Research

The objective of this engine testing research is to assess the impact hydrogen blends have on the emissions and performance of a rich-burn engine with a non-selective catalytic reduction catalyst (NSCR). The goal is to test how various air fuel ratio control processes can mitigate impacts. Researchers hypothesize that more advanced systems and controls are needed to accommodate blends with hydrogen content and remain in compliance with air quality requirements. There are approximately 1,000 - 2,000 engines in operation in our service territory, used for water pumping, distributed power generation, and pipeline gas compression. This research could help develop a statewide hydrogen injection standard as well as better understanding of hydrogen blending in commercial and industrial (C&I) equipment. The research will also benefit disadvantaged communities since most of these engines are in municipalities, water companies, and farming areas. Successful completion of the project will allow the C&I team to work with customers to retrofit their engines before they receive hydrogen blends. The research agreement was executed on 10/2021 and a project kick-off meeting was held shortly afterward. The research team is in the planning phase of the project lifecycle and focused on preparing the hydrogen blending system setup for the required engine testing.

Co-Funders: Caterpillar

Start Date:	09/01/2021
End Date:	09/01/2022
Status:	Active
2021 Funds Expended:	**$121,148**
Total Project Cost:	**$203,066**
Total SCG Cost:	**$173,066**
Total Co-Funding:	**$30,000**
Benefits:	

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI Gas Heat Pump Water Heating and Space Cooling in Restaurants Demonstration

In this project, the team demonstrated the potential of an innovative technology at two restaurant sites in the Los Angeles basin, a low-cost gas-fired heat pump (GHP) for integrated commercial water heating and air-conditioning (A/C). The GHP is a direct-fired, single-effect, absorption heat pump using an ammonia/water working pair, with an operating heating Coefficient of Performance of 1.40-1.90 (fuel HHV basis). In prior laboratory testing and field applications for space heating, it has an estimated Annual Fuel Utilization Efficiency of >140% and is anticipated to have an equipment cost approximately half that of comparable GHP equipment. To offset A/C energy consumption, this GHP was modified to deliver hot water and supplemental A/C, sized to provide 80 kBtu/h of hot water and 2.5 tons of cooling simultaneously, with 4:1 modulation. This GHP is designed by a startup company specializing in gas-fired heat pumps, Stone Mountain Technologies, Inc. (SMTI), with technical support from GTI and A.O. Smith. At the conclusion of the project, the research team found that therm savings at both sites were 16%-26% for the Integrated GHP System and 52%-53% for the heat pump itself. The daily net electricity increase for both sites (as-is) is 7-8 kWh. The therm savings translate to $970- $2,780/year, or $620-$2,530 when including electricity, and using mature quantity production estimates of GHP and other standard equipment costs. Simple paybacks for the Integrated GHP System range from 1.1 to 6.4 years (fuel savings basis). Lastly, the climate impact of the technology yielded a net greenhouse gas reductions of about 46-48% using 2018 CA-statewide emission factors. The project is pending a CEC final publication.

Co-Funders: CEC

Start Date: 04/17/2017
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,090,294**
Total SCG Cost: **$226,000**
Total Co-Funding: **$864,294**
Benefits:

GTI Model-Based Control Hospital Decarbonization Demonstration

This project will demonstrate an integrated model-based control solution for reducing space heating and hot water loads in order to decarbonize large commercial buildings. The proposed technology will significantly reduce energy use and greenhouse gas (GHG) emissions. GTI will monitor and report real energy savings and GHG reductions from the installation of advanced technologies at the Baldwin Park Medical Center. The goals of the project are to demonstrate an overall 30% reduction in natural gas usage and a simple payback of less than 3 years, advance the technologies integrated with model-based optimal control from TRL7 to TRL9, and showcase the retrofit measures and energy savings through outreach to encourage similar implementation of energy saving measures throughout the state. In 2021, the project team held their first technical advisory committee meeting on 7/2021 to share their project progress. During their meeting, they shared their analysis on the site characterization including technical information on the boiler and chiller systems used by the medical center. They also discussed their baseline monitoring plan which was submitted on 3/2021 and next steps in the project which include addressing outstanding metering issues, fine tuning energy models, and drafting the final hospital baseline energy usage and modeling report.

Co-Funders: CEC

Start Date: 12/01/2020
End Date: 03/31/2040
Status: Active
2021 Funds Expended: **$80,000**
Total Project Cost: **$1,585,954**
Total SCG Cost: **$161,250**
Total Co-Funding: **$1,424,704**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

Momentum Gas Heat Pump Demonstration

In this project, SoCalGas is leading an effort to deploy and demonstrate the technical and economic viability of high efficiency natural gas heat pumps at the Westin Bonaventure, a 1.5 million square foot hotel located in a low-income and disadvantaged community. The goals of the project are to optimally deploy state-of-the-art natural gas heat pump technology into the Westin Bonaventure Hotel that greatly reduces greenhouse gas emissions and air quality impacts to local communities and populations located next to and in the surrounding areas of this facility, while also demonstrating energy efficiency savings of a minimum of 35% reduction in natural gas consumption (target 50%). In 2021, the host site decided they could no longer host the technology demonstration. As a result, the project team spent the majority of the year developing a turnaround strategy including the identification of alternative sites. With the assistance of the CEC, several meetings were held with the project team to narrow down prime candidates including a large university and a major television production facility. An alternate site has not been finalized.

Co-Funders: CEC

Start Date: 12/01/2020
End Date: 03/31/2024
Status: Active
2021 Funds Expended: **$80,000**
Total Project Cost: **$1,585,954**
Total SCG Cost: **$161,250**
Total Co-Funding: **$1,424,704**
Benefits:

UC Davis Aerosol Sealant Demonstration

This project will advance the development of a unique technology that uses aerosolized sealant particles to remotely seal leaks in the low-pressure natural gas distribution systems downstream of the building pressure regulator. This technology has been commercialized for duct sealing and building envelope sealing but has only been tested to a limited extent for natural gas distribution sealing. Not only does this technology seal otherwise inaccessible leaks, but it also automatically tracks the sealing process, providing real-time feedback to the applicator, and documentation of the sealing performed. In 2021, the majority of the project tasks were complete. That is, the team built and tested a leakage measurement apparatus in the laboratory, applied the apparatus and protocol on ten systems, and built an aerosol sealing apparatus, and applied it to a building piping system. The team would like to rebuild the apparatus to test the sealing process again. The first apparatus leaked too much for the tightness levels that were needed in gas lines. Otherwise, the team expects to deliver a final report in June of 2022.

Co-Funders: N/A

Start Date: 07/01/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$67,097**
Total Project Cost: **$151,663**
Total SCG Cost: **$151,663**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Advanced Nozzle Burner for Commercial Water Heaters – Phase 2 (1.18.C.2)

In Phase 1 of this project, researchers successfully developed and tested a 3D-printed burner by integrating advanced nozzle prototypes with the blower, controls, and fuel inlet of a commercial water heater. The goal of the current Phase 2 effort is to develop and test a beta prototype version of this robust, smooth-and-safe-operating advanced retention nozzle in a commercial water heater (~200,000 Btu/hr capacity), offering improved efficiency, turndown, emissions, stability, and compactness. The project team is designing and fabricating prototypes of a nozzle burner. This design considers the key features to be adapted for the prototype (e.g., flame stability within the water heater and smooth ignition). Two to three design iterations will be fabricated by Oak Ridge National Laboratory. In 2021, the project team reviewed different integration methods for the burner within the water heater. Currently, researchers are in discussions with major water heater manufacturers regarding this technology development.

Co-Funders: UTD Members, ORNL

Start Date: 06/01/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$300,000**
Total SCG Cost: **$24,000**
Total Co-Funding: **$276,000**
Benefits:

UTD Advanced Systems for Self-Powered Water Heating – Phase 3 (1.14.K.3)

In this project, researchers investigated Two-Phase Thermo-Syphoning (TPTS) technology and ultra-low-power gas-water heater control technology in an effort to develop a prototype "unplugged" higher-efficiency, storage-type water heater. A TPTS water heater offers the potential for higher effiency, scalability, rapid startup, long life, minimal standby heat loss, minimal scaling, self-power capability, and low emissions. Phase 1 of this project began in 2014 with a preliminary cost analysis. In Phase 2, the project team developed a Computational Fluid Dynamics model of the surface combustor with embedded tubes. Phase 3 began in 2020 and continued through 2021. The bench-scale evaporator for the TPTS for self-powered water heaters was developed, designed, and tested in the laboratory. The modified evaporator was integrated with a new radiant burner and metal foam tubular heat exchanger. Experimental results were analyzed and are summarized above. A Phase 3 Final Report was issued in July 2021. Researchers recommend that a next phase of the project be considered to develop an alpha prototype of the TPTS water heater.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$165,000**
Total SCG Cost: **$45,000**
Total Co-Funding: **$120,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD CleanO2 CARBiNX Carbon Capture (1.21.C)

This project will evaluate the performance of a CleanO2 CARBiN-X v 4.0 carbon capture device in a laboratory setting in order to validate claims of a carbon dioxide capture rate of 4 metric tons per year and cost savings of at least 30% for hot water heating. It will further identify areas for continued technical improvement. Besides the CARBiN-X v 4.0, CleanO2 is working on more advanced prototypes that look to further disrupt the distributed carbon capture market. Depending on the progress in the development of these prototypes, GTI may perform preliminary regulatory and technical analyses to support advancement of this technology. Implementing distributed carbon capture technology such as the CARBiN-X will help reduce greenhouse gas emissions in the residential and light commercial and industrial spaces while retaining natural gas in Zero Net Energy Buildings.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 01/31/2023
Status: Active
2021 Funds Expended: **$20,000**
Total Project Cost: **$150,000**
Total SCG Cost: **$30,000**
Total Co-Funding: **$120,000**
Benefits:

UTD Commercial Gas Fired Heat Pump Water Heater – Phase 3 (1.16.I.3)

The objective of this project was to expand the duration and impact of the field demonstration currently underway at a multi-family residence in Evanston, IL of the prototype high-efficiency commercial gas heat pump water heater (GHPWH) developed in conjunction with Stone Mountain Technologies Incorporated. This project will: 1) further optimize the boiler & GHPWH controls when operating as a hybrid system, for both the specific (Evanston, IL pilot) and general case; 2) extrapolate the findings and optimized controls strategies to low-rise, mid-rise, and high-rise multifamily buildings in six North American climate regions using a building simulation tool; and 3) publicize the simulation results, design guidelines, and other project results in an industry white paper(s) to advance discussions and actions by developers, architects, engineers, and expected commercialization partner OEM Weil McLain.

Co-Funders: UTD Members, A.O. Smith

Start Date: 07/01/2019
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$180,000**
Total SCG Cost: **$26,211**
Total Co-Funding: **$153,789**
Benefits:

UTD Commercial Heat Pump Water Heater Field Performance Comparison (1.21.F)

In this project, a comparison between commercial gas and electric heat pump water heater technology will be conducted in one or two field locations as well as in GTI's laboratory using ASHRAE standards to establish the cost- and energy-saving capability of each technology. The goals are to assess the performance of these technologies under various conditions, and to provide equitable comparative information between commercial heat pump technologies. The project agreements were finalized in 2021 and work is expected to begin in early 2022.

Co-Funders: UTD Members, PERC, DOE

Start Date: 07/01/2021
End Date: 01/31/2024
Status: Active
2021 Funds Expended: **$1,800**
Total Project Cost: **$916,000**
Total SCG Cost: **$4,707**
Total Co-Funding: **$911,293**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Economical High-Efficiency Residential Gas Absorption Heat Pump with Integrated Cooling – Phase 2 (1.18.H.2)

The project team seeks to demonstrate an economical gas absorption heat pump (GAHP) with integrated cooling for a projected target equipment price of $5,000. The objective of this phase of the project is to finalize the design, fabrication, debugging, commissioning, and testing of a complete working "alpha" prototype unit that adds cost-effect cooling to the low-cost GAHP pre-commercial product developed in UTD project 1.13.F with Stone Mountain Technologies Inc. (SMTI). Laboratory tests were conducted to estimate the hybrid unit's performance using standardized steady-state testing. In addition to standardized rating tests, an extended 24-hour simulated use test was conducted in a virtual test home to obtain a complete mapping of performance and evaluate the impact of coincident loads. The project team is finalizing preparations for the installation of GAHP hybrid equipment in the laboratory, with thermal heat pump test station upgrades. Researchers are analyzing the results of testing to make recommendations on system design modifications, sizing considerations, and controls updates.

Co-Funders: UTD Members, SMTI, Natural Gas Innovation Fund

Start Date: 07/01/2019
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$370,000**
Total SCG Cost: **$24,324**
Total Co-Funding: **$345,676**
Benefits:

UTD Energy Source Options for Industrial Users (2.20.E)

The objective of this project was to develop an easy-to-use tool that allows industrial and commercial equipment end users to assess de-carbonization scenario options when comparing equipment and systems currently powered by fossil natural gas to the same equipment when employing other options. The project team performed a market assessment and techno-economic analysis of possible fuel-switching and decarbonization scenarios for a spectrum of industrial and large commercial subsectors and end-use applications. A database of 77,000 data points was used to categorize and analyze the energy use for each of the nine census regions based on five selected subsectors. Each of the five selected subsectors was then divided into 18 key technologies to better understand the overall spectrum of end uses and identify the technology consuming the highest amount of energy under each of the key subsectors, with a geographical indicator. A utility-member-specific "first-cut" version of the tool was prepared and provided to project funding members who choose to provide information for their industrial boiler customer base. The tool is expected to be used to develop a roadmap basis for natural gas and RNG to support the continued reliable and cost-effective supply of gaseous energy to industrial and large commercial sectors in locations where regulations or other drivers strive to adopt increased decarbonization goals.

Co-Funders: UTD Members, ESC

Start Date: 03/01/2020
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$120,000**
Total SCG Cost: **$10,909**
Total Co-Funding: **$109,091**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Field Evaluation of Central Condensing Tankless Water Heaters for Energy Savings (1.18.E)

The objective of this project was to perform a field demonstration of the central condensing tankless water heating system (CCTWH). The CCTWH is an emerging technology for high efficiency generation of service hot water (SHW). This field evaluation of CCTWHs at two multifamily buildings in Minnesota was the first third-party study to quantify the energy savings potential of CCTWH over conventional direct-fired gas storage and indirect (with dedicated boiler) SHW systems in this application. The primary goal of the project was to verify the energy savings potential of CCTWHs in multifamily housing, quantify benefits and potential drawbacks, and extrapolate to other sectors and regions outside of Minnesota by developing custom modeling and assessment tools. Data analyses were completed between the tankless and baseline systems. The findings included full-system efficiencies, which included the recirculation loop. System efficiencies are lower than water-heater efficiencies because they account for heat loss as the hot water circulates throughout the building in un-insulated pipes. For the baseline tank systems, the average system efficiency was 0.60 and for the CCTWH system, the average system efficiency was 0.66. For the water-heater-only efficiencies, the average baseline tank efficiency was 0.74 and for the CCTWH it was 0.85. A draft of the project Final Report was completed and is under internal review by the state of Minnesota as the prime sponsor of this research.

Co-Funders: UTD Members, State of Minnesota

Start Date: 06/01/2018
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$495,000**
Total SCG Cost: **$14,000**
Total Co-Funding: **$481,000**
Benefits:

UTD Gas Engine Heat Pump Modeling, Testing, and Implementation (1.21.E)

This project will validate natural gas engine-driven heat pump (GEHP) performance for variable refrigerant flow systems across a range of conditions. It will expand the market through enhanced energy models using measured performance data, validation of a new method of testing (ANSI/CGA) for new GEHP performance metrics, and technoeconomic assessment to determine the best use of three new GEHP equipment options. These options include air handler unit integration kits, Yanmar Hydrobox, and Aisin Hi-Power. The project agreements were finalized in 2021, and work is expected to begin in early 2022.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 01/31/2024
Status: Active
2021 Funds Expended: **$3,100**
Total Project Cost: **$320,000**
Total SCG Cost: **$7,631**
Total Co-Funding: **$312,369**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Gas Heat Pump Combination Space/Water Heating System Design – Phase 2 (1.17.C.2)

The objective of this project was to develop a smart combined space- and water-heating systems ("combi" systems) controller that infers the properties of a heat pump and/or water heater and hydronic air handler, and then optimizes the system performance for efficiency and comfort. The goals of the project were to: (1) reduce to practice a hydronic heating hub (H3) controller for combination space and water heating systems, and (2) design and build an alpha prototype that utilizes the H3 controller either built into the air handler unit (AHU) or as a hub between an AHU and water heater to automate otherwise field-engineered methods for maximizing combi efficiency and delivered comfort. The project team developed an alpha-prototype combi controller that implements control features for achieving 90%+ gas efficiencies down to 5% part-loads and 100%+ hybrid efficiencies in an integrated energy systems approach. Researchers finalized the shakedown of the laboratory test rig and completed the test plan to validate the controller's learning framework. Additionally, researchers secured a provisional patent and are pursuing a patent for the technology.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$24,000**
Total Co-Funding: **$126,000**
Benefits:

UTD Gas-Fired Binary Fluid Ejector Heat Pump Water Heater (1.20.E)

This project models, designs, and builds prototypes of a gas-fired ejector heat pump water heater (GFEHP). This first-of-a-kind heat pump uses a novel cycle that combines a binary-fluid ejector and sorption subsystem into one high-efficiency cycle. The technology integrates several components that are thermally and hydraulically coupled. The overall objective is to develop and demonstrate GFEHP technology at 12,000 Btu/hr (3.5 kW) capacity in the laboratory and to achieve a coefficient of performance of 2.0. This will make it twice as efficient as the current state-of-the-art technology on a primary energy basis. This will help retain a high-efficiency role for natural gas for more than 80 million residential users of gas-fired water heaters in the U.S. alone. The research team is finalizing the burner design and will begin designing and developing the heat-exchanger system between the flue gas and the working fluid.

Co-Funders: UTD Members, DOE

Start Date: 07/01/2020
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$6,375**
Total Project Cost: **$2,080,000**
Total SCG Cost: **$19,125**
Total Co-Funding: **$2,060,875**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD High Efficiency Thermo Vacuum Commercial Clothes Dryer – Phase 2 (2.17.C.2)

Start Date: 07/01/2019
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$1,990,225**
Total SCG Cost: **$15,225**
Total Co-Funding: **$1,975,000**
Benefits:

The objective of this project is to develop and test a prototype high-efficiency, natural gas-fired thermo-vacuum clothes dryer and demonstrate the technical and economic benefits over the state-of-the-art dryer. A successful prototype would result in drying time reduced up to 75%, fuel savings of 50% or more, and significant emissions reduction while lowering operating and maintenance expenses. Bench-scale experimentation for drying of selected fabric samples was conducted. These drying curves will serve as a basis for designing prototype units and help inform the development of refined drying curves. Commercial product lines were assessed and evaluated, and major equipment original equipment manufacturers were contacted. The integrated drying concept was characterized to establish the baseline performance. A benchmark unit for the laboratory-scale testing was defined and specification of key components is in progress. In 2020, the numerical model of the thermo-vacuum drying process was refined and verified with the initial bench-scale experimental data. The feasibility study and bench-scale evaluation demonstrated the superior performance of the technology and provided promising results for moving the technology forward. A paper that includes the methodology, model description, and process energy analysis was presented at the 18th International Refrigeration and Air Conditioning Conference in May 2021. Promising discussions occurred with major equipment manufacturers, which demonstrated significant market interest. In addition, the U.S. Patent Office continued to review related U.S. patent application 62/785,769.

Co-Funders: DOE, UTD Members

UTD High Efficiency Ultra-Low NOx Commercial Boiler Burner (2.17.I)

Start Date: 06/16/2017
End Date: 11/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$300,000**
Total SCG Cost: **$70,588**
Total Co-Funding: **$229,412**
Benefits:

The objective of this project was to commercialize a high-efficiency commercial burner that is economically and operationally more attractive to end users than current boiler systems. This project specifically focuses on incorporating advanced control systems and combustion stability techniques into a burner design. The technology is unique in its ability to achieve ultra-low emission levels and increase boiler efficiency compared to conventional burners. The monitoring system for the pre-commercial boiler/burner system was installed in early 2018 at the commercial laundry facility. The boiler/burner consistently achieved emissions <9 vppm NOx without the need for costly and complex selective catalytic reduction, external FGR, or operation at high-excess-air levels. Extensive evaluation of the technology for over 10,000 hours of real-world conditions proved the burner capable of meeting low-emission levels while operating with relatively low excess air and high efficiency levels. The host site demonstration documented a 9% savings in fuel usage as compared to the baseline boiler. An independent third party conducted a source test in May. Testing for all series confirmed <7 ppm NOx emissions and carbon monoxide emissions below their lower detectable limit (24 ppm). Burner operation was observed as the unit successfully followed changing load conditions. A Final Report was submitted to the California Energy Commission for review.

Co-Funders: UTD Members

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Hydrogen-Blended Gas in ResCom Combustion Equipment (1.20.H)

The objective of this project is to adapt and demonstrate solutions to use high-hydrogen blends (> 50% hydrogen by volume) and 100% hydrogen in residential and commercial combustion equipment, by demonstrating multiple solutions in a controlled laboratory environment and leveraging international developments and technology transfer. The specific project goals are three-fold: 1) build a hydrogen-blend test station demonstration and experimental test station and use it to evaluate the performance of hydrogen-compatible prototypes, products, and components from an emerging network of global developers; 2) develop a research and development roadmap to identify and address gaps and opportunities with high-hydrogen-compatible stationary combustion equipment; and 3) use the new hydrogen-blend experimental test station to disseminate and demonstrate technology, including hosting outreach events to a wide range of stakeholders. In 2021, the project team developed a comprehensive review of hydrogen demonstrations in Europe and Asia that included end-use customers, including materials from the EU-based THyGA project, adapting some of the timely findings for a February UTD member webinar. Additionally, researchers actively coordinated with other North American hydrogen studies and testing efforts. Researchers are finalizing the test plan, including specifying subject equipment and design/fabrication plans for a test rig.

Co-Funders: UTD Members

Start Date: 07/01/2020
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$8,400**
Total Project Cost: **$179,900**
Total SCG Cost: **$18,900**
Total Co-Funding: **$161,000**
Benefits:

UTD Hydrogen-Blended Gas in ResCom Combustion Equipment – Phase 2 (1.20.H.2)

This project will support the potential deployment of up to 30% hydrogen blended gas in North America in commercial and residential buildings, by assessing operational performance, emissions, and safety impacts on at least five standard appliances in a laboratory setting. Specific goals of Phase 2 are to determine the impact of hydrogen blends on efficiency rating and seasonal performance on appliances, to project greenhouse gas reduction potential of hydrogen blending at various levels for U.S. and Canadian blocking stocks, and to identify safety, emissions, and efficiency benefits or concerns.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 01/31/2023
Status: Active
2021 Funds Expended: **$2,900**
Total Project Cost: **$150,000**
Total SCG Cost: **$4,350**
Total Co-Funding: **$145,650**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Integrated, Self-Powered, High Efficiency Burner System (1.19.C)

The objective of this project is to develop and demonstrate a grid-resilient, self-powered, fuel-flexible, high-efficiency Advanced Burner Thermoelectric Generator (ABTEG) as an integrated system that can be dropped into many types of residential and commercial building space and water heating systems. The integrated system consists of two key subsystems: 1) a 3D-printed high-efficiency, ultra-low-emissions, fuel-flexible, modulating burner integrated with 2) a commercially available low-cost, high-efficiency, high-operating-temperature TEG. The technology is targeted to provide NOx emissions reduction of more than 70% compared to current designs. The following tasks will be performed: subsystem specifications and design; burner fabrication and testing; and testing of the integrated ABTEG system architecture. The team performed a detailed analysis to down-select three different materials for the TEG. In addition, three different water heaters were reviewed. In 2020, researchers performed Computational Fluid Dynamics (CFD) analysis for the fuel-flexible burner and generated a solid model for 3D printing. In 2021, testing was performed on multiple TEG units of different power levels and physical dimensions to understand the power output. CFD analysis of the burner and bench-scale setup for burner testing is in progress. CFD modeling of the burner is complete. Key design improvements were identified and implemented. TEG testing is in progress. Next steps are to determine the best method to integrate TEG with water-heating systems and perform testing with an advanced burner. Methods to improve the performance of the burner for pressure drop and air-fuel mixing are being evaluated.

Co-Funders: UTD Members, DOE, A.O. Smith, Sheetak, II-VI Marlow

Start Date:	07/01/2019
End Date:	07/31/2022
Status:	Active
2021 Funds Expended:	**$12,200**
Total Project Cost:	**$1,060,000**
Total SCG Cost:	**$36,600**
Total Co-Funding:	**$1,023,400**
Benefits:	

UTD Ionic Liquid Absorption Heat Pump for Commercial Water Heating (1.21.I)

The objective of this project is to design and demonstrate in a lab environment an "alpha" working prototype of a low-cost, ultra-high efficiency gas-fired commercial heat pump water heater with a novel semi-open absorption cycle (SOA-GHPWH) that uses a benign ionic liquid, and which provides integrated latent cooling to further maximize efficiency. The target efficiency is COPgas, HW ≥1.60 if only providing hot water, or COPtotal >1.80 if also providing indoor cooling and dehumidification. The prototype will be performance-tested at loads (steady and dynamic) typical of commercial buildings with 100 gallons storage and nominal heating output of 145 kBtu/hr. The system uses a simple plastic pump, and most materials of construction are polymers.

Co-Funders: UTD Members

Start Date:	12/31/2021
End Date:	12/31/2023
Status:	Active
2021 Funds Expended:	**$1,200**
Total Project Cost:	**$225,000**
Total SCG Cost:	**$2,400**
Total Co-Funding:	**$222,600**
Benefits:	

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Low Emission Efficiency Burner for Ovens and Dryers (2.20.A)

The objective of this project is to validate the performance of a novel burner assembly both in the laboratory and at an end-user host site. The goal is to advance the commercial introduction of a new burner that will reduce emissions, energy use, and operating and capital expenses for many end users. The novel burner technology was previously developed in Project No. UTD 2.15.D. This project will test the air-process heating assembly with a focus on the burner performance and progress from a laboratory to a host site. Specific tasks include: (1) integrating the burner assembly at the laboratory; (2) evaluating the burner performance at the laboratory; (3) designing and integrating the assembly at the host site; and (4) evaluating prototype-burner performance at different operation and process conditions. In 2020, fabrication of the burner assembly and the crossflow process-air section were completed. Insulation of the process-air section and installation and assembly to the furnace was completed. In 2021, the air and fuel trains for the burner and the crossflow air were installed for flow, pressure, and temperature measurements. Shakedown and turndown testing of the burner was performed. Researchers are currently performing preliminary burner performance evaluations in the laboratory.

Co-Funders: UTD Members, Preheat Inc.

Start Date: 06/01/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$11,900**
Total Project Cost: **$200,000**
Total SCG Cost: **$23,800**
Total Co-Funding: **$176,200**
Benefits:

UTD Membrane Based Ionic Liquid Absorption Heat Pump for Commercial HVAC (1.20.I)

The objective of this project is to develop an innovative thermally driven cooling technology for commercial heating, ventilation, and air conditioning (HVAC) applications. The technology will be demonstrated in a prototype ultra-high efficiency dedicated outdoor air system. The core technology under development is a novel, scalable absorption system for dehumidification using a highly efficient open double-effect liquid desiccant cycle enabled by the use of non-crystallizing ionic liquids. This absorption system is centered on a compact membrane-based heat and mass exchanger with no desiccant entrainment. The compact size facilitates easy retrofitting into existing building infrastructure. Regeneration of the system is driven by efficient heating (natural gas, propane, waste heat, solar, etc.). Modine Manufacturing, a commercial HVAC market leader, will provide industry support. The project team is completing the fabrication and experimental investigation of the desorber/condenser combustion system evaluation in the laboratory.

Co-Funders: UTD Members, PERC, DOE

Start Date: 08/01/2020
End Date: 08/31/2023
Status: Active
2021 Funds Expended: **$8,240**
Total Project Cost: **$1,800,000**
Total SCG Cost: **$24,033**
Total Co-Funding: **$1,775,967**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Next Generation Infrared Burner – Phase 3 (2.16.A.3)

The objectives of this project are to design, build, and test prototype high-efficiency, high performance, low emission gas-fired infrared burners that use advanced metal foam material to offer end users new high-efficiency products. The project team is collaborating with material and burner manufacturers. Using gas-fired infrared (IR) heaters instead of electric driven IR heaters can significantly reduce both source energy emissions and end users' operating costs. The goal of this project is to build on earlier developments to advance a gas-fired IR burner for commercial and industrial use. In this project, researchers investigated advanced metal foam IR burners, with better material properties. In the current phase of the project, the research team will design, build, and test in the field a prototype next generation, high response, higher-efficiency IR burner.

Co-Funders: UTD Members, Solaronics, Alantum Corp

Start Date: 06/01/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$300,000**
Total SCG Cost: **$92,00**
Total Co-Funding: **$290,800**
Benefits:

UTD Sequestering Non-Condensable Gases for Enhanced Gas Absorption Heat Pump Reliability (1.19.E)

The objective of this project is to design and develop Non-Condensable Gas Isolation Modules, and to provide research and development support to employ novel, low-cost aluminum heat exchangers to increase system reliability and safe operation, and to reduce the cost of any absorption-type heat pump. The project team demonstrated the performance of the technology in a prototype gas-fired absorption Gas Heat Pump. The project focused on developing and demonstrating solutions to address non-combustible gases through isolation, storage, or both. Isolation was performed by a selective membrane. Membrane development centered on testing metal alloys which are non-embrittling and which offer the potential for high permeability. To achieve cost and weight reductions, the project team performed corrosion testing of alloy samples in an ammonia-water solution at standard and elevated pressures and temperatures to investigate the potential of aluminum evaporators and absorbers. The project team initiated and completed rounds of corrosion testing with the alloy samples. In parallel, university researchers are initiating atmospheric pressure testing. Testing includes bare metal (baseline) and various coatings—in total, 96 alloy and 16 low-carbon steel samples. The project team reviewed the results and is preparing a report.

Co-Funders: UTD Members, DOE

Start Date: 07/01/2019
End Date: 10/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$800,000**
Total SCG Cost: **$93,637**
Total Co-Funding: **$706,363**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Sequestering Non-Condensable Gases for Enhanced GHP Reliability – Phase 2 (1.19.E.2)

To successfully advance the use of high-efficiency gas absorption heat pumps (GAHP), it is important to minimize the impact of non-condensable gases on long-duration performance and reliability. The goal of this project is to design and develop non-condensable gas isolation modules and provide research and development support to employ novel, low-cost aluminum heat exchangers to increase long-term system efficiency and reliability and safe operation and reduce the cost of any absorption-type heat pump. The project team plans on demonstrating the performance of the technology in a prototype GAHP. In 2020 through 2021, the project team initiated and completed rounds of corrosion testing with the alloy samples. In parallel, university researchers are initiating atmospheric pressure testing.

Co-Funders: UTD Members, SMTI, Robur

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$1,300**
Total Project Cost: **$240,000**
Total SCG Cost: **$2,364**
Total Co-Funding: **$237,636**
Benefits:

UTD Thermoelectric Generator for Self-Powered Water Heater – Phase 4 (1.17.B.4)

The objective of this project is to develop a self-powered, gas-fired tankless water heater to save rate-payers money and energy while enhancing resiliency. In Phase 4, the team will design, build, and test a working alpha prototype. Phase 4 will build upon the hardware testing performed in prior phases to develop the critical components and integrate the design to power a condensing tankless water heater. GTI plans to utilize UTD's Phase 4 funding as cost share to leverage a next round of funding from the U.S. Department of Energy (DOE) towards implementing this technology. Phase 4 will also leverage GTI's efforts and relationship with DOE's Building Technology Office (BTO) on a related, current DOE BTO project, as well as from past UTD projects.

Co-Funders: UTD Members, DOE, AO Smith, Sheetak, Marlow

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$3,000**
Total Project Cost: **$1,280,000**
Total SCG Cost: **$6,000**
Total Co-Funding: **$1,274,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Triathalon 2030 5-ton Cold Climate Gas Heat Pump (2.19.D)

The objective of this project is to assist in prototype design of a new 5-ton natural gas engine-driven cold climate heat pump. The project will involve developing market and functional design requirements, detailed design review, and energy and economic modeling of the proposed design. The first stage of this project was to develop a product design to determine the performance, reliability, serviceability, and cost targets. The Triathlon 2030 design focus was on heating and cooling applied to small commercial building load profiles, including office, lodging, restaurants, fitness, health care, box retail, strip malls, light commercial, and education. The major technical design challenge was to re-design and improve engine-heat recovery for cold-climate operation. Researchers developed Energy Plus™ models to compare energy costs and full-fuel-cycle greenhouse gas emissions for the gas heat pump (GHP) prototype design vs. conventional equipment, taking into account current and future power-generation mix and the natural gas supply. Based on published laboratory data, the GHP prototype design has the potential to achieve seasonal efficiencies of 1.6 COPg cooling and 0.9 to 1.2 COPg heating. A draft report on the Triathlon 2030 GHP design and its value proposition for New York State was developed and presented to New York State Energy Research & Development Authority project team meeting in July 2021.

Co-Funders: UTD Members, NYSERDA

Start Date: 07/01/2019
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$994,368**
Total SCG Cost: **$3,487**
Total Co-Funding: **$990,881**
Benefits:

SUB-PROGRAM: COMMERCIAL FOOD SERVICE

GTI SCAQMD HE/Low-NOx EcoZone Burner Kroger Demonstration

The objective of the project is to demonstrate at least 25% NOx emission reduction by optimizing the combustion process in a multi-zoned commercial wholesale baking oven at a South Coast Air Quality Management District environmental justice area. Carbon dioxide emissions will also be reduced by 10% through combustion system optimization. The goal is to install the major components of the demonstration system (such as the innovative high-efficiency low-NOx ribbon burners and flame analyzers along with advanced combustion and flow controls) on a multi-zone baking oven at a major commercial bakery located in La Habra, California. This will be followed by testing and performance data collection over a wide range of operating conditions to prove the anticipated energy savings and environmental benefits. The proposed approach provides the means to minimize carbon monoxide, carbon dioxide, and NOx emissions while operating the burners at the most efficient firing rate possible at every moment of the baking process. Due to limitations caused by COVID-19, the field engineering completion and demonstration system installation were stalled to mid-2021. Fortunately, the team was able to turn around the project in August of 2021 where they were able to install the demonstration system (i.e., installation of the modified combo-burners and oven control system). Due to quarantine restrictions, a remote monitoring system was installed to collect and monitor conditions of the oven such as fuel and emission data.

Co-Funders: SCAQMD, Kroger, SoCalGas Energy Efficiency

Start Date: 11/01/2019
End Date: 01/31/2023
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$2,052,000**
Total SCG Cost: **$200,000**
Total Co-Funding: **$1,852,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UCI Hydrogen Blend Commercial Stove Low NOx Catalytic Burner Development

Currently, NOx emissions from cookstoves are not subject to regulation, but they are a strategic end-use device to be considered for future building emissions reduction. While studies suggest a modest decrease in NOx when a low amount of hydrogen is added to natural gas in typical stove burners, the levels still approach 80-90 ppm. Reduction in NOx emissions can be achieved by i) reducing the combustion temperature, ii) decreasing the flue gas residence time in the high temperature zone and iii) reducing the excess oxygen in the fuel/oxidizer mixture. Catalytic combustion provides the advantage of lowering the temperature of the oxidation reaction, thus resulting in significantly lower NOx emissions. Catalytic combustion of hydrogen and natural gas has been studied in literature separately for various applications. However, there is no study on the evaluation of fuel blends, resulting NOx emissions, and application for commercial cooking. Therefore, in the proposed work, an ultra-low NOx catalytic burner will be designed and built to burn natural gas/hydrogen blends (up to 50%) for commercial cooking applications. This work will be the phase I of a two-phase study. After burner development, phase II will include development of a commercial prototype and involve a commercialization partner to help with the commercialization process. Since the research agreement was executed in the fourth quarter of 2021 there are no project updates to report.

Co-Funders: N/A

Start Date: 11/01/2021
End Date: 11/01/2023
Status: Active
2021 Funds Expended: **$100,000**
Total Project Cost: **$305,000**
Total SCG Cost: **$305,000**
Total Co-Funding: **$0**
Benefits:

UTD CFS Burner Technology Carbon Reduction Including Hydrogen Blending (1.21.H)

In this project, the team aims to determine the potential decarbonization of typical commercial food service appliances using improved burner technologies, control systems and blending with hydrogen. It will do this, in part, by testing existing commercial food service appliances with blends of hydrogen and natural gas. Specific topics to consider include decarbonization, hydrogen blending (0-30%), and energy reduction technologies and controls including burner modulation. The project was initiated in the fourth quarter of 2021 and work is expected begin in early 2022.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$40,000**
Total Project Cost: **$150,000**
Total SCG Cost: **$40,000**
Total Co-Funding: **$110,000**
Benefits:

UTD Commercial Foodservice Equipment Demonstrations – Phase 6 (1.14.B.6)

Through restaurant and commercial-cooking field demonstrations, researchers are gathering valuable data to quantify the operating and efficiency benefits of gas-fired commercial foodservice equipment in real-world situations. Testing is being conducted with some of the industry's most recent market introductions, including a steam kettle, range, wok, conveyor oven, convection oven, boilerless steamer, low-oil-volume fryer, and griddle. Activities were focused in two areas: The first area focuses on single-day demonstrations at test kitchens and trade shows showing how well specific equipment performs. The second area focuses on long-term demonstrations in restaurants. This project provides end users, utilities, and researchers with the ability to quickly evaluate appliances, whether gas-fired or electric-driven, and understand the true performance of the appliance. The project is currently still collecting data at two demonstration sites.

Co-Funders: UTD Members

Start Date: 06/17/2019
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$190,000**
Total SCG Cost: **$24,000**
Total Co-Funding: **$165,300**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Commercial Foodservice Equipment Demonstrations – Phase 7 (1.14.B.7)

Through restaurant and commercial-cooking field demonstrations, researchers are gathering valuable data to quantify the operating and efficiency benefits of gas-fired commercial foodservice equipment in real-world situations. Testing is being conducted with some of the industry's most recent market introductions, including a steam kettle, range, wok, conveyor oven, convection oven, boilerless steamer, low-oil-volume fryer, and griddle. Activities were focused in two areas: The first area focuses on single-day demonstrations at test kitchens and trade shows showing how well specific equipment performs. The second area focuses on long-term demonstrations in restaurants. This project provides end users, utilities, and researchers with the ability to quickly evaluate appliances, whether gas-fired or electric-driven, and understand the true performance of the appliance. The project is currently still collecting data at two demonstration sites.

Co-Funders: UTD Members

Start Date: 07/01/2020
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$3,000**
Total Project Cost: **$90,000**
Total SCG Cost: **$9,000**
Total Co-Funding: **$81,000**
Benefits:

UTD Gas Fired Warewasher (1.19.B)

The project objective was to develop gas-fired prototypes of two types of warewashers (dishwashers): doortype (low-volume) and conveyor-type (high-volume). These represent a combined 43% segment of the warewasher market. Most commercial warewashers are electric driven, and many electric warewashers use chemicals rather than high temperatures to disinfect, further increasing their environmental impact. Initial estimates indicate that a site will only use one-third of the source energy with a gas warewasher compared to alternative technologies. In this project, researchers and a manufacturing partner modified current electric-driven warewashers, modeling different heat exchanger designs to determine the best-performing designs that fit into the footprint of an existing electric warewasher. Prototype heat exchanger(s) were fabricated and put into a prototype along with a burner and blower. A functional prototype was tested for combustion efficiency, safety, and emission standards. Researchers modeled thirteen variations of different heat-exchanger designs and tested the combustion system in the laboratory with the prototype tank and heat exchanger. Custom controls were used to tune everything, and excellent results (under 10ppm NOx) were achieved. Technicians assembled the burner, blower, and gas valve assembly, along with a new control for the combustion system. Initial testing of the combustion system in the prototype heat exchanger was completed. A follow-on project could be to apply the design to additional models or to prove its performance and reliability in a field test.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$180,000**
Total SCG Cost: **$16,000**
Total Co-Funding: **$151,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Gas Fired Warewasher Door Machine Demonstration – Phase 3 (1.19.B.3)

The objective was to develop gas-fired prototypes of two types of warewashers (dishwashers): the doortype (low-volume) and the conveyor-type (high-volume). These represent a combined 43% segment of the warewasher market. Presently, most commercial warewashers are electric driven, and many electric warewashers use chemicals rather than high temperatures to disinfect, which further increases their environmental impact. Initial estimates indicate that a site will only use one-third of the source energy with a gas warewasher compared to alternative technologies. In this project, researchers and a manufacturing partner modified current electric-driven warewashers. Different heat exchanger designs were modeled to determine the best-performing designs that fit into the needed footprint of an existing electric warewasher. Prototype heat exchanger(s) were fabricated and put into a prototype along with a burner and blower. A functional prototype was tested for combustion efficiency, safety, and emission standards. Researchers modeled thirteen variations of different heat-exchanger designs and tested the combustion system in the laboratory with the prototype tank and heat exchanger. Custom controls were used to tune everything, and excellent results (under 10ppm NOx) were achieved. Technicians assembled the burner, blower, and gas valve assembly, along with a new control for the combustion system. Initial testing of the combustion system in the prototype heat exchanger was completed. A follow-on project could be to apply the design to additional models or to prove its performance and reliability in a field test.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$11,000**
Total Project Cost: **$145,000**
Total SCG Cost: **$19,938**
Total Co-Funding: **$125,062**
Benefits:

UTD High Efficiency Smart Convection Oven (1.19.A)

In this project, researchers are incorporating a heat exchanger to recover heat from the flue and feed it back into the combustion air. The objective is to develop a prototype high-efficiency smart convection oven that increases efficiency by at least 5%, and also integrates superior smart operating controls to maximize food preparation quality and consistency. Earlier, researchers investigated a high-efficiency oven design, showing that this design in bench-scale tests was able to achieve a 3% improvement to cooking efficiency and a 10% improvement to preheat energy use despite not being fully optimized. Based on these results and areas for improvement that were found in that initial design, the project team anticipates that a 5%-10% cooking efficiency should be achievable once the design has been optimized. In addition, a targeted 10%-20% reduction in NOx and carbon monoxide emissions is expected. In 2021, the project team completed basic testing on the modified heat exchanger. Pre-mix testing will follow. The proposed design is targeted to be 10% more efficient than current ENERGY STAR designs. When compared to installed ovens, it could save more than 50% of the energy use (i.e., over 400 therms per year). A 50% savings translates to $300 in savings annually for the customer (assuming $0.75 per therm) compared to baseline existing ovens. It would be expected to pay back in one to two years, since the cost premium may only be around $300-$400. Discussions with a leading manufacturer continue regarding commercialization opportunities and other next steps to make this more efficient oven available to end users.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$180,000**
Total SCG Cost: **$44,471**
Total Co-Funding: **$135,529**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD High Efficiency Smart Convection Oven – Phase 2 (1.19.A.2)

In this project, researchers are incorporating a heat exchanger to recover heat from the flue and feed it back into the combustion air. The objective is to develop a prototype high efficiency smart convection oven that increases efficiency by at least 5%, and also integrates superior smart operating controls to maximize food preparation quality and consistency. Earlier, researchers investigated a high-efficiency oven design, showing that this design in bench-scale tests was able to achieve a 3% improvement to cooking efficiency and a 10% improvement to preheat energy use despite not being fully optimized. Based on these results and areas for improvement that were found in that initial design, the project team anticipates that a 5%-10% cooking efficiency should be achievable once the design has been optimized. In addition, a targeted 10%-20% reduction in NOx and carbon monoxide emissions is expected. In 2021, the project team completed basic testing on the modified heat exchanger. Pre-mix testing will follow. The proposed design is targeted to be 10% more efficient than current ENERGY STAR designs. When compared to installed ovens, it could save more than 50% of the energy use (i.e., over 400 therms per year). A 50% savings translates to $300 in savings annually for the customer (assuming $0.75 per therm) compared to baseline existing ovens. It would be expected to pay back in one to two years, since the cost premium may only be around $300-$400. Discussions with a leading manufacturer continue regarding commercialization opportunities and other next steps to make this more efficient oven available to end users.

Co-Funders: UTD Members, Blodgett

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$26,000**
Total Project Cost: **$215,000**
Total SCG Cost: **$49,111**
Total Co-Funding: **$165,889**
Benefits:

UTD Low NOx Ribbon Burner – Phase 3 (2.12.M.3)

The objective of this project was to perform technology transfer activities that result in the introduction of a commercial product from one or more major baking industry manufacturers that uses the technology developed and patented in prior phases of UTD project 2.12.M. An innovative cost-effective, low-NOX ribbon burner combustion system that can be used for a wide variety of industrial processes was developed and subsequently demonstrated in a full-scale production environment at a wholesale commercial bakery in California. Results of the prototype unit in the full-production field test demonstrated 50% NOx reduction and approximately 5% energy savings. A 30% market penetration in the baking industry in California alone would result in estimated emissions reductions in natural gas reductions of 1.3 to 1.5 million therms per year; carbon emission reductions of 7,500 to 10,000 tons per year; and NOx emission reductions of 200 to 300 tons per year. The project team is continuing discussions with baking industry leaders (manufacturers, suppliers, and end-users) and investment entities. A potential commercialization partner was identified, and licensing discussions are in progress.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$125,000**
Total SCG Cost: **$33,000**
Total Co-Funding: **$92,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Next Generation Commercial Foodservice Burners – Phase 6 (1.14.A.6)

This project focuses on designing, developing, and testing prototype higher efficiency, lower-emission commercial foodservice appliances using advanced burner concepts proven for other markets and products (e.g., residential furnaces and water heaters). The objective for this phase of the project is to test and develop combustion systems for commercial foodservice (CFS) applications that improve cooking performance, efficiency, and/or emissions with an emphasis on developing commercialized units. This phase will take the knowledge acquired on burner performance and characteristics from the previous phases and begin designing and constructing prototype CFS units. The goal is to take CFS burner technology from Stage 4: Technology Development to Stage 5: Product Development for prototype units. At this stage, at least three new prototype units are demonstrated with a manufacturer for commercializing.

Co-Funders: UTD Members

Start Date: 06/15/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$7,875**
Total Project Cost: **$140,000**
Total SCG Cost: **$18,375**
Total Co-Funding: **$121,625**
Benefits:

UTD Next Generation Infrared Burner – Phase 2 (2.16.A.2)

The objectives of this project are to design, build, and test prototype high-efficiency, high performance, low emission gas-fired infrared burners that use advanced metal foam material to offer end users new high-efficiency products. The project team is collaborating with material and burner manufacturers. Using gas-fired infrared (IR) heaters instead of electric driven IR heaters can significantly reduce both source energy emissions and end users' operating costs. The goal of this project is to build on earlier developments to advance a gas-fired IR burner for commercial and industrial use. In this project, researchers investigated advanced metal foam IR burners, with better material properties. In the current phase of the project, the research team will design, build, and test in the field a prototype next generation, high response, higher-efficiency IR burner.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$250,000**
Total SCG Cost: **$16,000**
Total Co-Funding: **$234,000**
Benefits:

SUB-PROGRAM: INDUSTRIAL PROCESS HEAT

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI Booster Ejector Enhancement of Compressor Refrigeration Demonstration

The objective of the project is to demonstrate at least 25% NOx emission reduction by optimizing the combustion process in a multi-zoned commercial wholesale baking oven at a South Coast Air Quality Management District environmental justice area. Carbon dioxide emissions will also be reduced by 10% through combustion system optimization. The goal is to install the major components of the demonstration system (such as the innovative high-efficiency low-NOx ribbon burners and flame analyzers along with advanced combustion and flow controls) on a multi-zone baking oven at a major commercial bakery located in La Habra, California. This will be followed by testing and performance data collection over a wide range of operating conditions to prove the anticipated energy savings and environmental benefits. The proposed approach provides the means to minimize carbon monoxide, carbon dioxide, and NOx emissions while operating the burners at the most efficient firing rate possible at every moment of the baking process. Due to limitations caused by COVID-19, the field engineering completion and demonstration system installation were stalled to mid-2021. Fortunately, the team was able to turn around the project in August of 2021 where they were able to install the demonstration system (i.e., installation of the modified combo-burners and oven control system). Due to quarantine restrictions, a remote monitoring system was installed to collect and monitor conditions of the oven such as fuel and emission data.

Co-Funders: CEC

Start Date: 12/01/2020
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$45,000**
Total Project Cost: **$1,731,556**
Total SCG Cost: **$110,000**
Total Co-Funding: **$1,621,556**
Benefits:

GTI Burner Exchange to Support Radiative Recuperator Demonstration

For this CEC funded project (PIR-15-006), GTI and the host site, California Die Casting (CDC), will modify a furnace used to melt aluminum for die casting with an advanced radiative recuperator with secondary emitters (RRSE). The goal of the project is to demonstrate natural gas savings and emission reduction utilizing the RRSE. The RRSE is more efficient and cost effective than commercially available recuperators which primarily recover heat from the exhaust gas and preheat combustion air. The RRSE will be coupled with commercial hot air, ultra-low NOx burners (Bloom 1500S 060C) operated with air preheated to as high as 1200ºF, forming a combined heat recovery system that is highly efficient with low NOx. In addition, a stack to preheat scrap on its way to the furnace with exhaust gas leaving the RRSE will also further increase furnace efficiency, lowering natural gas demand even more. The simple payback for this technology is 30 months. In 2021, the project was delayed due to the California wildfire season. There are not many experts in the Los Angeles area to do refractory work to install the high-temperature Bloom 1500S 060C furnace burners on the die casting furnace. The burners were installed and the die-cast furnace was modified for the inclusion of the RRSE in October. They are now in the data collection phase of the project.

Co-Funders: CEC, UTD Members

Start Date: 09/01/2020
End Date: 09/01/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$1,694,999**
Total SCG Cost: **$74,999**
Total Co-Funding: **$1,620,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI Ceramic Radiant Tube Inserts for Waste Heat Recovery Demonstration

In this field demonstration, Radiant Tube Inserts (RTI) will be inserted in the exhaust ends of tubes at California Steel in Fontana, California. Once installed, the RTIs will absorb the heat from the hot exhaust gas that would otherwise escape and re-radiate the captured heat back into the furnace. The resulting heat capture improves energy efficiency, temperature uniformity, tube life, emissions reduction, production quality, and furnace throughput. Thus, this demonstration will prove that low-cost, highly effective waste heat recovery devices in the form of RTIs are available for commercial application and that this new patented design by PSNERGY overcomes previous shortfalls (e.g., material-degradation, back pressure, and performance problems). In 2021, the project team completed milestone 1 (furnace evaluation with delivered recommendations through a preliminary report, milestone 2 (baseline testing with delivered test report), and milestone 3 (installation of the radiant tube inserts into the furnace burners). The project team is on schedule and expects to review pre- and post-retrofit data, determine measurement and qualification qualifiers, and assess data quality to validate and draw results in 2022.

Co-Funders: SoCalGas ETP

Start Date: 01/04/2021
End Date: 01/04/2022
Status: Active
2021 Funds Expended: **$268,467**
Total Project Cost: **$392,798**
Total SCG Cost: **$352,798**
Total Co-Funding: **$40,000**
Benefits:

GTI Solar Thermal and Particle Fluid Demonstration

Use of particle heating in combination with thermal transfer and storage technology has the potential for recovery and storage of energy at up to 1000°C (1832°F) for on demand generation of heat and/or power. It would allow recovery and storage of energy from solar, or exhaust gases of natural gas fired equipment, even those that are cyclic or batch processes, which are challenging for conventional heat recovery approaches. Therefore, the goal of the project is to successfully demonstrate the technology which comprises of a solar thermal collector and a novel particle thermal storage medium in an industrial heating application. The demonstration will verify the performance, energy savings, and emissions benefits of the technology. This project will test the technology at the 60kW (12m solar collector) scale first at the UC Merced campus. Upon successful testing, the system will be deployed at the USG plant in the Imperial Valley. In 2021, the on-sun testing was completed. The technical results were not satisfactory. Ultimately, multiple factors related to the absorber tube contributed to the reduction of efficiency: 1) the displacement effects of absorber and secondary reflector causing intercept factor reduction, 2) higher fluid flow rate required as per thermal model to minimize temperature gradients, and 3) superposition of bending caused by dead weight of the receiver and bending caused by non-uniform temperature distribution.

Co-Funders: ARPA-E, CEC

Start Date: 10/01/2018
End Date: 04/23/2022
Status: Active
2021 Funds Expended: **$60,000**
Total Project Cost: **$3,260,000**
Total SCG Cost: **$350,000**
Total Co-Funding: **$2,910,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI Waste Heat Effective Transfer in Brewery & Distillery Demonstration

In this CEC sponsored field demonstration (PIR-19-004), a Waste Heat Effective Transfer (WHET) technology will be installed in the flue of two micro-distilleries. The WHET recovers waste heat from the brew kettle to provide preheated plant water in the facility hot water tank which will result in significant reduction in natural gas consumption and emission. The WHET is unique because it utilizes a low-cost heat exchange module made of modified tubing that provides excellent heat transfer in minimum space and minimum pressure drop. The tubing surface features disrupt boundary layers which increases gas mixing, resulting in increased average gas temperature, and higher overall heat transfer rates as compared to its competitors. The objectives of this project are to demonstrate a cost-effective, modular, and unintrusive waste heat recovery solution that can be installed in a variety of industrial applications and achieve a 15 to 25% recovery of heat from the brew kettle which would result in natural gas savings and the lowering of emissions (carbon dioxide and NOx).

Co-Funders: CEC, Yolo Brewing, Tower Brewing, PG&E, UTD Members

Start Date: 12/01/2020
End Date: 03/29/2024
Status: Active
2021 Funds Expended: **$47,665**
Total Project Cost: **$1,948,387**
Total SCG Cost: **$177,821**
Total Co-Funding: **$1,770,566**
Benefits:

UCI Solid Oxide Electrolysis Cells for Green Steel Production Demonstration

Rinnai recently issued a press release promoting the compatibility of its commercial product line (i.e., tankless water heaters, boilers, and direct vent wall furnaces) with hydrogen-blended fuels with concentrations of up to 30% hydrogen. Given this development, the SoCalGas Engineering Analysis Center (EAC) will conduct validation testing on the super-high-efficiency RU130iN tankless water heater to confirm the manufacturer's claim and demonstrate the decarbonization benefits of hydrogen. The focus of this project is to perform a comprehensive validation at the EAC with different concentrations of hydrogen blends up to 30%, covering safety (i.e., flashback, ignition failure/delay, flame profile), emissions, and energy efficiency, which is useful for estimating energy savings. The study may yield interesting results. Since hydrogen requires less combustion air than methane, the excess air in the system could have a cooling effect and decrease formation of nitrogen oxides. The research team recently procured the tankless water heater and will begin testing in March 2022.

Co-Funders: DOE, UCI, Politecnico di Milano, FuelCell Energy, Inc., LEAP

Start Date: 03/01/2021
End Date: 03/01/2024
Status: Active
2021 Funds Expended: **$275,000**
Total Project Cost: **$5,699,861**
Total SCG Cost: **$550,000**
Total Co-Funding: **$5,149,861**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Advanced Immersion Tube Burner (2.18.B)

The focus of this project was on developing a low-emission, high-efficiency advanced immersion tube technology. Besides immersion tubes, the technology may have applications in water heaters, fire-tube boilers, steam generators, duct heaters, gas turbines, air heaters, absorption chillers, thermal oxidizers, synthetic gas combustion, and combined heat and power systems. There are an estimated 25,000 or more immersion tube burners in use in the U.S. This does not include a much larger number of these units used in the oil and gas industry. For comparison, oil and gas operations in Alberta, Canada, alone use an estimated 20,000 to 40,000 immersion tube burners, according to a 2005 analysis performed for Petroleum Technology Alliance Canada. Project efforts will help end users meet increasingly-stringent environmental regulations while retaining an easy-to-operate gas-fired unit. A final report was issued in July 2021, and the project team is exploring next steps to make this technology available to end users, such as by testing a beta prototype unit at an end-user host site.

Co-Funders: UTD Members

Start Date: 07/01/2018
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$180,000**
Total SCG Cost: **$37,200**
Total Co-Funding: **$142,800**
Benefits:

UTD Direct Contact Flue Gas Heat Exchanger with Innovative Particle Thermal Storage (2.19.A)

The goal of this project was to demonstrate at pilot scale the direct-contact heat exchange between process exhaust flue gas and a novel heat-transfer particle system. The 50kW prototype would provide a step up in scale from earlier laboratory to demonstration pilot, moving towards 1 megawatt. The project demonstrated a direct-contact particle-heating technology with integrated storage of particles heated to ≥ 650°C (1,202°F). In 2020, researchers developed a theoretical model based on thermodynamic equations to predict results from the test matrix under various/variable operating conditions. Performance calculations and design assessment show that the system will be capable of continuous and stable operation. It can heat solid particles to high temperatures using direct-contact heat transfer with hot gases. The hot particles can be used to provide thermal energy to a process or stored for later use. A Final Report was issued in July 2021. It is recommended to continue the development of the technology by first testing it in the laboratory followed by field testing at an industrial site for waste-heat recovery and reuse. All components have been designed and the system is ready for fabrication, installation, and testing.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$3,050,000**
Total SCG Cost: **$390,000**
Total Co-Funding: **$3,440,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Energy Recovery Heat Exchanger – Phase 2 (2.16.G.2)

The objective of this project was to demonstrate an advanced recuperator with secondary inserts to preheat combustion air and increase overall system efficiency. This project team demonstrated a technology known as the Radiative Recuperator with Secondary Emitters (RRSE) – a technology that has been found to be more compact, less expensive, and more efficient than heat exchangers currently available in North America. The RRSE's shorter payback time can enable this technology to be installed on many commercial and industrial furnaces that currently have no cost-effective means to recoup exhaust gas heat to save energy and reduce emissions. This phase of the project demonstrated the capabilities of the RRSE in a real-world setting in North America. Phase 2 also provided final additional UTD co-funding to a California Energy Commission-funded project to demonstrate efficiency improvements on an aluminum melting die-casting furnace.

Co-Funders: CEC, UTD Members

Start Date: 07/01/2019
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$1,405,000**
Total SCG Cost: **$13,780**
Total Co-Funding: **$1,391,220**
Benefits:

UTD Energy Source Options for Industrial Users (2.20.E)

In this multi-phase project, researchers are developing and validating a spreadsheet tool to analyze the economic and environmental impact of fuel substitution options with related strategies. The tool has several interactive worksheets which allow the user to examine several potential scenarios for carbon emissions mitigation on both an economic and environmental basis – including fuel substitution, renewable natural gas blends, and efficiency upgrades for industrial and large commercial applications. The initial version of the tool focused on boilers used for process and/or space heating, one of the largest end-use applications in multiple industries. The objective of this project is to perform a market assessment and techno-economic analysis of possible fuel-switching and decarbonization scenarios for a spectrum of industrial and large commercial subsectors and end-use applications. The ultimate goal is to develop an easy-to-use tool that allows industrial and commercial equipment end users to assess de-carbonization scenario options when comparing equipment and systems currently powered by fossil natural gas to the same equipment when employing the other options.

Co-Funders: UTD Members, ESC

Start Date: 03/01/2020
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$4,909**
Total Project Cost: **$120,000**
Total SCG Cost: **$10,909**
Total Co-Funding: **$109,091**
Benefits:

UTD Energy Source Options for Industrial Users – Phase 2 (2.20.E.2)

This project expands and simplifies the use of a detailed techno-economic analysis developed in a previous phase of the project. The analysis considered fuel-switching and electrification scenarios for industrial and large commercial end users by transitioning a spreadsheet-based analysis to a convenient online tool and including a spectrum of applications beyond boilers. The overall objective is to develop a roadmap basis for natural gas and other energy source options to support the reliable and cost-effective supply of energy to industrial and large commercial sectors to achieve the local environmental targets by providing a robust user-friendly analytical tool that helps decision-making by end users and others as they strive to decarbonize.

Co-Funders: UTD Members, ESC

Start Date: 07/01/2021
End Date: 01/31/2023
Status: Active
2021 Funds Expended: **$1,300**
Total Project Cost: **$165,000**
Total SCG Cost: **$2,581**
Total Co-Funding: **$162,419**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Field Validation of Gas Quality Sensor for Natural Gas – Phase 2 (2.14.0.2)

The objective of this phase of the project was to continue to develop and demonstrate in field-operating conditions, a practical, reliable, and low-cost gas-quality sensor (GQS) capable of detecting changes in gas quality in real time and of providing these data to natural gas pipeline operators and end users of natural gas. The GQS uses the infrared light-absorption properties of hydrocarbon gases to measure the Btu content and composition of a natural gas mixture. It has been shown that this sensor technology can be used to measure the air/fuel ratio in air/hydrocarbon gas mixtures delivered to combustion equipment. The accuracy of heating-value measurements made by this new instrument can closely match those of gas chromatography, but at a much lower cost. An experimental apparatus was used to calibrate and test the GQS after upgrades and modifications. A Final Report for Phases 1 and 2 of this project was issued in February 2021. Phase 3 efforts began in the summer of 2021.

Co-Funders: UTD Members

Start Date: 07/01/2018
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$152,000**
Total SCG Cost: **$16,000**
Total Co-Funding: **$136,000**
Benefits:

UTD Gas Quality Sensor Validation Hydrogen Sensor – Phase 3 (2.14.0.3)

Phase 3 of this project will conduct calibration tests on the Gas Quality Sensor (GQS) developed in previous phases with an add-on hydrogen detector so the economical GQS instrument can support introduction of hydrogen blending with natural gas. Measuring hydrogen will broaden the GQS capability to measure gas composition, heating value, Wobbe number, and methane number for anticipated natural gases containing hydrogen. Indicators suggest that GQS accuracy will improve when a hydrogen detector is added. Phase 3 will provide data allowing extension of the GQS capabilities beyond natural gases to hydrocarbon fuel gas mixtures containing hydrogen. The generated data will be provided to licensee CMR Group, adding to results from CMR testing, to help accelerate GQS deployment with hydrogen detection capability.

Co-Funders: UTD Members, CMR Group

Start Date: 07/01/2021
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$15,000**
Total Project Cost: **$85,000**
Total SCG Cost: **$15,000**
Total Co-Funding: **$70,000**
Benefits:

UTD High Efficiency Crop Drying Process (2.21.D)

Sun drying is the simplest and cheapest method of drying. It is used for high volume foods such as grain, rice, and raisins. The disadvantage of sun drying is that it is almost impossible to control the drying conditions and the quality of the dried fruit during the drying process. Therefore, there is a technology gap that meets the customer's drying needs while also providing an effective high-efficiency crop drying device. The objective of this project is to advance the development of a high-efficiency, low temperature, UTD-patent-pending low-labor crop drying process that can be retrofitted into existing farm operations by performing preliminary design and technoeconomic analysis on two crops of high market value and identifying partners for commercial scale-up. The project was executed in late 2021 and work will begin in 2022.

Co-Funders: UTD Members

Start Date: 12/31/2021
End Date: 12/31/2023
Status: Active
2021 Funds Expended: **$38,000**
Total Project Cost: **$97,000**
Total SCG Cost: **$38,000**
Total Co-Funding: **$59,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD High Hydrogen Burner for Commercial and Industrial Applications (2.21.A)

This project aims to design, fabricate, and test an advanced fuel-flexible hydrogen/renewable natural gas (H2/RNG) 0.5 to 1 MMBH burner in a commercial scale furnace at GTI's laboratory. The team will partner with two leading large industrial end users and two national laboratories to ensure that the final prototype burner meets the requirements of the representative end users. GTI has successfully developed and bench-scale tested a 3D-printed burner design at 0.05 MMBH scale capable of operating efficiently and robustly with hydrogen up to 40% hydrogen. The funding will demonstrate a scaled-up burner with higher hydrogen (up to 60%) to evaluate and commercialize the technology with California Steel, Inc. (CSI), Gopher Resources, Inc., Oak Ridge National Laboratory (ORNL), and Argonne National Laboratory (ANL). Actual field testing of the prototype will be separately funded/authorized. The project agreements were finalized in 2021, and work is expected to begin in early 2022.

Co-Funders: UTD Members, ORNL, CalSteel, Gopher Resources, ANL

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$42,000**
Total Project Cost: **$340,000**
Total SCG Cost: **$84,000**
Total Co-Funding: **$256,000**
Benefits:

UTD Thermal Ejector for Water Capture from Humid Exhaust Demonstration – Phase 3 (2.17.A.3)

The objective of this project is to demonstrate a novel and new thermal ejector technology to recover useful process water from humid exhaust gas and increase energy efficiency in a field demonstration at a large industrial facility operated by USG (US Gypsum Co.) in Plaster City, CA. UTD's support is leveraging $1.3 million in co-funding from the California Energy Commission (CEC). This is a new and synergistic benefit of natural gas combustion, and the field demonstration will recover up to 100 gallons of water per hour, representing up to 95% of the water in the exhaust gas from the Line 3 drying kiln at USG. Automated operation and data collection worked well through the first four months of the demonstration period. Results confirm an average water-recovery rate of 83 gallons per hour. More than 60,000 gallons of water were recovered so far. The algorithm controlling the two heat exchanger units responded appropriately as ambient air temperature rose and fell. Water-recovery rate drops as temperatures exceed 85ºF. The required process energy in kWh per gallons of water recovered declines as ambient air temperature declines because less outside air is needed to remove heat from the thermal ejector pipes.

Co-Funders: CEC, UTD Members

Start Date: 07/01/2019
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$3,125**
Total Project Cost: **$1,480,000**
Total SCG Cost: **$16,250**
Total Co-Funding: **$1,463,750**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Zero Emission Combustion at Commercial or Industrial Scale (2.19.B)

The focus of this project was on developing a low-emission, high-efficiency advanced immersion tube technology. Besides immersion tubes, the technology may have applications in water heaters, fire-tube boilers, steam generators, duct heaters, gas turbines, air heaters, absorption chillers, thermal oxidizers, synthetic gas combustion, and combined heat and power systems. Researchers tested a burner concept developed in part during a prior UTD project. The burner, with prototypes manufactured by UTD research partner Oak Ridge National Laboratory, has the potential to provide a very high turndown ratio, uniform heat flux, and low NOx levels. The project team conducted performance testing for different conditions of the advanced immersion tube burner. The project team evaluated different immersion tube burner design configurations for impacts of the nozzle configuration, size, throat diameter, number of nozzles, and the included angles of the converging and diverging sections of the venturi nozzles. A Final Report was issued in July 2021. The project team is exploring next steps to make this technology available to end users, such as by testing a beta prototype unit at an end-user host site.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 01/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$125,000**
Total SCG Cost: **$16,666**
Total Co-Funding: **$108,334**
Benefits:

UTD Zero Emissions Processes with Carbon Recovery (2.21.C)

This project will advance through laboratory testing the development of a new synthetic air combustion (SAC) process in order to simultaneously improve industrial boiler or furnace efficiency when using natural gas while also lowering carbon dioxide emissions and providing a means to capture or convert carbon dioxide to valuable products. Laboratory tests will be conducted at industrial conditions, and results will help compare calculated and experimental results when using SAC to typical air-fired combustion. The ultimate objective is for this process technology to help create a lower-carbon future while using natural gas in industrial boilers and furnaces. The project agreements were finalized in 2021, and work is expected to begin in early 2022.

Co-Funders: UTD Members

Start Date: 07/01/2021
End Date: 07/31/2023
Status: Active
2021 Funds Expended: **$7,500**
Total Project Cost: **$150,000**
Total SCG Cost: **$15,000**
Total Co-Funding: **$135,000**
Benefits:

SUB-PROGRAM: RESIDENTIAL APPLIANCES

EAC Hydrogen Blended Residential Tankless Water Heater Validation Research

Rinnai recently issued a press release promoting the compatibility of its commercial product line (i.e., tankless water heaters, boilers, and direct vent wall furnaces) with hydrogen-blended fuels with concentrations of up to 30% hydrogen. Given this development, the SoCalGas Engineering Analysis Center (EAC) will conduct validation testing on the super-high-efficiency RU130iN tankless water heater to confirm the manufacturer's claim and demonstrate the decarbonization benefits of hydrogen. The focus of this project is to perform a comprehensive validation at the EAC with different concentrations of hydrogen blends up to 30%, covering safety (i.e., flashback, ignition failure/delay, flame profile), emissions, and energy efficiency, which is useful for estimating energy savings. The study may yield interesting results. Since hydrogen requires less combustion air than methane, the excess air in the system could have a cooling effect and decrease formation of nitrogen oxides. The research team recently procured the tankless water heater and will begin testing in March 2022.

Co-Funders: N/A

Start Date: 12/01/2021
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$70,300**
Total SCG Cost: **$70,300**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI Advanced High Efficiency, Low-Capacity HVAC Systems

The goal of this project was the field demonstration and performance testing of advanced high-efficiency, low-capacity heating, ventilation, and air conditioning (HVAC) systems coupled with measures to reduce infiltration and improve building envelopes in five existing single-family homes to achieve HVAC energy savings in excess of 30 percent compared to a typical, existing Los Angeles Basin home with standard equipment. The project team produced 24 months of data from five homes in Los Angeles and Orange County where advanced low-capacity systems were installed to replace existing equipment. The newly installed equipment had lower capacity than Title 24 compliant or existing systems; 50% or lower than the equipment in the demonstration homes. The results demonstrated the benefits of envelope upgrades and right-sizing the HVAC for homes with improved envelopes. A combination of utility data analysis and calibrated BEopt modeling proved the potential for savings to be greater than 30% in HVAC consumption. The project team submitted the final report in November 2021, which will be published as an official CEC publication. A public webinar was held on August 25, 2021, to share the project findings.

Co-Funders: CEC

Start Date: 10/01/2017
End Date: 09/30/2021
Status: Completed
2021 Funds Expended: **$25,000**
Total Project Cost: **$900,000**
Total SCG Cost: **$150,000**
Total Co-Funding: **$750,000**
Benefits:

GTI Hydrogen Blend Burner Design Analysis and Guidelines Research

In support of efforts to blend hydrogen into the distribution system, GTI is investigating the implications of hydrogen blends on gas-fired equipment common in California (e.g., water heaters, furnaces, boilers, pool heaters, dryers, outdoor cooking equipment, and hearth products). Due to the variety of appliances and burner types existing in the market, there is not always time and budget to test all variations in the lab. In this project, GTI proposes developing numerical models (i.e., computational fluid-dynamic and reduced-order models) that can quickly simulate different burner types and design variations. The models will be validated against experimental data and then used to 1) identify blending limits with existing burner designs; 2) understand the impact of hydrogen blends on flame stability, burner material durability, and emissions; 3) propose mitigation strategies; and 4) develop industry guidelines for burner designs which expand hydrogen blending limits while maintaining compatibility with natural gas. This project builds on studies performed by the University of California, Irvine, Appliance Engineering, manufacturers, and utilities. In 2021, GTI completed the initial literature review of reduced-order models and classic burner design methods. Based on the literature review, GTI is developing a computational fluid dynamic (CFD) model to use as a testbed for different CFD methods to test design theories for fuel-flexible burners. GTI has also begun assembling a list of appliances and burners to test. Lastly, GTI is preparing a market survey to research the types of legacy appliances still in operation today to understand their prevalence in the SoCalGas service territory.

Co-Funders: N/A

Start Date: 09/01/2021
End Date: 11/30/2022
Status: Active
2021 Funds Expended: **$210,000**
Total Project Cost: **$280,000**
Total SCG Cost: **$280,000**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI Improving Efficiency of Wall Furnaces in CA Homes Demonstration

GTI is seeking to accelerate the availability and adoption of higher efficiency retrofit options for atmospherically vented wall furnaces prevalent in California's affordable multifamily housing. There is a significant opportunity for better retrofit solutions, which is the focus of this project. As wall furnaces are popular in affordable multifamily housing due to their low up-front costs, the benefits of developing better replacement options would be concentrated in low-income and disadvantaged communities. These communities pay a higher proportion of their income in energy costs than most Californians, yet relatively little research and development have gone into the wall furnace product category over the years. This project will overcome barriers for wall furnace retrofits by demonstrating several different solutions to cover the gamut of retrofit scenarios: 1) A/C powered and self-powered drop-in replacement for existing gravity furnaces, offering improved efficiency up to 80% annual fuel utilization efficiency (AFUE) and reduced pilot light energy use, and 2) a direct-vent solution targeting higher efficiency up to >90% AFUE, but requiring electrical service and other potential building modifications such as drywall patching, venting modifications, and/or access to a drain. GTI anticipates that the retrofit packages will result in 10-20% annual savings with a 10-year payback over existing replacement technologies. To accelerate adoption, the project team will conduct market outreach and technology transfer to property owners, installers, manufacturers, and utilities. In 2021, baseline monitoring of all demo units was completed. At the end of 2021, the wall furnace retrofit field demonstration and monitoring of site and equipment were underway.

Co-Funders: CEC

Start Date: 07/31/2019
End Date: 08/15/2022
Status: Active
2021 Funds Expended: **$38,500**
Total Project Cost: **$1,110,000**
Total SCG Cost: **$110,000**
Total Co-Funding: **$1,000,000**
Benefits:

GTI Residential Gas Heat Pump Water Heater Field Demonstration

For this project co-funded by the California Energy Commission (CEC), GTI sought to advance the commercialization of a residential Gas-fired Heat Pump Water Heater (GHPWH) through a five-site field demonstration, extended-life laboratory testing, and stakeholder outreach events. During 12 months of field and lab testing, GTI identified and addressed several challenges, including minor mechanical failures and a lack of installation guidelines addressing venting, electrical service, and space requirements for the new system. Upon project completion, GTI believed it had demonstrated a product for market and proved there was a market for the product. Preliminary results show that, in comparison to conventional water heaters, this technology provides energy consumption and greenhouse gas emissions reductions of roughly 54% and 49%, respectively. Project outcomes and results will be published in an official CEC publication.

Co-Funders: CEC

Start Date: 04/17/2017
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$1,272,355**
Total SCG Cost: **$188,125**
Total Co-Funding: **$1,084,230**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI Residential Gas Heat Pump Water Heater North America Field Demonstration

The objective of the project, in partnership with GTI and multiple North American utilities, is to support the development and commercialization of residential gas heat pump water heaters (GHPWH). This demonstration project will deploy approximately 60 GHPWHs in order to collect qualitative and quantitative data in regions representing diverse climates and housing characteristics. The goals are to 1) demonstrate a commitment to GHPWH commercialization and launch; 2) evaluate product readiness across various climates and housing stocks with emphasis on reliability, efficacy, efficiency, installation experience, customer satisfaction, and manufacturer/technology developer business capabilities; 3) support utility program development with savings, cost, and installation information needed to quickly develop and deploy programs upon product launch; 4) support timely product launch by communicating *in situ* performance information to the manufacturer with a goal of product launch by 2022; and 5) prime the market by providing hands-on experience to local distribution and installation companies. In 2021, the project was delayed due to the need to search for a technology partner for product development. GTI is planning to finalize an agreement with a potential technology partner in March 2022.

Co-Funders: Nicor Gas, FortisBC, NEEA, Spire, Enbridge

Start Date: 03/31/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$6,081,602**
Total SCG Cost: **$1,081,602**
Total Co-Funding: **$5,000,000**
Benefits:

GTI Strategic Pathways and Analytics For Tactical Decommissioning of Natural Gas Infrastructure Research

California has some of the most ambitious policies in the U.S. for reducing emissions associated with natural gas use. In some areas, decommissioning natural gas and switching customers to electricity may be a cost-effective approach to meeting these goals. How the gas system is decommissioned over time will have a large impact on customers and the gas and electric utilities. Ensuring that socioeconomic equity issues are not exacerbated through decommissioning is of paramount concern. This project will develop a multi-disciplinary and objective analytical framework to identify locations in Southern California where decommissioning can occur in a just, equitable, and cost-effective way. The team includes an impartial California-based think-tank—the RAND Corp—along with SoCalGas, Southern California Edison, GTI, and LA Regional Collaborative (LARC). The team will bring together detailed models of the gas system with data on the socioeconomic conditions of candidate communities to evaluate different decommissioning approaches. The team will work directly with stakeholders in Long Beach and Santa Monica in a series of workshops to understand the key needs and concerns of the natural gas customers and then evaluate different decommissioning strategies along with cost, viability, and equity lines. Through these workshops, the team will present specific recommendations for three decommissioning pilot projects and write a set of guidelines and criteria to inform decommissioning of natural gas infrastructure in other areas. Since the research agreement was signed in December 2021, there is no meaningful progress update to provide.

Co-Funders: CEC

Start Date: 10/01/2021
End Date: 08/01/2022
Status: Active
2021 Funds Expended: **$100,000**
Total Project Cost: **$1,091,358**
Total SCG Cost: **$125,000**
Total Co-Funding: **$966,358**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

GTI Trane Residential Combi Heat Pump Field Demonstration

The objective of this project was to advance the residential gas heat pump combi technology to pre-production readiness by addressing manufacturing, balance of system/control design and installation, cost, reliability, and field application questions. During the project, a key technology partner revealed corporate priority shifts that would delay their ability to bring an integrated gas heat pump system to market as originally planned, despite commitment and support for both the technology and this project. The COVID-19 global pandemic brought further uncertainty to their future commercialization timelines. Despite this, the project yielded valuable findings for the manufacturing partners and insights that will be applicable to other gas heat pump system manufacturers as this is a new, emerging product category (e.g., changes to system sequencing controls). Additionally, the project team identified opportunities for further improvements to system design and controls, emissions reduction while maintaining thermal comfort, and performance.

Co-Funders: Enbridge, Intermountain Gas, NEEA, Nicor Gas, Spire

Start Date: 08/31/2019
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$1,100,000**
Total SCG Cost: **$200,000**
Total Co-Funding: **$900,000**
Benefits:

Lantec Development of Ultra Low NOx Forced Air Residential Furnace

The goal of this project is to achieve the design, development, performance and operational testing, certification, and commercialization of residential condensing and non-condensing forced air furnaces utilizing MicroNOx ultra-low NOx combustion technology emitting no more than 7 ng/J NOx. This project will take a novel burner technology "MicroNOxTM", developed by Lantec Products, from its current early product development stage along the product readiness levels to a point where the manufacturing partner has a viable product to begin introduction into a commercialized product line. The project team will test the prototype units in accordance with the certification test procedure contained in AQMD Rule 1111 including AQMD Method 100.1. The prototype furnaces will also be tested against ANSI Z21.47 including 10,000 combustion cycles as prescribed within the standard. In 2021, the project schedule was delayed by COVID-19. Despite this, Lantec focused on finalizing the condensing and non-condensing prototype design and completion of non-condensing retrofit furnace. The project team anticipates delivery of the furnaces to GTI for operational testing based on ANSI Z21.47 standards by March 2022.

Co-Funders: SCAQMD

Start Date: 05/01/2019
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$12,720**
Total Project Cost: **$432,500**
Total SCG Cost: **$92,500**
Total Co-Funding: **$340,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

ORNL Hydrogen Fueled Cooking Equipment Development

In this project, a residential cooking range top and oven will be retrofitted with flameless radiant burner technology for testing in the lab. The objective is to develop clean, reliable, and safe residential cooking appliances equipped with catalytic oxidation burners capable of operating on 100% hydrogen and natural gas blends (up to 50% hydrogen) while producing zero NOx. There are many advantages to this type of technology such as emissions reduction, wide turndown, safety, and operation with lean mixtures beyond the flammability limits. In 2021, the project made good progress towards the design and specification of a prototype. Preliminary burner designs are being evaluated for different operating scenarios. The team worked with a couple of manufacturers to fabricate the early-stage prototype design and a purchase order was made at the end of the year. The team anticipates studying the modified burner integration in early 2022.

Co-Funders: DOE

Start Date: 10/01/2020
End Date: 10/03/2022
Status: Active
2021 Funds Expended: **$400,000**
Total Project Cost: **$900,000**
Total SCG Cost: **$400,000**
Total Co-Funding: **$500,000**
Benefits:

Rinnai Residential GHPWH Product Development and Testing

The objective of this project is to support Rinnai America Corporation (RAC) in evaluating a European GHP combination space and water heating system (combi) and how it can scale down the technology components to function in the standalone gas heat pump water heater (GHPWH) currently under development for the North American GHPWH field demonstration. In 2021, the project team determined it was not feasible to scale down the technology components to function as a standalone gas heat pump water. This was primarily due to changing business conditions arising from COVID-19, as the manufacturer of the GHP combi did not have the resources to assist in the R&D efforts. Therefore, the project team pivoted the scope of work towards evaluating a proof-of-concept (POC) combi conversion to North American requirements and testing the performance of the converted unit. Fortunately, the project team was able to complete the evaluation and deliver the final report in December of 2021. The final report mainly focused on: an analysis of critical components required for conversion to North American spec, building a POC prototype of the converted combi unit, and preliminary tests to evaluate POC prototype performance in comparison to the European unit. Evaluation results show the feasibility to convert the European unit and achieve similar performance and efficiency characteristics. A plan to fully develop and convert the European unit, including certifying to North American standards and requirements, was also evaluated and presented.

Co-Funders: NEEA

Start Date: 09/01/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$30,000**
Total Project Cost: **$300,000**
Total SCG Cost: **$150,000**
Total Co-Funding: **$150,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UCI Catalytic Burner Retrofitted Water Heater Lab Demonstration

This project is a follow-up to a previous project which identified several viable flameless radiant burners that could be retrofitted into commercially available water heaters to achieve essentially zero NOx emissions. While these burners have existed for some time in different applications, they have not been implemented into water heaters. Thus, several burner configurations will be procured and installed into water heaters for comparison. The performance of the retrofitted water heaters (i.e., ignition performance, efficiency, emissions, and tolerance to hydrogen content) will be assessed. The study will compare against the legacy burner technology commonly found in water heaters. Additionally, the relative tolerance to hydrogen content will be evaluated, providing insight into how these burners can help reduce carbon emissions from natural gas through use of hydrogen/natural gas blends. In 2021, the University of California at Irvine (UCI) procured and designed one of three burner technologies they plan to develop as a retrofit kit for commercially available water heaters. They are currently completing the first batch of preliminary tests on the first burner design. So far, they have tested the burner on natural gas (baseline), 10%, and 20% hydrogen blend based on water heating load of 30% excess air and 40,000 BTU/hr.

Co-Funders: N/A

Start Date: 09/01/2020
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$210,000**
Total Project Cost: **$295,000**
Total SCG Cost: **$295,000**
Total Co-Funding: **$0**
Benefits:

UCI Low NOx Water Heater Retrofit for Hydrogen Blends Development

The objective of the project is to take existing low NOx water heaters and improve the operational limits of hydrogen tolerance. The goals of the project are to evaluate the modifications that would allow additional hydrogen to be added, carry out the modifications, and demonstrate the amount of additional hydrogen that could be added and allow reliable operation. Laboratory testing will be done to evaluate general observations, ignition, flashback, and efficiency. In addition, emissions will be quantified to understand how the NOx, carbon monoxide, and unburned hydrocarbons (UHC) levels change with increased hydrogen addition. In 2021, the team evaluated, baselined, and proposed several modifications to the water heaters they received. Some of the methods they used to evaluate the water heaters included thermal imaging of the burner top to understand the temperature distribution, thermocouples to measure the surface temperature, and fuel control to vary the hydrogen-natural gas mixture. For 2022, the team will focus on design modifications to improve the hydrogen tolerance of the burners, test the burner designs, and submit a test report by March.

Co-Funders: N/A

Start Date: 10/01/2020
End Date: 03/01/2022
Status: Active
2021 Funds Expended: **$89,900**
Total Project Cost: **$241,468**
Total SCG Cost: **$241,468**
Total Co-Funding: **$0**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Boostheat Thermal Compression-Based Gas Heat Pump (1.20.B)

The objective of this project is to develop a North American thermal heat pump THP with a focus on: (1) high modulation ratio, (2) integration with forced-air distribution, and (3) adding cost-effective cooling. Project partner BOOSTHEAT has recently established an innovative and new business model in Europe. To successfully enter the North American market, however, this UTD project will address key product development needs. THPs have significant potential for 20% or greater improvement in energy use and emissions reductions versus best-in-class conventional sorption and vapor compression-type THPs. Amid the ongoing COVID-19 pandemic, BOOSTHEAT experienced a significant product delay in 2020. In response, the company addressed the technical challenges and consolidated staff under a single roof in 2021. The project team completed laboratory preparations for testing of the BH.20 using a Virtual Test Home (VTH) protocol. The test infrastructure is complete, with the remainder of the activity focusing on data acquisition and controls setup. The test apparatus is undergoing shakedown for testing of a different heat pump in advance of the arrival of BOOSTHEAT's unit.

Co-Funders: UTD Members, OEMs

Start Date: 07/01/2020
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$10,667**
Total Project Cost: **$225,000**
Total SCG Cost: **$26,667**
Total Co-Funding: **$198,333**
Benefits:

UTD Comparative Assessment of Heat Pump Water Heaters in the Virtual Test Home – Phase 2 (1.19.I.2)

In the current Phase 2 of project 1.19.I, researchers are investigating the performance of a hybrid system that is commercially available in the U.S. for space and water heating. This hybrid system will be evaluated in the VTH to develop performance curves for space and water heating in multiple part-load and ambient temperatures. These performance curves can be implemented in building energy models to quantify annual operating cost, greenhouse gas emissions, and source-energy efficiencies more accurately in all U.S. climate zones. UTD partnered with the Propane Education and Research Council (PERC) on this research, with PERC providing co-funding to UTD. Phase 2 of project 1.19.I is exploring integration in the VTH with the hybrid space- and water-heating equipment leveraging the incoming heating season of 2021-2022.

Co-Funders: UTD Members

Start Date: 05/19/2020
End Date: 03/31/2022
Status: Active
2021 Funds Expended: **$2,432**
Total Project Cost: **$130,000**
Total SCG Cost: **$8,432**
Total Co-Funding: **$121,568**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Economical High-Efficiency Residential Gas Adsorption Heat Pump with Integrated Cooling (1.18.H)

The objective of this project was to add cost-effective cooling to the low-cost gas absorption heat pump (GAHP) pre-commercial product developed in UTD project 1.13.F with Stone Mountain Technologies Inc. (SMTI) that currently only provides whole-house heating and domestic hot water. The project team seeks to demonstrate an economical GAHP with integrated cooling for a projected target equipment price of $5,000. This system would be designed for low-load homes; however, scaling up or down at a later date to fill out the product family is expected to be very feasible and economical. Laboratory tests were conducted to estimate the hybrid unit's performance using standardized steady-state testing. In addition to standardized rating tests, an extended 24-hour simulated use test was conducted in a virtual test home to obtain a complete mapping of performance and evaluate the impact of coincident loads. The project team is finalizing preparations for installation of GAHP hybrid equipment in the laboratory, with thermal heat pump test station upgrades. Researchers are analyzing the results of testing to make recommendations on system design modifications, sizing considerations, and controls updates.

Co-Funders: UTD Members, Natural Gas Innovation Fund, SMTI

Start Date: 07/01/2018
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$400,000**
Total SCG Cost: **$18,600**
Total Co-Funding: **$381,400**
Benefits:

UTD Field Evaluation of Indoor Air Quality in Residential Kitchens (1.20.K)

The objective of this project is to determine the effect of cooking emissions on residential indoor air quality (IAQ) in a scientific manner in real-world situations through field evaluations. This project presents the opportunity to collect field data to differentiate emissions from cooking processes versus emissions from appliances by comparing direct-vent range hoods versus recirculating hoods. A residential kitchen ventilation test setup was also prepared in a laboratory facility in order to provide additional comparative data. Current activities include: (1) interactions with the property manager to schedule installation of remaining IAQ sensor packages and range sensor arrays; (2) surveying tenants for IAQ and cooking procedures; (3) scheduling a controlled-cook event where residents will be participating in cooking the same product, such as pizza, stir fry, etc., and the kitchen IAQ data will be compared among apartments; (4) analyzing IAQ data from multi-unit residences; and (5) planning for switchover of select gas ranges to electric ranges.

Co-Funders: UTD Members, BHE

Start Date: 07/01/2020
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$43,235**
Total Project Cost: **$335,000**
Total SCG Cost: **$92,235**
Total Co-Funding: **$242,765**
Benefits:

UTD HeatAmp Adsorption Thermal Heat Pump (1.21.A)

The objective of this project is to advance the development of a cost-competitive, fuel-fired Thermal Heat Pump technology from HeatAmp of Sweden, by optimizing a cost-effective alpha prototype "burner/boiler" assembly and then designing a system for future evaluation in GTI's laboratory. The unit draws in and upgrades ambient heat via an outdoor fan coil unit, achieving projected energy/emission reductions of >33% vs. standard fuel-fired equipment. The heat pump effect is driven by a sorption module which houses ammoniated salts. The primary target use is domestic hot water applications, with options for combined space/water heating ("combi") or pool heating functions. The project was executed in the fourth quarter of 2021, and work is expected to begin in 2022.

Co-Funders: UTD Members

Start Date: 12/31/2021
End Date: 12/31/2022
Status: Active
2021 Funds Expended: **$1,600**
Total Project Cost: **$140,000**
Total SCG Cost: **$3,200**
Total Co-Funding: **$136,800**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD High-Efficiency Combi System Integrating PV and Self-Power (1.20.G)

The objective of this project is to develop and demonstrate a hybrid residential combined heating, ventilation, and air conditioning and water heating (combi) system in the laboratory that uses off-the-shelf appliances and novel controls to integrate gas/electric systems with micro-combined heat and power, energy storage, and renewable energy in order to reduce operating costs and greenhouse gas emissions by up to 50% and achieve coefficients of performance up to 1.5. This approach will improve energy resilience and help retain a high-efficiency role for natural gas-liquefied petroleum gas in the residential forced-air market. Moreover, it prepares the industry for nascent gas heat pump technology that will also require solutions for system integration.

Co-Funders: UTD Members, PERC, Aisin, Enginuity, Mitsubishi, iFLOW, Rinnai

Start Date: 07/01/2020
End Date: 03/21/2022
Status: Active
2021 Funds Expended: **$32,073**
Total Project Cost: **$580,000**
Total SCG Cost: **$68,073**
Total Co-Funding: **$511,927**
Benefits:

UTD Mitigating Methane Emissions from ResCom End Use Equipment – Phase 3 (1.18.F.3)

This project will quantify methane emissions from at least six key residential appliances that have not been quantified in past phases of the project in order to develop and publish representative methane emission factors and to determine the conditions under which these appliances release unburned methane and identify potential mitigation options. At least six residential appliances, including cooking ranges and tank water heaters, will be tested under specific operating conditions and representative use patterns, including steady-state, standby, and cyclic operation.

Co-Funders: UTD Members

Start Date: 08/01/2021
End Date: 08/31/2023
Status: Active
2021 Funds Expended: **$9,500**
Total Project Cost: **$150,000**
Total SCG Cost: **$19,000**
Total Co-Funding: **$131,000**
Benefits:

UTD Next Generation Residential Gas Dryer Development – Phase 2 (1.15.C.2)

In this project, researchers investigated next generation gas dryer technologies to exceed Energy Star efficiency levels. They developed an early-stage prototype with promising technology. The goal was to find a technology to achieve a 5-15% boost over standard efficiency gas dryers. Phase 1 of this project focused in part on assembling a test station in an environmental chamber to maintain temperature and humidity to ensure accurate testing. In Phase 2, researchers investigated additional heat-recovery options, modulation techniques, indirect-fired methods, direct venting, and alternative burners. Testing at four firing rates showed around a 2% boost consistently with lower firing rates. The dryer was insulated and sealed to test potential boost from better sealing and allow for implementing heat recovery. After several variations, technicians were able to achieve a 5%-6% increase in efficiency with insulation and sealing as well as a 6% reduction in drying time. The insulation and sealing also allowed researchers to implement an innovative heat-recovery design. Phase 3 testing is currently underway. Any proprietary technologies discovered during the project will result in a UTD invention disclosure.

Co-Funders: UTD Members

Start Date: 07/01/2018
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$150,000**
Total SCG Cost: **$24,706**
Total Co-Funding: **$125,294**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Next Generation Residential Gas Dryer Development – Phase 3 (1.15.C.3)

In this project, researchers investigated next generation gas dryer technologies to exceed Energy Star efficiency levels. They developed an early-stage prototype with promising technology. The goal was to find a technology to achieve a 5-15% boost over standard efficiency gas dryers. Phase 1 of this project focused in part on assembling a test station in an environmental chamber to maintain temperature and humidity to ensure accurate testing. In Phase 2, researchers investigated additional heat-recovery options, modulation techniques, indirect-fired methods, direct venting, and alternative burners. Testing at four firing rates showed around a 2% boost consistently with lower firing rates. The dryer was insulated and sealed to test potential boost from better sealing and allow for implementing heat recovery. After several variations, technicians were able to achieve a 5%-6% increase in efficiency with insulation and sealing as well as a 6% reduction in drying time. The insulation and sealing also allowed researchers to implement an innovative heat-recovery design. Phase 3 testing is currently underway. Any proprietary technologies discovered during the project will result in a UTD invention disclosure.

Co-Funders: UTD Members

Start Date: 07/01/2020
End Date: 07/31/2022
Status: Completed
2021 Funds Expended: **$14,000**
Total Project Cost: **$160,000**
Total SCG Cost: **$28,000**
Total Co-Funding: **$132,000**
Benefits:

UTD Residential Cooking Pollutants and Indoor Air Quality – Phase 2 (1.17.H.2)

The objective of this project is to conduct an analytical and laboratory investigation on issues and concerns for indoor air quality (IAQ) and residential cooking with natural gas based on information from a review of existing literature and data from the previous phase of this project. Phase 1 of the project studied capture hoods and showed that the capture effectiveness of residential hoods was less than 50% for cooking on the front burners and would be ineffective at capturing cooking and combustion emissions. The current phase of the project is being conducted to determine what types and the volumes of emissions that are present in residential cooking, including NOx, particulates, heat, and moisture. Phase 2 testing to measure and compare the cooking emissions of natural gas, propane, and electric residential ranges is ongoing. Based on the results of the literature review, researchers identified the following essential information as missing from existing data: (1) accurate data on NOx emissions from residential ranges using established protocols; (2) data on particulate matter emissions for both gas and electric cooktops; and (3) quantification of how improved ventilation and improved oven-burner technology could improve IAQ.

Co-Funders: UTD Members

Start Date: 06/01/2020
End Date: 06/30/2022
Status: Active
2021 Funds Expended: **$4,333**
Total Project Cost: **$85,000**
Total SCG Cost: **$11,333**
Total Co-Funding: **$73,667**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Residential Gas Absorption Heat Pump Water Heater – Phase 5 (1.11.H.5)

This project builds upon a gas-fired heat pump water heater (GHPWH) developed and supported in conjunction with UTD Project 1.11.H, scaling up the same absorption heat pump technology by an eight-fold factor. The objective of this project is to support the development of next generation GHP-WH by eliminating a major cost hurdle for some installations and enhancing reliability and efficiency diagnostics. One effort was to reduce the installation cost/barrier of condensate drain by developing a proprietary method of neutralizing, collecting, and disposing of combustion condensate where access to a sanitary sewer drain is otherwise cost-prohibitive and improving the onboard diagnostics by exploring the use of Enhanced Solution Level Control (ESLC) which can improve system reliability and long-term performance. Using the experience of 12 demonstrations of Phase 1 to 4 GHPWH precommercial prototypes, GTI and the late-stage start-up Stone Mountain Technologies, Inc. (SMTI) have identified typical conditions and root causes of poor efficiency and/or product failure. In July 2021, it was announced that UTD member Enbridge had invested CAN $4,000,000 in SMTI, the developer of the technology advanced in this and other UTD projects. The project team is finalizing preparations for installation of gas absorption heat pump hybrid equipment in the laboratory, with thermal heat pump test station upgrades. Researchers are analyzing the results of testing to make recommendations on system design modifications, sizing considerations, and controls updates.

Co-Funders: SMTI, UTD Members

Start Date: 07/01/2019
End Date: 12/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$170,000**
Total SCG Cost: **$42,491**
Total Co-Funding: **$127,509**
Benefits:

UTD Residential Gas Absorption Heat Water Heater – Phase 6 (1.11.H.6)

This project builds upon a gas-fired heat pump water heater (GHPWH) developed and supported in conjunction with UTD Project 1.11.H, scaling up the same absorption heat pump technology by an eight-fold factor. The objective of this project is to support the development of next generation GHP-WH by eliminating a major cost hurdle for some installations and enhancing reliability and efficiency diagnostics. One effort was to reduce the installation cost/barrier of condensate drain by developing a proprietary method of neutralizing, collecting, and disposing of combustion condensate where access to a sanitary sewer drain is otherwise cost-prohibitive and improving the onboard diagnostics by exploring the use of Enhanced Solution Level Control (ESLC) which can improve system reliability and long-term performance. Using the experience of 12 demonstrations of Phase 1 to 4 GHPWH precommercial prototypes, GTI and the late-stage start-up Stone Mountain Technologies, Inc. (SMTI) have identified typical conditions and root causes of poor efficiency and/or product failure. In July 2021, it was announced that UTD member Enbridge had invested CAN $4,000,000 in SMTI, the developer of the technology advanced in this and other UTD projects. The project team is finalizing preparations for installation of GAHP hybrid equipment in the laboratory, with thermal heat pump test station upgrades. Researchers are analyzing the results of testing to make recommendations on system design modifications, sizing considerations, and controls updates.

Co-Funders: UTD Members

Start Date: 07/01/2020
End Date: 01/31/2022
Status: Active
2021 Funds Expended: **$15,000**
Total Project Cost: **$200,000**
Total SCG Cost: **$15,000**
Total Co-Funding: **$185,000**
Benefits:

- Reliability
- Safety
- Operational Efficiency
- Improved Affordability
- Environmental: Reduced GHG Emissions
- Environmental: Improved Air Quality

UTD Residential Kitchen Cooking Ventilation Effectiveness – Phase 2 (1.15.G.2)

Despite most home kitchens having a ventilation system above the stove, most homeowners do not use the system unless excess smoke is being produced and many existing systems are ineffective at capturing food and combustion emissions. The objective of this project was to quantify the emissions from residential cooking that impact indoor air quality. Work in a previous phase of this project using a shadow graph system determined that the plume volume from residential cooking spilled 20-40% along the front edge of the hood and 10-20% along the sides of the hood. Modifications were made to the existing hood design to attempt to improve capture effectiveness, including adding side shields and extending the hood out further over the range top. Analysis for both configurations showed some improvement in terms of capture effectiveness of only a few percent and generally less than a 10% improvement. Based on these results, it was determined that a new design or method of operation of residential hoods was needed to reduce emissions into the indoor environment.

Co-Funders: UTD Members

Start Date: 07/01/2019
End Date: 07/31/2021
Status: Completed
2021 Funds Expended: **$0**
Total Project Cost: **$70,000**
Total SCG Cost: **$31,080**
Total Co-Funding: **$38,920**
Benefits:

UTD Robur and SMTI Low-Capacity Gas Absorption Heat Pump Laboratory Evaluation (1.20.A)

The objective of this project is to evaluate and optimize the performance of low-capacity gas absorption heat pumps (GAHP)s, specifically the Robur K18 (60 MBH) and SMTI 40K (40 MBH), when applied to residential combination space/water heating systems (forced-air heating). These low capacity GAHP systems, sized for residential homes in mild climates or with improved thermal envelopes, must be controlled optimally for comfort and efficiency. How the GAHP performs in addition to how system parameters are optimally controlled (system modulation, space vs. water heating modes, air handler operation, etc.) will be assessed in this experimental effort.

Co-Funders: UTD Members, OEMs

Start Date: 07/01/2020
End Date: 07/31/2022
Status: Active
2021 Funds Expended: **$8,000**
Total Project Cost: **$175,000**
Total SCG Cost: **$24,000**
Total Co-Funding: **$151,000**
Benefits:

UTD Thermoelectric Generator for Self-Powered Water Heater – Phase 3 (1.17.B.3)

The initial objective for this project was to validate that a Thermoelectric Generator Heat Exchanger (TEG-HX) device can generate enough electric energy to power a tankless natural gas water heater. Now in Phase 3, efforts are underway to incorporate a novel new heat-pump configuration with a TEG-HX design to prove the concept of a self-powered natural-gas-driven tankless (instantaneous) water heater with ultra-low emissions (<5 ppm NOx) and with excess power capability. The objective for this project is to develop and prove the concept of a novel self-powered natural-gas-driven tankless (instantaneous) water heater with ultra-low emissions <5 ppm NOx, and with excess power capability or a primary COP of >1.0, by incorporating a novel new heat pump configuration with a TEG-HX design.

Co-Funders: UTD

Start Date: 07/01/2019
End Date: 01/31/2022
Status: Active
2021 Funds Expended: **$0**
Total Project Cost: **$1,340,000**
Total SCG Cost: **$80,000**
Total Co-Funding: **$1,260,000**
Benefits:


SoCalGas™